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The sound of silence: children's own perspectives on their hearing and listening in classrooms with different acoustic conditions

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Abstract

In this study, we investigated primary school children's perspectives on their hearing and listening in classrooms with different acoustic quality levels. The sample included 213 children. The children completed a self-report questionnaire rating how well they could hear and listen in various situations in classrooms with two different acoustic conditions: *Poor acoustic quality* (long reverberation time [Long RT]) versus *Adequate acoustic quality* (short reverberation time [Short RT]) equipped with a sound-absorbing system. The results showed that auditory perception in the two conditions depends on the child's age, with only fourth- and fifth-grade children reporting benefits from classroom acoustic correction. Our study provides preliminary results on children's perspectives regarding their hearing and listening experiences during school learning, drawing out the implications for the design and implementation of school metacognitive interventions aimed at improving children's and teachers' awareness of motivational-affective, regulative, and environmental aspects favoring listening at school.

Keywords Children's perspective on listening · Learning · Primary school children · Reverberation time · Metacognitive intervention on listening at school

Introduction

Listening at school can be a stressful activity for young children who are required to process information quickly enough to construct meanings and learn (Goh & Taib, 2006). School environment characteristics, in addition to personal motivational-affective factors, may support children's hearing and listening when learning occurs. A growing body of research (e.g., Vettori et al., 2022; Connolly et al., 2019; Klatte et al., 2010a, b) shows a significant interaction between children's cognitive and language processes and the school environments in which

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learning occurs. Prior research has demonstrated that adverse listening conditions at school have detrimental effects on children's learning (Dockrell & Shield, 2006). A study by Neuman et al. (2010) showed the negative impact of the combination of high noise levels and reverberation in classrooms on the recognition of word sounds. Other studies have documented the influence of poor classroom acoustic quality on children's attentional and mnestic processes (Clark & Sörqvist, 2012), which are important for the encoding, storage, and manipulation of mental representations based on auditory information (Baddeley, 2003), to the point of showing negative effects on reading and text comprehension even in high school students (Connolly et al., 2019). These data highlight the importance of internal and external noise levels and the type of noise children are exposed to. When thinking about school indoor acoustic quality, we need to think about different types of aspects, such as the noise generated inside the classroom mainly due to the interaction between pupils and teachers and the teaching activities that take place throughout the day, but also, we need to think about noise generated in the school corridors by chattering or movement when other classes of children pass by, which can have a negative impact on the proper listening of children who are doing exercises in their classes. One of the most important factors of indoor acoustic quality is reverberation, intended as a phenomenon to which any sound source is subject and which occurs when a sound reflects off an obstacle placed in front of the source, causing a large number of sound reflections. In a classroom, reverberation causes an amplification of sounds and noises, which can create rumbling, seriously affecting the perception of the teacher's and students' voices and consequently the classroom activity. Reverberation has a significant impact on classroom noise levels and occupant behavior (Canning et al., 2012). Previous research has shown that the level of reverberation time in internal classroom acoustic quality impacts negatively on speech recognition (Puglisi et al., 2021), working memory span (Jianxin & Jiang, 2017), and verbal working memory in 8- to 10-year-old children (Sullivan et al., 2015), which are key processes to learn and successfully achieve at school. Some previous research (Vettori et al., 2022) conducted in the Italian context investigated whether the acoustic quality of classrooms, in particular reverberation time and background noise, could influence verbal working memory performance in children at the beginning of primary school, when cognitive processes are still developing. Verbal working memory is a process that underlies all learning, as it allows new information to be stored in short-term memory and processed simultaneously. Twenty-five second-grade primary-school children participated in the research and performed a verbal working memory task in the condition of *Poor* acoustic quality with "Long RT"—the reverberation time in the octave frequency bands 500–2000 Hz was variable between 1.4 and 1.2 (s)—as well as in the condition of *Adequate* acoustic quality with "Short RT"—the reverberation time in the octave frequency bands 500–2000 Hz was about 0.3 (s), corrected with a soundproofing system (Lauria et al., 2020). The optimal value recommended by the Italian standard UNI 11532–2:2020 for the two classrooms which were characterized by a volume of about 190 m^3, is 0.56 (s). In each of the acoustic conditions, a sound source reproduced a typical background babble noise that simulated the "classroom babble" with a TalkBox. The results showed that children remembered fewer words and did so less accurately when performing the verbal working memory task in a classroom with poor acoustics compared to a classroom with adequate acoustics. Furthermore, the children omitted more words in the recall task in the poor acoustic condition than in the adequate acoustic condition. The results suggest that verbal working memory functioning in young children is sensitive to changes in the acoustic conditions of the classroom and is adversely affected by the high levels of reverberation that characterize classrooms. The high level of reverberation, combined with the noise normally present in the classroom, can in fact generate unclear or masked speech information, which increases children's cognitive effort and confuses the processing of the meaning of what is being said or distracts from the task at hand.

At the national level, normative values for optimal reverberation times have been fixed to assure adequate acoustic comfort conditions at school. Unfortunately, the normative has not been accompanied by any school intervention to promote children's and teachers' awareness about the importance of listening and hearing comfort at school. Nevertheless, we know about children's own authentic perspectives on hearing and listening in various learning situations in classrooms. In the Italian context, school settings are notorious for being poor listening environments. Thus, it is essential that efforts are made to ensure that children in school settings can hear to the best of their abilities in the best possible environment. Sound correction systems can help in children's hearing and listening by reducing reverberation time in classrooms. However, there are limited studies assuming a child-centered perspective on hearing and listening at school in different real classroom acoustic conditions, especially when considering the Italian context. To contribute to filling these research gaps, this research project assumed a child-centered perspective to investigate children's own point of view of their hearing and listening in various learning situations occurring in classrooms with *Adequate* acoustic quality (short reverberation time (Short RT)) equipped with a sound-absorbing system and in classrooms with *Poor* acoustic quality (long reverberation time (Long RT)) in an Italian primary school setting.

Classroom noise affects learning and cognition

Prior research has demonstrated that school environment characteristics affect learning and cognition processes in children. Studies in the literature indicate that children's speech perception and reading achievement are negatively impacted when noise in classrooms is high (Anderson, 2001; Choi & McPherson, 2005; Shield et al., 2015). Dockrell and Shield (2006) found that classroom babble negatively affected 7- to 8-year-old children's performance accuracy in verbal tasks. Verbal tasks which involve working memory processes are sensitive to the interference of speech. The study by Vettori et al. (2022) conducted in Italian primary school classrooms found that high levels of reverberation and background noise negatively impacted verbal working memory performances in children attending the second year of primary school. Several explanations have been advanced for the specific impact of noise and reverberation on verbal task outcomes in classrooms. In particular, the high level of reverberation in addition to the classroom babble may determine unclear or masked speech information that increases children's cognitive efforts or diverts their attention away from the task challenging their performances (e.g., Sörqvist, 2010). Thus, it is important to implement solutions to control the sound environment in the classroom and work with children to promote awareness of conditions that facilitate good listening at school. As suggested by Nutbrown and Clough (2009), getting children to participate in identifying and exploring issues important to them promotes a positive sense of inclusion for the development of pedagogies of citizenship and belonging. An evaluation of actual practices in real-life school should include children's perspectives (Dunn et al., 2018; Merrick & Roulstone, 2011) which are a crucial element in understanding their conceptualization of hearing and listening at schools to add further insights to the debates on the relationship between school environment and learning in early years of schooling and revise current praxis to improve children's school hearing and listening experiences.

Children's own perspectives on listening at school

The inclusion of the child's perspective is an important dimension for understanding the relationship between learning and environmental factors. Following a children's participatory rights-based framework (Dockett & Perry, 2021), students should have a view on matters that affect them (Vettori et al., 2022; Lipponen et al., 2018). Children's own perspectives are crucial to understanding their school experiences and the aspects that contribute to their positive cognitive and socioemotional functioning. The UN convention on the Rights of the Child (UN General Assembly, 1989) advocates an integration of children's views in evaluation and development of the child's environment. Some studies, especially in the UK context, have elicited students' subjective responses to hearing in their classrooms via self-report questionnaires. The study by Canning (2009) in Essex schools used extensive objective and qualitative (interview and questionnaire) measures to investigate the impact of room acoustics on classroom noise. Dockrell and Shield (2012) compared 8- to 11-year-old elementary school children's evaluation of classroom listening conditions over time in classes with and without sound-field systems installed over a 6-month period by using a previously tested questionnaire sensitive to different acoustic conditions (Dockrell & Shield, 2004). Their results showed that there were no significant differences between students in amplified classrooms and those without sound-field systems with respect to external noise. Furthermore, although there were increases in students' perceptions of audibility over time, there were no significant differences for those in amplified and non-amplified classrooms. Connolly et al. (2013) used an online questionnaire survey to investigate 11- to 16-year-olds' impressions of their school's acoustic environment. Those data inform us that adolescent learners are sensitive judges of the acoustical qualities of their learning environment and are able to reliably identify the acoustic conditions that interfere with their learning. A result confirmed in a subsequent study by Connolly et al. (2015). However, few studies have tried to capture primary school children's awareness about adequate or poor listening conditions at school and the most challenging acoustic situations for them. McFarland and Dealtry (2017a) investigated 3- to 5-year-old children's perspectives on their hearing during early childhood group-time situations through self-report booklets about their hearing. Their findings showed that children not formally identified with a hearing problem report most difficulty hearing during group time while other children are talking and when sitting at the back of the room. In a further study, McFarland and Dealtry (2017b) investigated, through self-report booklets, 3- to 5-year-old children's and early childhood educators' perspectives on the impact of a sound amplification system in a preschool setting. Their findings indicated that children's hearing and listening improved after the implementation of a sound amplification system.

Starting from children's own perspectives on their hearing helps gain insights into children's views on the best hearing and listening conditions for learning that can support teacher–pupil collaboration in building effective pedagogies and securing more personalized metacognitive programs on listening and learning. For example, drawing on some key recommendations on how to create and implement powerful methods of authentic learning (see Nachtigall et al., 2022), the "classroom (positive and negative) hearing and listening conditions" generated by the research may provide a useful starting point for conversations between teachers and pupils about cognitive, motivational, affective, and contextual factors that sustain good hearing and listening, which others challenge them, and the ways in which teaching and learning might be enhanced and personalized. Given those benefits, the aim of the current study is to better understand children's hearing and listening when experiencing various learning situations in *Poor* versus *Adequate* acoustic conditions across primary school years by surveying their own perspectives. More specifically, we seek to explore children's own perspectives on their hearing and listening with respect to individual and group-time activities, both widely used in Italian primary school teaching. It is important to consider different learning scenarios (individual vs. collaborative) that might be more challenged by *Poor* acoustic conditions. The primary school setting is a particularly important context to examine in relation to children's hearing and listening. Primary education years are a central stage for learning to read, write, and calculate. As in other countries, in Italy, the primary education level is compulsory for children starting around the age of six. Children spend a considerable amount of time of their life in classes composed of an average of twenty-two children following the same public school curriculum that is regulated by the Ministry of Education. Over the years, in Italy, education has undergone major changes toward favoring laboratory and participatory approaches (Ministry of Education, University and Research [MIUR], 2018). We have moved from a school with a frontal approach, in which the main subject was the teacher who transmitted her/his knowledge to the pupils, to an approach in which the main subjects are the pupils, at the center of a collaborative learning system, in which everyone participates and enriches the experience of others with his/her own peculiarities. A participative and interactive approach is widely used with younger children through group activities and discussion. During group-time activities multiple children speak at once, this generates a noisy atmosphere that could interfere with children's ability to hear the educator or to cognitively process information when a high level of reverberation is present in the classroom. Older children are more often required to work individually at their seats, to be silent and to concentrate during teaching activities, potentially perceiving the impact of negative acoustic quality on cognitive and language processing more.

Aim and hypothesis

The main objective of the study was to investigate primary school children's own perspectives on hearing and listening in various learning situations at school when carrying out school activities in classrooms with *Poor acoustic quality* (long reverberation time [Long RT]) versus *Adequate acoustic quality* (short reverberation time [Short RT]) equipped with sound-absorbing systems. The focus of the research concerned the primary school period, an early stage of schooling that is particularly sensitive to the development and consolidation of literacy processes. Specifically, the research question is: Do primary school children's perspectives on their hearing and listening in various learning situations change in relation to different classroom acoustic conditions, i.e., *Poor acoustic quality* (long reverberation time [Long RT]) versus *Adequate acoustic quality* (short reverberation time [Short RT])? It is expected that children working in classrooms with *Adequate acoustic quality* report higher indoor acoustic comfort rather than children working in classrooms with *Poor acoustic quality.*

Method

Participants

The sample was composed of 213 children (*M age* = 8.67 and *SD* = 1.47, range = 6–11 years; 48.45% female) from 10 classes in 5 primary schools in the city metropolitan area, Italy. As the study took place in classrooms, participants were recruited through their schools. The schools were identified based on the presence of some classrooms equipped with sound-absorbing panels which had proved to reduce the level of reverberation, as well as some classrooms characterized by high reverberation levels. In each school, experimental and control classes of the same educational level were randomly chosen. All schools involved in this research were urban public schools. Public primary schools are the most prevalent in the Italian context. As emerged from a parental questionnaire about socio-demographic information, the classes were composed of a majority of middle-class pupils and a minority of lower or high-class children.

Socio-demographic characteristics and the distribution of cases according to the experimental condition (poor-adequate) and course level (1st, 2nd, 3rd, 4th, 5th) are presented in Tables 1 and 2, respectively.

This research project was conducted after agreement with the school director and following privacy requirements (Legislative Decree DL-196/2003). Ethical standards for research were guaranteed by adhering to the World Medical Association guidelines for conducting research, described in the most recent version of the Declaration of Helsinki. In addition, the study was approved by the Ethics Committee of the University of Florence, and informed consent was obtained from parents.

Procedure

This study is part of a larger funded research project on the relationship between school indoor acoustic quality and children's cognitive-linguistic processes started in the school years 2018/2019. This study started in 2021/2022 with the aim of expanding the research results obtained on working memory performance in 2nd graders and of understanding children's perspectives on their hearing and listening at school in the primary school years. The study was conducted in classrooms with different reverberation time levels. The reverberation levels were chosen as a parameter to evaluate the classroom acoustic quality as in previous studies in the literature (Shield et al., 2015). In the classrooms assigned to the *Poor* condition, the range of differences in reverberation levels was controlled by the research group of the Department of Architecture (University of city, country). Specifically, the range of Reverberation Time values was from 0.7 to 1.3 s as average values in octave frequency bands of 250–2000 Hz. Measurements were carried out in unoccupied classroom conditions while results are reported at 80% of occupancy of the classroom as requested by Italian regulations. Frequency values of reverberation time are shown in Fig. 1.

Table 1 Socio-demographic characteristics

Variables	Classroom acoustical conditions	
	Poor (Long RT) ($n = 109$)	Adequate (Short RT) ($n = 104$)
Age (years, mean ± standard deviation, range)	8.68 (1.37; 6–11)	8.66 (1.57; 6–11)
Female (count, %)	48 (52.75%)	46 (44.66%)

The first-graders in the poor acoustic condition did not report their age or gender

Table 2 Distribution of cases according to the experimental condition (poor-adequate) and course level (1st, 2nd, 3rd, 4th, 5th)

	Classroom acoustical conditions	
	Poor (Long RT) (*n*)	Adequate (Short RT) (*n*)
1st	16	18
2nd	25	22
3rd	23	18
4th	22	21
5th	23	25

In the classrooms assigned to the adequate condition, the acoustic comfort was obtained through a sound-absorbing system composed of wall panels and hanging panels, adaptable to classrooms of different sizes and shapes. This acoustic system was developed by the research team of the Department of Architecture and the Department of Industrial Engineering, University of city, country that collaborated with the Psychology Unit for this research funded by the Savings Bank Foundation of city, country. The sound-absorbing system intervention had already been implemented when the research started. Previous studies proved its efficacy in acoustic correction (see Laurìa et al., 2020; Vettori et al., 2022; Amodeo & Secchi, 2023). Every year, the Department of Architecture of the city (country) develops numerous acoustic correction interventions by implementing this sound-absorbing system in the schools of the Municipality of city (country). Each year, the Municipality of city (country) continues to plan new interventions to ensure that all schools and classrooms achieve adequate levels of acoustic quality (see, Amodeo & Secchi, 2023).

The range of reverberation time values in the classrooms with adequate acoustics was from 0.4 to 0.5 s as average values in octave frequency bands of 250–2000 Hz and with 80% of occupation of the classroom. Frequency values of reverberation time in these classrooms are shown in Fig. 2.

Noise input from outside, from adjacent classrooms and from equipment was not different in classrooms with adequate acoustics or with poor acoustics.

The research was introduced to the teachers by the school director. The questionnaire was administered in the classrooms where the teaching takes place every day. The administration took place at the end of the school year in a single session lasting between 30 and 45 min, based on the educational level of the children. A trained researcher, together with the teacher, assisted the compilation. At the beginning of the session, the researchers explained why the children were being invited to take part in the research, what they would be expected to do, and that it was okay to tell their teachers they did not want to be involved.

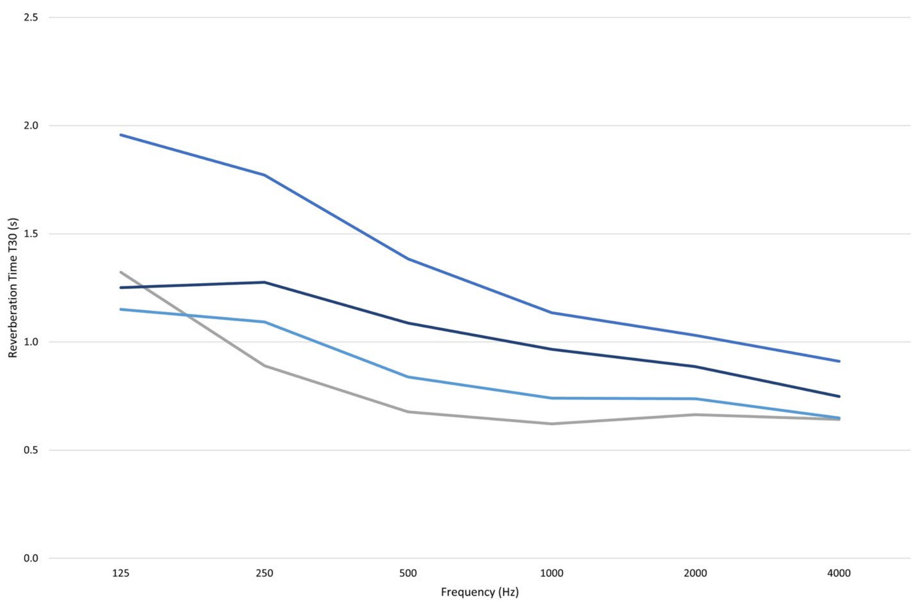

Fig. 1 Reverberation time measured in the classrooms with poor acoustic conditions

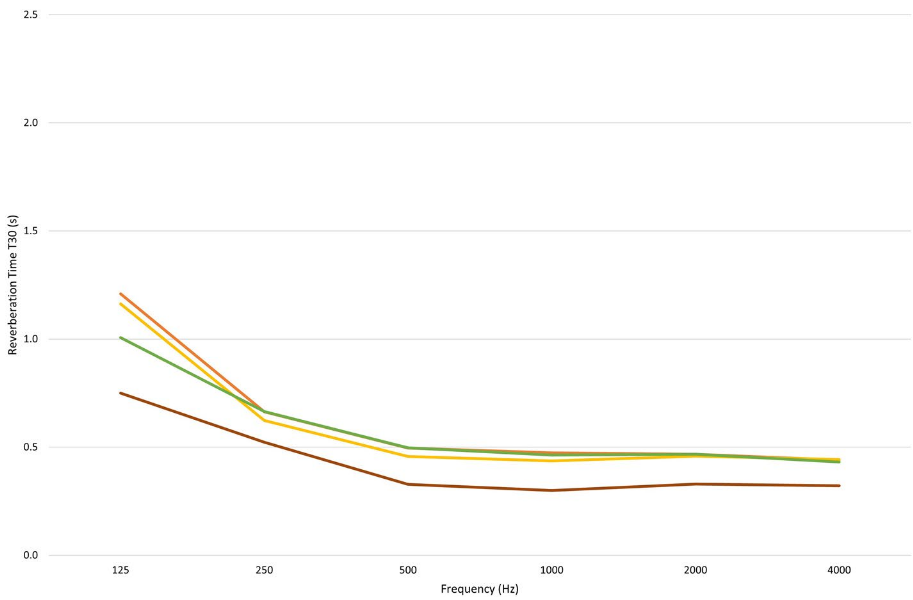

Fig. 2 Reverberation time measured in the classrooms with adequate acoustic conditions

In particular, the researcher pointed out that the questionnaire was not a school assignment, and they would not be evaluated. There were no right or wrong answers, and researchers were interested in knowing their opinion, so they should answer truthfully. Then, a sample item was used to help the children understand how the questionnaire works and how to answer. During the actual administration, the researcher read each question to the children and asked them to answer individually. At the end of the questionnaire, there was a short section for the children to fill in optionally to enter ideas about noise in the classroom.

Measures

Questionnaire on children's perspectives of listening during learning

Children were provided with a self-report scale to investigate their perspectives of hearing and listening during learning in classrooms with different acoustic conditions, *i.e. Poor acoustic quality* (long reverberation time [Long RT]) versus *Adequate acoustic quality* (short reverberation time [Short RT]) equipped with sound-absorbing systems. Consistent with the relevance that emerged in the international scientific literature investigating the perception of noise through questionnaires filled in by the children themselves, the subjective impression of noise disturbance was assessed through a 14-item self-report scale. The scale included items derived from previous published works (i.e., Dockrell & Shield, 2004; McFarland & Dealtry, 2017a) chosen for their adaptability to children's age (i.e., 7- to 10-year-olds) and Italian education methodology. The items selected were adapted from English to Italian using a mixed forward- and back-translation procedure (Behling & Law, 2000). Before being utilized in this study, the Italian version of the scale was administered to a small number of participants to verify its adequacy in terms of comprehensibility. All items were found easy to understand and score. The scale consisted of 14 items referring to how well children hear and listen in different learning scenarios, including individual and group-time activities (see the final pool of items in Appendix). At the beginning of the session, the researcher gave verbal instructions, trained the children for the task with some examples, and responded to their questions. Subsequently, all items were presented verbally by the researcher in a fixed order. Children were asked to respond on a 3-point Likert scale (1 = *I hear little*, 2 = *I hear enough*, 3 = *I hear very well*). These responses were accompanied by illustrated images to facilitate the indication of their perceived hearing and listening. A final open-ended question (optional) allowed children to provide any additional information they thought was relevant to their hearing during learning in the classroom.

Data analysis

Statistical analysis was performed using the JASP software package, version 0.18.1 (JASP Team, 2023).The item response distributions, mean, standard deviation, range, skewness, kurtosis, and item-total correlations for the initial 14 items were initially examined at the descriptive level. Item-total correlation values below 0.30 were deemed insufficient, and departures from normal distribution values outside the [−1; +1] range were considered significant (Muthén & Kaplan, 1985).

The scale's dimensionality was examined through exploratory and confirmatory factor analyses. Exploratory factor analysis (EFA) was performed using a polychoric, instead of a Pearsonian, correlation matrix. EFA based on polychoric correlations is recommended when ordinal variables are measured by fewer than five to seven categories or when distributions of the ordinal variables are asymmetrical (Bandalos & Gerstner, 2016; Fabrigar et al., 1999; Izquierdo et al., 2014; Lloret et al., 2017; Norris & Lecavalier, 2010).

To carry out the CFA, the diagonally weighted least squares (DWLS) estimator was employed. This robust estimator is highly recommended when normality is not met, and it provides the best option for modeling ordinal data (Brown, 2006). The goodness-of-fit of the CFA model was assessed using comparative fit index (CFI), the Tucker-Lewis index (TLI), and the root-mean-square error of approximation (RMSEA). For TLI and CFI indices, values above 0.90 suggest an acceptable fit, while values above 0.95 indicate an excellent fit (Hu & Bentler, 1999). An RMSEA value is considered acceptable when below 0.08 and good when below 0.05 (Kline, 2010).

The McDonald's omega was computed to evaluate the internal consistency of the scale. Additionally, we calculated the corrected item-total correlation, which is considered satisfactory when it exceeds 0.30 (Zijlmans et al., 2019), and McDonald's omega if the item is dropped.

To examine whether the subjective impression of classroom noise changes in different acoustic conditions, we performed a two-way ANOVA. The independent variables considered were the condition (*Adequate* and *Poor* acoustics) and school grade, while the dependent variable was the subjective acoustic perception in the classroom. Then, pairwise comparisons were conducted to examine the direction of the differences. A p value less than 0.05 was considered statistically significant. Effect sizes of 0.20, 0.50, and 0.80 were considered small, medium, and large in magnitude, respectively.

Results

First, an item analysis was conducted to assess the appropriateness of the items. In particular, we examined the indices of skewness, kurtosis, and item-total correlation. Three items from the original pool showed insufficient item-total correlation (< 0.30), and their skewness and kurtosis indices revealed unacceptable deviations from normality (Marcoulides &

Hershberger, 1997). These items reflected situations in which the teacher is engaged in reading a story while the other children remain silent (item 3, “When your teacher is reading a story and the other children are silent, how well do you hear his/her voice?”), the teacher is speaking and there are no noises coming from outside the classroom (item 4, “When there are no noises coming from outside your classroom, how well do you hear your teacher’s voice?”), and the teacher is speaking and there is silence in the classroom (item 7, “When there is silence and no noise in the classroom, how well do you hear your teacher’s voice?”). Furthermore, upon examining the response range, it emerged that not all possible response categories for item 7 were endorsed by the children. This evidence suggested that these items lacked good informative and discriminative properties, and consequently, they should be removed from subsequent analyses. The results of the descriptive analysis are presented in Table 3.

An EFA based on polychoric correlations and ordinary least squares estimation (Christoffersson, 1975; Edwards, 2009) was performed on the remaining 11 items to examine the factor structure of the scale. The factorability of the data was assessed using Bartlett’s test of sphericity, and the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy. Bartlett’s test of sphericity reached statistical significance ($\chi^2 = 667.424$, $df = 55$, $p < 0.001$), and the KMO value was 0.72, exceeding the recommended value of 0.60, supporting the factorability of the correlation matrix (Pallant, 2016; Tabachnik & Fidel, 2011). To determine the numbers of factors to extract, we considered the Kaiser-Guttman rule, the interpretation of the elbow of the Scree plot and the results from the parallel analysis (PA). Using Kaiser’s criterion, the first two factors recorded eigenvalues above 1 (3.743 and 1.365), explaining 28.6% and 7.1% of the variance, respectively. However, an inspection of the Scree plot revealed a clear break after the first factor so, as suggested by Pallant (2016), only the first factor was retained since it also captured much more of the variance accounted for. The unidimensional model explained a total of 27.8% of the variance. All factor loadings were greater than 0.30, ranging from 0.39 to 0.66.

Subsequently, a CFA was performed to confirm the one-factor structure of the scale. The diagonally weighted least squares (DWLS) estimator was specified to account and correct for the ordinal nature of the data and to produce accurate indices of model fit

Table 3 Means (M), standard deviations (SD), skewness, kurtosis, and item-total correlations of the initial fourteen items of the pupils questionnaire

Item	Min–max	M	SD	Skewness	Kurtosis	Item-total correlation
1	1–3	2.24	0.61	−0.18	−0.54	0.44
2	1–3	2.28	0.63	−0.31	−0.67	0.31
3	1–3	2.88	0.35	−3.04	9.12	0.21
4	1–3	2.77	0.52	−2.19	3.96	0.17
5	1–3	1.54	0.60	0.65	−0.52	0.42
6	1–3	2.64	0.53	−1.06	0.05	0.45
7	2–3	2.93	0.25	−3.53	10.56	0.09
8	1–3	2.14	0.57	0.01	−0.07	0.39
9	1–3	1.98	0.69	0.03	−0.88	0.32
10	1–3	1.46	0.58	0.88	−0.21	0.40
11	1–3	2.64	0.57	−1.35	0.86	0.30
12	1–3	2.73	0.51	−1.67	1.95	0.38
13	1–3	2.22	0.63	−0.21	−0.61	0.30
14	1–3	2.467	0.56	−0.42	−0.83	0.30

Likert scale is the following: 1 = I hear little, 2 = I hear enough, 3 = I hear very well. $n = 213$

(Christoffersson, 1975; Flora & Curran, 2004). The model showed a good fit (TLI = 0.921, CFI = 0.937, RMSEA = 0.074, 90% CI [0.053, 0.094]). All the standardized factor loadings were higher than 0.30, ranging from 0.40 to 0.67, and all were significant at the 0.001 level (Fig. 3).

McDonald's ω for the total scale was 0.72 (95% CI [0.66, 0.77]). All the corrected item-total correlations were above 0.30, ranging from 0.30 to 0.45. No increases in omega values were observed if any item was deleted. Cronbach's alpha value was equivalent to McDonald's ω value (α = 0.72). Following the cutoffs proposed by the European Federation of Psychological Assessment (EFPA; Evers et al., 2013), the values of internal consistency were adequate.

We initially inspected the data at the individual item level. Figure 4 shows the mean values of the answers to the items related to children's perspectives on their own listening and hearing in classrooms with *Adequate* versus classrooms with *Poor acoustic quality*.

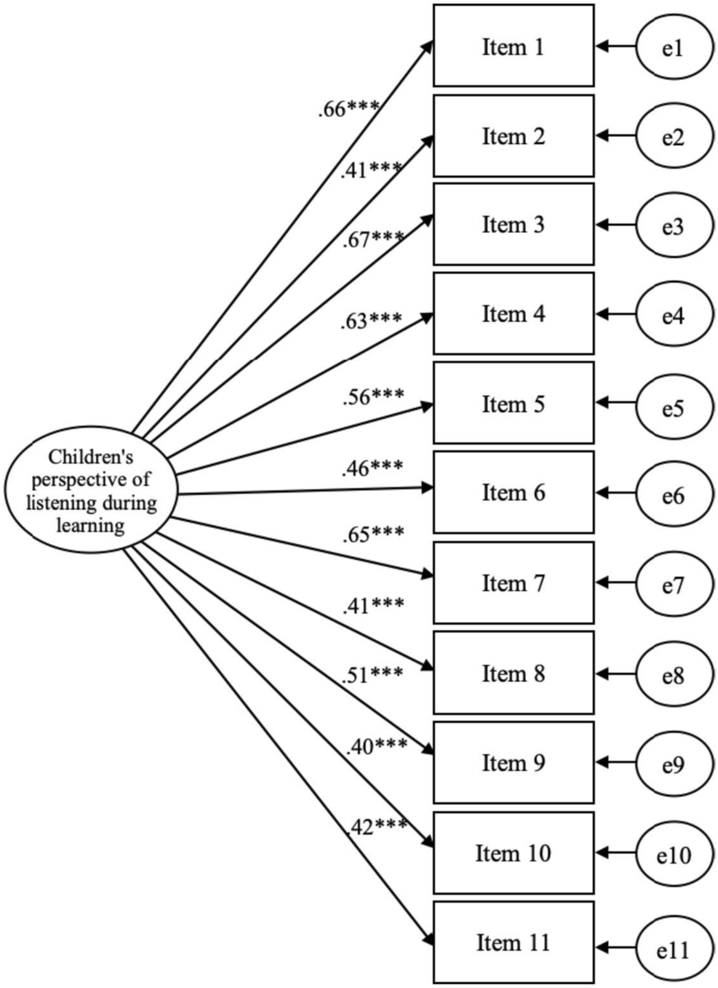

Fig. 3 Factorial structure of the Children's Perspective of Listening During Learning Questionnaire

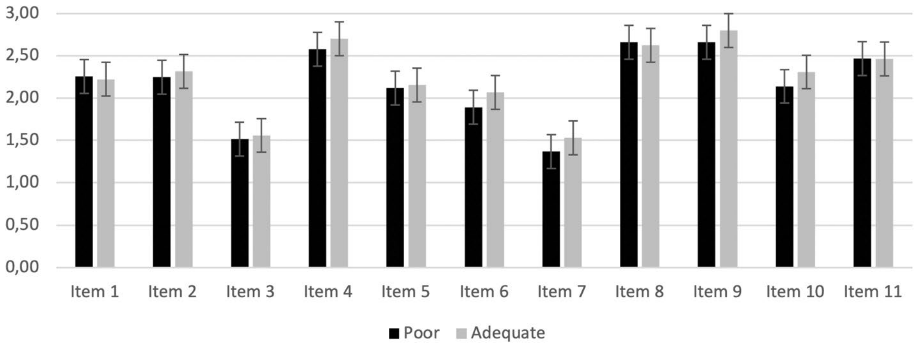

Fig. 4 Children's mean responses to Children's Perspective of Listening During Learning Questionnaire. Black and gray bins refer to responses given in poor and adequate acoustics, respectively. Error bars indicate standard deviations between subjects

To assess whether the subjective impression of noise disturbance among children who carry out school activities in classrooms with *Poor acoustic quality* (long reverberation time [Long RT]) versus *Adequate acoustic quality* (short reverberation time [Short RT]) equipped with sound-absorbing systems changed, a two-way ANOVA was conducted to compare the main effects of acoustic condition and school grade as well as their interaction effect on the pupil questionnaire scores. The results are reported in Fig. 5.

Overall, the classrooms were rated positively for listening conditions. There was no significant main effect of acoustic condition ($F(1,203)=2.58$, $p=0.110$, $\eta^2=0.01$) or school grade ($F(4,203)=1.00$, $p=0.406$, $\eta^2=0.02$) on the questionnaire total scores.

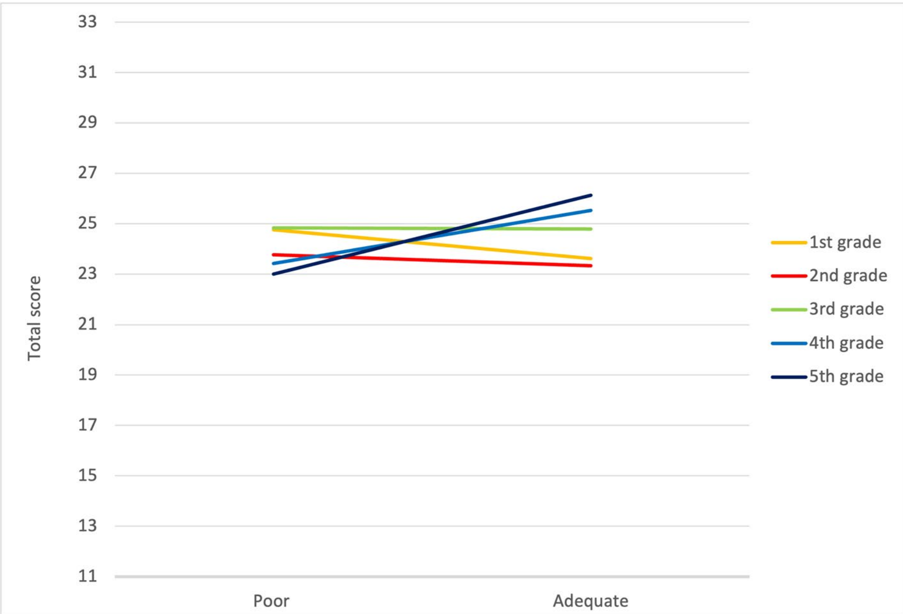

Fig. 5 Differences in responses in the two conditions for each school grade

However, there was a significant interaction effect between acoustic condition and school grade, $F(4,203)=3.33$, $p<0.05$, $\eta^2=0.06$. Multiple comparisons showed that there was no significant difference between first grade classes, $t(32)=1.17$, $p=0.251$, *Cohen's* $d=0.40$, second grade classes, $t(45)=0.43$, $p=0.670$, *Cohen's* $d=0.13$, or third grade classes, $t(39)=0.05$, $p=0.962$, *Cohen's* $d=0.01$. There was a significant difference between fourth grade classes, $t(41)=-2.04$, $p<0.05$, *Cohen's* $d=-0.62$, and fifth grade classes, $t(46)=-3.52$, $p<0.001$, *Cohen's* $d=-1.02$. Fourth grade children in the good acoustical condition scored significantly higher ($M=25.52$, $SD=3.37$) than children in the poor acoustical condition ($M=23.41$, $SD=3.43$). Fifth grade children in the good acoustical condition scored significantly higher ($M=26.12$, $SD=3.73$) than children in the poor acoustical condition ($M=23.00$, $SD=2.11$).

Discussion

In this study, after verifying the fundamental psychometric properties of dimensionality and reliability of the *Children's Perspective of Listening During Learning Questionnaire*, we investigated children's own perspectives on their hearing and listening in various learning situations (e.g., individual, group-time activities) occurring in classrooms with *Poor acoustic quality* (long reverberation time [Long RT]) and in classrooms with *Adequate acoustic quality* (short reverberation time [Short RT]) equipped with sound-absorbing systems previously developed and tested for its efficacy of acoustic correction (see Lauria et al., 2020; Vettori et al., 2022; Amodeo & Secchi, 2023). To our knowledge, this was one of the few research contributions assuming children's own perspectives on listening at school. Previous studies have focused on preschool children belonging to the Australian context (McFarland & Dealtry, 2017b), 8- to 11-year-old elementary school children (Dockrell & Shield, 2012), and adolescent learners (Connolly et al., 2013, 2015). Our study was unique due to its focus on 6- to 10-year-old primary school children in the Italian context.

At a preliminary inspection of the data, the answers to the questions related to children's perspectives on their own listening and hearing in classrooms with *Adequate* versus classrooms with *Poor acoustic quality* indicated low listening comfort when learning occurred with underlying chattering and babbling, outside (item 3: *When there are children making noise outside your classroom, how well do you hear your teacher's voice?*) and inside (item 7: *When your teacher is reading a story and other children are talking, how well do you hear your teacher's voice?*) the classroom. This was in line with previous results on younger children (McFarland & Dealtry, 2017b). Although there were large standard deviations indicating considerable heterogeneity between classrooms and maybe between schools as well, our results indicated that children in primary school may face challenges in these specific learning situations with a detrimental effect on cognitive and language processing. The hearing challenges reported by children may prompt teachers to become better informed about teaching strategies that can properly support children to adequately listen and hear, especially in chattering and babbling learning situations. Understanding the circumstances under which children have the most hearing-related difficulties can help teachers plan more effective group activities to preserve social and group activities (e.g., visual aids, eye contact), which are very common in Italian primary schools.

Regarding our aim of investigating primary school children's perspectives on their hearing and listening in different classrooms' acoustic conditions, our expectation was partially confirmed. The results of our study highlighted that elementary-level children were able to provide their personal perspectives on listening in various acoustic conditions at school, and this ability varied depending on the children's age.

As expected, the results of the comparison of children's own perspectives on their hearing and listening at school when learning occurred in classrooms with *Adequate acoustic quality* (short reverberation time [Short RT]) equipped with a sound-absorbing system versus when learning occurred in classrooms with *Poor acoustic quality* (long reverberation time [Long RT]) showed that older children of 9 to 10 years, attending fourth and fifth grade of primary school, reported more listening problems in the classrooms with *Poor acoustic quality* in comparison to children of the same age in classrooms with *Adequate acoustic quality*. Instead, it was interesting to note that younger children of 6 to 8 years, attending first, second and third grade of primary school, did not report significant differences in listening comfort when learning occurred in classrooms with *Adequate acoustic quality* versus *Poor acoustic quality*.

On the one hand, in older children self-reporting was useful to grasp differences. Our findings suggested that older children were aware of their hearing and listening experience at school, capturing the poorer acoustic quality of classrooms with long reverberation time in comparison to those classrooms with short reverberation time equipped with a sound-absorbing system. When classroom acoustic conditions are challenging, children may easily become passive and disengaged from participation in learning and experience boredom and frustration. Information derived from our results could be an important starting point for conversations between teachers and pupils about cognitive, motivational, affective and contextual factors that sustain good hearing and listening, which others challenge them, and the ways in which teaching and learning might be enhanced and personalized. Being aware of their listening experience, older primary school children are in an optimal state to be supported in discovering and strengthening their strategies on how they might take control and regulate their listening depending on the circumstances. Further research based on self-report questionnaires could add more questions about hearing and listening when learning occurs in a larger range of situations, such as the class-group level or outside the classroom. Linked to this, future studies could investigate the relationships between older children's perspectives on listening when learning occurs in classrooms with *Adequate acoustic quality* versus classrooms with *Poor acoustic quality* and children's school outcomes, such as children's levels of attention and interest in joining group activities and discussions (involvement) or ability in completing planned activities (task orientation) (e.g., Yuen-Yee & Watkins, 1994).

The present study has some limitations. For younger children, our results might indicate that they did not consciously realize the detrimental effects of working in classrooms with *Poor acoustic quality*. However, this result needs further investigation. For example, the use of a 3-point Likert scale, while simple and easy to administer especially to children, has several limitations that may impact the quality of the data collected. In particular, with only three response options, the scale may not capture subtle variations in respondents' perceptions. This lack of discrimination can result in a loss of valuable information. Furthermore, the literature suggests that children may encounter challenges when describing their psychological condition using graduated measurement scales and emphasizes that self-assessments exhibit limited reliability, particularly in younger children (Edelbrock et al., 1985). In future studies other methods, such as drawing (see a previous study on children's metaknowledge about attention at school expressed through drawings by Pezzica et al., 2016), could be used with younger children to investigate their capacity to grasp differences in their hearing and listening when working in classrooms with *Adequate* or *Poor acoustic quality*. Finally, the number of participants in each group may not have been sufficient to adequately capture differences in children's perspectives on their own listening and listening in the classroom. Future research should replicate these findings using larger sample sizes.

Although this is a preliminary study opening to further investigations, our findings have important practical implications. Teachers may rely on results to enhance children's listening metacognitive knowledge to better self-regulate their learning (see recent model by Wirth et al., 2020) in various acoustic conditions, especially in children in the first classes of primary school who seem to lack the capacity to capture the *Poor acoustic quality* of classrooms. Teachers may use a variety of teaching listening, including direct teaching instruction, classroom metacognitive thinking and group activities on affective and motivational aspects impacting on listening. Currently, to our knowledge, there are few programs to use as models (see e.g., Mendelsohn, 1998). One of the few is the study by Goh and Taib (2006), a small scale of metacognitive instruction for 11- to 12-year-old pupils providing a range of strategies used for facilitating listening. This fact thus highlights the need to develop research-based interventions on enhancing young children's awareness of the importance of listening at school and conditions to support it. Obviously, building awareness among elementary-school teachers about taking care and scaffolding the aspects of metacognitive thinking and self-regulation about listening at school and the benefits of teaching them to children is therefore an important next step towards improving children's learning predisposition and enjoyment at school. A metacognitive work on enhancing awareness of listening at school should be accompanied by fostering adaptive behaviors that children and school operators take with them to school and by intervening at architectural and engineering levels to develop and implement sound-absorbing solutions to optimize hearing and listening inside and outside the classroom environments (Laurìa et al., 2020). Furthermore, our analysis was restricted to children with no school problems or learning disabilities. More studies would be required to further investigate the link between children's own perspectives on listening in atypical populations and the authentic school environment characteristics in which learning occurs.

Appendix

Table 4 Final eleven items of the pupils questionnaire (responses on a 3-point Likert scale: 1 = I hear little, 2 = I hear enough, 3 = I hear very well)

No	Item
1	*When your teacher is speaking but you cannot see his/her face because he/she is turned away, how well do you hear his/her voice?* (Italian version: Quando il tuo insegnante sta parlando ma non puoi vedere la sua faccia perché girato da un'altra parte, come senti la sua voce?)
2	*When your teacher is talking and moving around the class, how well do you hear his/her voice?* (Italian version: Quando il tuo insegnante sta parlando e si muove nella classe, come senti la sua voce?)
3	*When there are children making noise outside your classroom, how well do you hear your teacher's voice?* (Italian version: Quando ci sono dei bambini che fanno rumore fuori dalla tua classe, come senti la voce del tuo insegnante che parla?)
4	*How well do you hear your teacher's voice explaining the delivery, i.e., telling you what you have to do?* (Italian version: Come senti la voce del tuo insegnante che spiega la consegna, cioè che dice cosa dovete fare?)
5	*When your teacher is asking a question and one of your classmates is giving an answer, how well do you hear what the teacher says and what the child answers?* (Italian version: Quando il tuo insegnante sta facendo una domanda e uno dei tuoi compagni di classe sta dando una risposta, quanto senti bene quello che dice l'insegnante e quello che risponde il bambino?)
6	*When you are working in a group with your peers, how well do you hear your teacher's voice?* (Italian version: Quando stai lavorando in gruppo con i tuoi compagni, come senti la voce del tuo insegnante che parla?)
7	*When your teacher is reading a story and other children are talking, how well do you hear your teacher's voice?* (Italian version: Quando il tuo insegnante sta leggendo una storia e altri bambini stanno parlando, come senti la voce del tuo insegnante?)
8	*When your teacher is asking questions to the whole class, how well do you hear his/her voice?* (Italian version: Quando il tuo insegnante sta facendo domande a tutta la classe, come senti la sua voce?)
9	*When your teacher is asking you a question, how well do you hear his/her voice?* (Italian version: Quando il tuo insegnante sta facendo una domanda a te, come senti la sua voce?)
10	*When a child is speaking from his seat to the whole class, how well do you hear his/her voice?* (Italian version: Quando un bambino sta parlando dal suo posto a tutta la classe come senti la sua voce?)
11	*When a child is speaking from his or her desk to the whole class, how well do you hear his/her voice?* (Italian version: Quando un bambino sta parlando dalla cattedra a tutta la classe come senti la sua voce?)

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Declarations

Conflict of interest The authors declare no competing interests.

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Most relevant publications in the field of Psychology of Education:

Vettori, G., Di Leonardo, L., Secchi, S., Astolfi, A., & Bigozzi, L. (2022). Primary school children's verbal working memory performances in classrooms with different acoustic conditions. *Cognitive Development, 64,* Article 101256.
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Rasmussen B, Carrascal T, Secchi S. A. (2023). Comparative study of acoustic regulations for hospital bedrooms in selected countries in Europe. *Buildings, 13*, 1–22.
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Current theme of research:

Specific learning disorders, identification of predictors of developmental dyslexia, explanatory factors of specific spelling learning disorder, the relationship between lexical competence, spelling and reading comprehension in typical and atypical development, school interventions; teaching and learning processes; effectiveness of teaching methods.

Most relevant publications in the field of Psychology of Education:

Bigozzi, L., Vettori, G., & Incognito, O. (2023). The role of preschoolers' home literacy environment and emergent literacy skills on later reading and writing skills in primary school: A mediational model. *Frontiers in Psychology, Article 14:1113822*
Vettori, G., Di Leonardo, L., Secchi, S., Astolfi, A., & Bigozzi, L. (2022). Primary school children's verbal working memory performances in classrooms with different acoustic conditions. *Cognitive Development, 64,* Article 101256.
Bigozzi, L., Tarchi, C., & Pinto, G. (2017). Consistency and stability of Italian children's spelling in dictation versus composition assessments. *Reading & Writing Quarterly*, *33*, 109–122.
Bigozzi, L., Tarchi, C., & Pinto, G. (2016). Spelling across tasks and levels of language in a transparent orthography. *PLoS One, 11,* e0163033.
Pinto, G., Tarchi, C., & Bigozzi, L. (2015). The relationship between oral and written narratives: A three-year longitudinal study of narrative cohesion, coherence, and structure. *British Journal of Educational Psychology, 85*, 551–569.
Bigozzi, L., & Vettori, G. (2016). To tell a story, to write it: developmental patterns of narrative skills from preschool to first grade. *European Journal of Psychology of Education, 31,* 461–477.
Pinto, G., Bigozzi, L., Gamannossi, B. A., & Vezzani, C. (2012). Emergent literacy and early writing skills. *The Journal of Genetic Psychology, 173*, 330–354.