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Review

Towards a child-centred perspective on classroom acoustics: A systematic review of perceptual attributes, methods and contextual drivers☆

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ABSTRACT

Research on indoor environments adopting a soundscape approach is increasingly recognised as a key direction for the acoustic design of supportive and comfortable spaces. However, its application to educational buildings remains limited, particularly for primary school children. This systematic review synthesizes evidence on children's perception of classroom acoustic environments using Scopus, APA PsycINFO, and Web of Science, focusing on perceptual attributes, assessment methods, contextual factors, and linguistic aspects of the tools used. Following PRISMA guidelines, the search included English-language studies published after 1990 involving children aged 6–12 and addressing primary school sound environments, children's sound perception, and related well-being or restoration outcomes. In total, 32 studies were analysed. The literature resulted highly fragmented, with substantial heterogeneity in terminology, measurement approaches, outcome variables, and linguistic reporting. Perceptual attributes were grouped into 12 macro-categories spanning sensory, affective, cognitive, and behavioural responses, with a strong predominance of negative and performance-related outcomes, and limited consideration of positive or restorative dimensions. Most studies used questionnaires, mainly Likert-type scales, while interviews and qualitative methods were less common. Across studies, acoustic indicators such as sound levels and room-acoustic parameters showed limited associations with perceptual outcomes. Children's evaluations were found to be shaped by sound type and non-acoustic contextual factors, such as classroom activity, pedagogical organisation, and spatial configuration. The linguistic analysis showed that translation, semantic adaptation, availability of original wording, and children's comprehension of descriptors were rarely reported systematically, despite the use of adult-oriented soundscape terminology in some studies. These findings indicate that children's perception cannot be fully understood through physical descriptors alone but should be interpreted as a context-dependent and activity-driven experience. The review supports the development of child-centred, linguistically transparent, and context-sensitive assessment tools for classroom soundscape research.

1. Introduction

Occupants' perceptions of the indoor acoustic environment have attracted increasing attention across a wide range of settings. Given that people spend approximately 85% of their time indoors [1], understanding how the acoustic quality of indoor spaces shapes occupants' affective and cognitive reactions is essential, as these effects ultimately influence well-being and health [2]. This growing interest coincides with the extension of the soundscape concept, originally developed for outdoor environments and defined as the "acoustic environment as perceived and/or understood by a person or people in context" [3], to indoor settings. The *indoor soundscape* concept reframes the analysis of indoor acoustic environments through a subjective, perception-oriented perspective, recognising that individuals' responses arise from the dynamic interaction between physical acoustic parameters, psychoacoustic characteristics, along with personal and contextual factors, in which building features play a key role [4]. Within the soundscape framework, perceptual dimensions (e.g., *pleasantness* and *eventfulness* in outdoor settings [5]) are used to characterise how people interpret and evaluate the sound environments. Over time, context-specific soundscape

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dimensions have been developed for specific settings, including residential environments [6] and open-plan offices [7].

Despite growing interest in soundscape research, relatively few studies have examined educational buildings from this perspective [8], and most have focused on high schools and universities [9]. Research on younger children, particularly in primary schools, remains limited, even though this group is especially sensitive to acoustic conditions. Previous research has shown that classroom acoustics in primary school influence speech intelligibility and performance in complex tasks [10], listening and cognitive effort [11], and longer-term learning and academic achievement [12], due to the children's ongoing development of cognitive and linguistic resources [13,14].

Although the soundscape framework has rarely been purposefully applied, the question of how primary school children perceive their classroom sound environment is not entirely new. Early questionnaire-based studies (e.g., [15,16]) showed that children can reliably discriminate between situations with different noise levels and sources. More recently, a pilot study administered a questionnaire survey adapted from the technical specification [17] and found that children often perceive themselves as exposed to unpleasant sounds at school, and that significant relationships exist between children's perceptions and both acoustic and personal factors [18]. Notably, children tend to prefer learning environments that are quiet but not completely silent, suggesting expectations of acoustic comfort that go beyond the traditional noise-reduction focus of classroom acoustics. As acoustic design standards for classrooms become more established [19], a broader soundscape perspective can help address not only the foundational objective of classrooms acoustic (i.e., speech communication) but also pupils' well-being, comfort, and engagement. By acknowledging that emotional responses to the acoustic environment influence children's learning and social outcomes, soundscape design can then contribute to more holistic and supportive educational settings [20]. However, several important gaps remain before such an approach can be fully grounded in children's perspectives.

Studies on school soundscapes have primarily explored the topic through adult viewpoints, such as those of teachers and researchers [21]. As a result, instruments and semantic scales used for soundscape assessment have been developed for adult populations and may not be fully reliable for younger age groups. Children differ from adults in physiological, linguistic, cognitive, and emotional development, which may affect how they interpret and report perceptual experiences [22–24]. Concrete judgments (e.g., identifying sound sources or evaluating whether the teacher's voice is clearly audible) are generally easier for children to understand and report than more abstract affective evaluations, which are often highly context dependent [25]. Compared with adults, primary school children also possess a less differentiated emotional lexicon, typically using broad categories (e.g., good/bad; happy/sad) and providing less nuanced affective ratings, with emotions mainly described along simple valence dimensions rather than granular states [26,27]. Notably, even adults have a relatively limited vocabulary for describing sound compared with visual experience [28], suggesting that children may face even more constraints.

As noted by Dockrell and Shield [16] "careful wording is particularly important in classroom noise surveys". This issue is especially relevant in soundscape research, where perceptual assessment relies heavily on verbal descriptors and subjective interpretation. However, the extent to which studies report translation procedures, linguistic adaptations, or validation of children's comprehension remains unclear.

Finally, children's evaluations appear to be strongly shaped by the immediate context and the meaning of the ongoing activity [15,16]. Consequently, the same noise level may be perceived very differently depending on whether children are engaged in playtime, group work, or teacher-led instruction. As already noted in the adult soundscape literature [29], perceptual responses are influenced by a constellation of contextual factors. However, how these variables jointly shape children's perceptions has not yet been systematically examined.

This systematic review addresses these gaps through the following research questions, specifically referred to the literature on children's perception of acoustic environments in primary schools:

- RQ1: Which perceptual attributes have been examined?
- RQ2: What methodologies and measurement tools have been used?
- RQ3: How do acoustic and contextual factors influence children's perceptions?
- RQ4: Which languages and linguistic contexts are represented, and how are perceptual attributes translated, adapted, or formulated for children?

By synthesising the available evidence, this review aims to support the application of the indoor soundscape framework to primary school contexts and to identify key methodological gaps for future research, as well as the factors that can be leveraged to improve the perceived acoustic conditions for children in the classroom.

2. Methodology

In the review, the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses [30]) for systematic review reporting were followed.

2.1. Eligibility criteria

The studies eligible for the review had to meet the following criteria: (I1) focus on primary school settings (both in the field or in the lab), (I2) report on children's perception of the sound environment, (I3) report on the effects of the sound environment on children's well-being and restoration, and (I4) be published in English after 1990. Studies were included if they involved participants within the 6–12 age range. Given cross-country differences in the definition of primary school age, studies including broader age ranges were retained when at least 75% of participants fell within the 6–12 age range and the study context remained relevant to primary school learning environments. Studies focusing exclusively on children outside the 6–12 age range (E1), or children with hearing impairments or sensory disabilities, or with neurodivergence (E2) were excluded. Studies reporting only objective acoustic measurements without subjective data (E3) and studies focusing on online learning environments (e.g., virtual classrooms or remote learning platforms) were also excluded (E4). Finally, the review considered only papers that were available in full text and did not include any duplicates of results from other papers (E5). The detailed inclusion and exclusion criteria are reported in Table 1.

Table 1
Eligibility criteria used in the selection process of the studies.

Inclusion Criteria	Exclusion Criteria
I1 – Field studies conducted in primary schools or laboratory settings recreating such environments.	**E1** – Studies focusing exclusively on children under 6 years of age and over 12 years of age
I2 – Studies investigating children's perception of the acoustic environment.	**E2** – Studies focusing exclusively on children with hearing impairments, other sensory disabilities, or neurodivergent conditions.
I3 – Studies examining the effects of sound on children's well-being and restoration.	**E3** – Studies that only report objective acoustic measurements without subjective evaluations by children.
I4 – Journal articles and conference papers published after 1990, and whose text is available in English.	**E4** – Studies based on online learning environments.
	E5 – Studies reporting duplicate results, lacking full-text availability, or providing incomplete documentation of methods and results.

2.2. Information sources

The literature search was first conducted in January 2025 and later updated in May 2026 to identify relevant studies in the following databases: Scopus, APA PsycINFO, and Web of Science. Where document-type filters were available, both journal articles and conference papers or proceedings were selected in the databases.

2.3. Search strategy

The search string was formulated starting from the identification of four main domains: *site of study*, *perception*, *acoustics*, and *population*. Several keywords were then identified for each domain and combined to formulate the following search string: (“school*” OR “educational” OR “classroom*” OR “learning spaces” OR “environment*”) AND (“comfort*” OR “soundscape” OR “perception” OR “restor*”) AND (“sound*” OR “acoustic*” OR “noise” OR “auditory”) AND (”student*“ OR ”child*“ OR ”kid*“ OR ”pupil*“ OR “young learner*”) AND NOT (”hearing loss“ OR ”hearing impair*“ OR ”audiolog*“ OR ”phonetic*“ OR ”toddlers“). The final terms of the string were added to address exclusion criterion E2.

2.4. Selection process

Studies identified across various databases were first aggregated into a single dataset, after which duplicate entries were excluded. Title and abstract screening were conducted by one reviewer (SS), following the inclusion and exclusion criteria in Table 1. Any records for which eligibility was uncertain were discussed with the other two reviewers (CV and ST). If uncertainty persisted after discussion, the record was retained for full-text screening to ensure that potentially relevant studies were not excluded prematurely. Next, one reviewer conducted full-text screening for inclusion. Again, records of uncertain eligibility were reviewed with the other two reviewers, and consensus on inclusion or exclusion was reached through discussion.

2.5. Data collection process

A data extraction spreadsheet was developed and pilot-tested on three randomly selected articles, after which it was refined to optimise its format. Once finalised, two reviewers manually performed the initial data extraction for all included studies (CV and SS), and the other reviewer (ST) independently verified the accuracy of the extracted data.

2.6. Data items

The extracted information included general bibliographic details such as title, authors, year of publication, type of publication (journal or conference), and keywords. Additionally, general information about the study was recorded: sample characteristics (i.e., total number of participants, gender balance, mean age and range; number of schools and classes involved in the study), country, experimental design (field or lab study; observational or experimental study), listening conditions investigated in laboratory studies or monitored in the real classrooms (e.g., sound types, sound levels, acoustic parameters), and type of classroom activity targeted in the perceptual assessment (e.g., individual work, frontal lesson).

To address the research questions, the following data were also extracted. For RQ1, data were extracted from all instruments used to assess children’s perceptions of the acoustic environment. Specifically, for each study, all questionnaire items or survey questions were systematically identified, extracted, and reported in the review table.

For RQ2, information was extracted on the data collection tools (questionnaires and/or interviews). For closed-set questionnaires, additional information was recorded regarding the type of scale used (e.g., Likert or dichotomous scales), and the response format (e.g., three-, five, or multi-point scales).

For RQ3, data were extracted on the contextual factors included in the studies and analysed to assess potential effects on children’s perception. The reviewed studies examined associations between these factors and perceptual outcomes using statistical analyses or descriptive statistics. For each reviewed combination of contextual factor and perceptual attribute, the extracted information included the baseline condition, the range of variation (in the case of a continuous predictor), and the direction of the statistically significant effects.

Finally, for RQ4, information was extracted on the linguistic characteristics of the assessment tools, including the language of questionnaire/interview administration, any reported translation or adaptation procedures, and whether children’s comprehension of the terminology or descriptors was assessed.

2.7. Synthesis methods

For RQ1, an inductive thematic approach was used. Questionnaire and interview items extracted from each study were first mapped to perceptual attributes. These attributes were then grouped into broader macro-categories based on semantic similarity, with the mapping and grouping jointly reviewed and agreed upon by the three authors. As several attributes may overlap across emotional, cognitive, and behavioural domains, these macro-categories were not intended to represent mutually exclusive constructs. Rather, they were used as synthesis categories, with each item assigned according to its dominant meaning and how it was operationalised in the original study. A frequency table and a qualitative graph (i.e., word cloud) were created to quantify the occurrence of perceptual attributes across studies.

To address RQ3, factors influencing the perception of the sound environment were categorised based on the reviewed studies. The initial categorisation followed the framework proposed for residential spaces [4] and was subsequently refined to reflect the specific characteristics of learning environments. Graphical charts were developed to illustrate the positive, negative, and neutral/no relationships between perceptual attributes and these contextual factors.

3. Results

3.1. Study selection

The database search identified 7607 studies. Duplicate records of 1050 studies were removed before conducting separate title and abstract screenings, which were performed according to the inclusion and exclusion criteria outlined in Table 1. Application of criteria E2, I2, and I3 to the dataset resulted in the exclusion of 6137 studies, based on title screening. A total of 420 studies were retained for abstract screening, during which 326 were excluded based on criteria I1, I4, and E4. Of the 17 conference papers, five were excluded because the same work was subsequently available as a full journal article, and ten were excluded based on the inclusion and exclusion criteria. The full texts of the remaining 94 studies were then assessed, leading to the exclusion of an additional 55 articles due to age mismatch (E1: 19 studies), studies reporting duplicate results, lack of full-text access or incomplete documentation (E5: 23 studies), focus on teacher’s perception rather than children (I2: 17 studies), and publication type or date mismatch (I3: 3 studies).

Ultimately, 32 studies were included in the review. Fig. 1 illustrates the study selection process in accordance with the PRISMA guidelines. Table 2 provides a summary of the 32 studies included in the review, organised chronologically.

3.2. Study characteristics

Of the 32 studies included in the review, 30 were published in peer-reviewed journals and two in conference proceedings. No studies on this

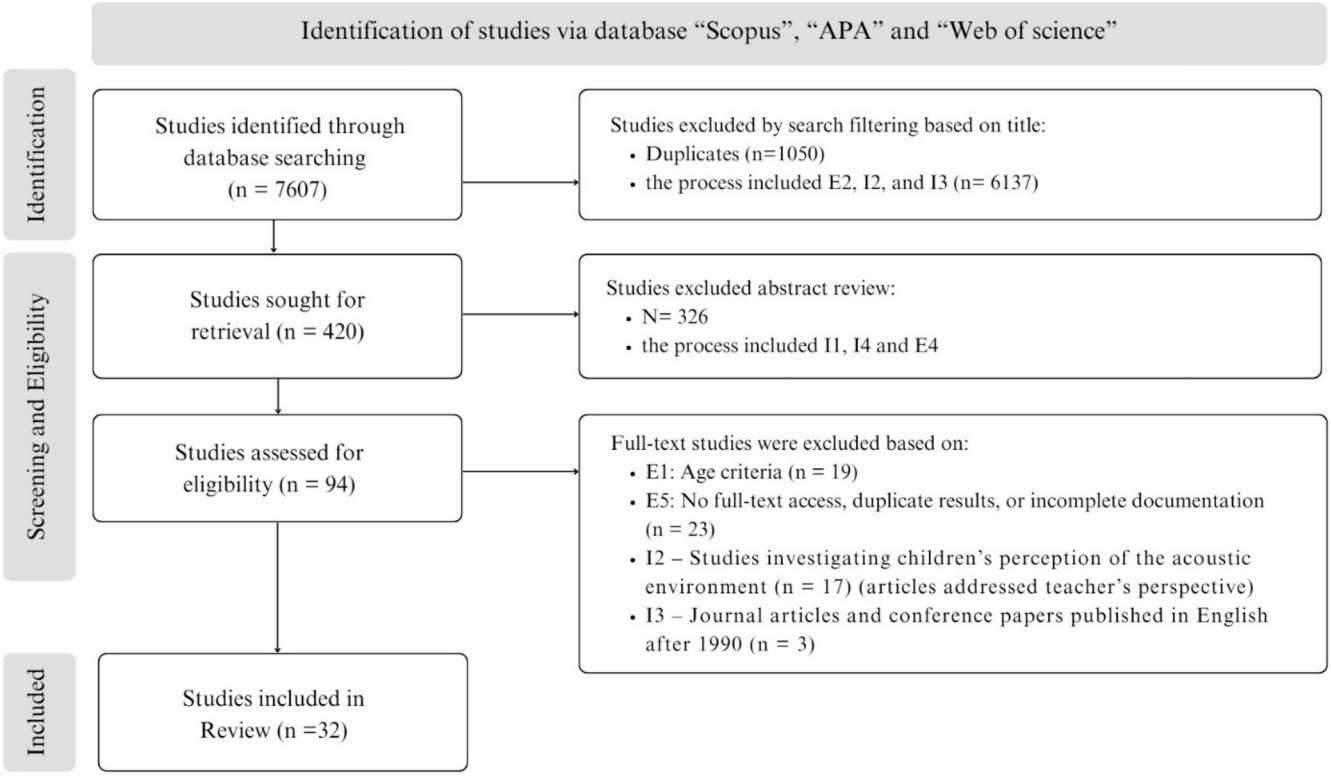

Fig. 1. Flowchart of study selection.

topic were published before 2003, with a peak in publications observed in 2023 (Fig. 2a). Most studies were conducted in Italy and the United Kingdom (Fig. 2b).

Laboratory studies accounted for the smallest proportion (12%, n = 4), followed by field studies that included perceptual assessment without acoustic monitoring (19%, n = 6), and field studies combining perceptual assessment with acoustic characterisation of the environment (69%, n = 22). Most of these studies focused exclusively on acoustics; however, 19% (n = 6) considered acoustics as one of the domains of Indoor Environmental Quality.

Regarding the age of the students involved in these studies, Fig. 3a shows that most studies focused on children aged 9–11 years. The number of studies gradually decreases for younger age groups, highlighting a concentration of research interest in late childhood.

With respect to the context, understood as the interrelationship between person, activity, and place in space and time [3], and specifically the functional context (i.e., the activities taking place within the space [6]), it was found that only 13 of the 32 studies provided contextual information to the children, in terms of the task at hand (e.g., frontal lesson). Among these, only one study [18] clearly anchored all questions to a specific context, asking children to respond in relation to a "doing a test" situation. In the other 12 studies, questions referenced various classroom situations or activities, implicitly recognising that multiple activities take place within a primary classroom learning space. Fig. 3b visualises the classroom situations addressed across the studies, which, according to the literature [59,60], could be broadly categorised into individual activity, one-to-one communication and group work. In the remaining studies, participants were asked to answer the survey or interview questions with reference to "their classroom" or "during lessons".

Finally, the acoustic metrics used to characterize the sound environment comprised a combination of sound-level indicators and room-acoustic parameters. The most frequently adopted metric was the equivalent A-weighted sound level ($L_{A,eq}$), reported in 15 of the 32 studies. Sound levels were measured either outside school buildings or within learning spaces, under both unoccupied (i.e., ambient noise) and occupied conditions. In the latter case, three studies further distinguished sound levels associated with different classroom situations [44,53,59].

Concerning room acoustic parameters, reverberation time was used in 13 studies, with measurements performed under unoccupied conditions. Only two studies reported reverberation time values estimated for occupied classrooms (80% occupancy) [44,55]. Other acoustic descriptors (e.g., speech clarity C_{50}, Speech Intelligibility Index STI), were measured in a subset of studies in unoccupied conditions to provide supplementary information on speech communication quality [18,40,44,46,52,53,59].

Among the 32 studies reviewed, psychoacoustic metrics, namely loudness, roughness, fluctuation strength, and sharpness, were measured in only two studies [52,59]. Data on the sound insulation performance of vertical and horizontal partitions and façades were similarly reported in only one study [40].

3.3. RQ1: perceptual attributes

The reviewed studies investigated children's perception of the sound environment using attributes across multiple dimensions, which were organized into 12 macro-categories, including individual sensations, emotional, cognitive, and behavioural responses (Fig. 4). As some perceptual attributes (e.g., annoyance, disturbance, and distraction) may overlap conceptually across different domains the proposed macro-categories should be interpreted as organisational categories rather than strictly distinct psychological constructs.

Studies addressing individual sensations investigated the frequency-related attributes or dominance of specific sounds (n = 9), along with their detectability (n = 5), in terms of both sound source identification and spatial localisation. Sound level in the classroom was assessed either in terms of perceived loudness (n = 4) or noisiness (n = 5). Concerning emotional responses, studies focused on affective reactions, including aspects such as comfort, pleasantness, annoyance (n = 19). Two studies

Table 2
Summary of the 32 studies included in the review. The following information is reported: (1) reference of the study, (2) year of publication, (3) type of publication (J: journal article, C: conference paper), (4) country where the study was conducted, (5) number and age of the children involved, (6) study setting (in laboratory or in field), (7) methodological approach: type of assessment (I: interview, Q: questionnaire), scale type and number of points in the scale, (8) presence or absence of contextual information for the perceptual assessment, (9) acoustic measurements (where not otherwise specified, measurements refer to the unoccupied environment; the subscript "mid" refers to the average value in the mid-frequency octave bands; OCC: occupied conditions; L_s: speech level; mLs: decay slope of the speech level), and (10) macro categories of the perceptual attributes assessed. For [57], only data referring to the 11–12-year-old participants were considered in the review results.

Ref.	Year	Pub. type	Country	N (age range)	Study setting	Methodological approach			Context	Acoustic measurements	Perceptual attributes
						Type	Scale type	n. points			
[31]	2003	J	UK	18 (10–13)	Field	I	Semi-structured questions	–	No	$L_{A,eq,16h}$ (outdoor, aircraft noise exposure): high exposure > 63 dB(A), low exposure < 57 dB(A)	- affective response - effects on performance - perceived control
[16]	2004	J	UK	2036 (6–11)	Field	Q	Dichotomous Likert (emoji)	yes/no 5	Yes	$L_{A,eq}$ (outdoor) = 57.4 dB(A)	- affective response - sound source detectability - speech perception
[32]	2006	J	Brazil	557 (6–12)	Field	Q	Likert (verbal)	3	No	$L_{A,eq}$ (outdoor) = 66.1–80.3 dB(A) $L_{A,eq}$ (OCC) = 54.7–76.4 dB (A)	- affective response
[33]	2006	C	Turkey	2019 (7–15)	Field	Q	Dichotomous	yes/no	No	–	- affective response - speech perception
[34]	2009	J	UK, Netherlands, Spain	2844 (9–11)	Field	Q	Likert (verbal)	4 and 5	Yes	Noise exposure (predicted $L_{A,\ eq,16h}$): aircraft = 46.1—54.2 dB(A) road traffic = 49.3–54.1 dB (A)	- affective response - effects on performance - frequency-related attributes
[35]	2010	J	Germany	398 (7–8)	Field	I	Dichotomous	yes/no	No	T_{mid} = 0.49–1.00 s	- noisiness
[36]	2011	J	Canada	1011 (5–9)	Field	I	Semi-structured questions		No	$L_{A,eq}$ = 33.6–52.3 dB(A)	- affective response - effects on performance - social interaction - speech perception
[37]	2012	J	UK	393 (8–11)	Field	Q	Likert (emoji)	5	Yes	T_{mid} = 0.38–0.90 s	- sound source detectability - speech perception
[38]	2012	J	Italy	614 (9–11)	Field	Q	Likert (verbal)	4, 5	No	–	- affective response - frequency-related attributes - perceived control - speech perception
[39]	2014	J	Turkey	611 (7–13)	Field	Q	Likert (verbal) Dichotomous	3 yes/no	No	$L_{A,eq}$ (school corridors) = 58.5–93.0 dB(A)	- affective response - noisiness - perceived control
[40]	2014	J	Italy	66 (9–11)	Field	Q	Likert (verbal)	4	No	T_{mid} = 1.3–1.8 s D_{50} = 0.28–0.56 dB EDT = 0.92–2.17 s STI = 0.48–0.58 R'_w (vertical) = 43–45 dB R'_w (horizontal) = 48 dB $L'_{n,w}$ = 73–78 dB $D_{2m,nT,w}$ = 22–33 dB	- affective response - frequency-related attributes - perceived control - sound source detectability - speech perception

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Table 2 (*continued*)

Ref.	Year	Pub. type	Country	N (age range)	Study setting	Methodological approach			Context	Acoustic measurements	Perceptual attributes
						Type	Scale type	n. points			
[41]	2016	J	Portugal	213 (8–11)	Field	Q	Likert (verbal) Dichotomous	4 yes/no	No	$L_{A,eq}$ (outdoor) = 48.9–63.3 dB(A) $L_{A,eq}$ (indoor, school occupied) = 67.2–72.3 dB (A) $L_{A,eq}$ (indoor, school empty) = 37.5–39.4 dB(A)	- disturbance - effects on performance - noisiness - sound source detectability - speech perception
[15]	2017	J	Sweden	149 (7–16)	Field	Q	Likert (verbal)	5	Yes	–	- affective response - effects on performance - frequency-related attributes - speech perception
[42]	2018	J	Slovakia	41 (9–13)	Field	Q	Likert (verbal)	3	No	$L_{A,eq}$ (OCC) = 72.2–77.9 dB (A)	- noisiness
[43]	2018	J	Netherlands	1145 (9–11)	Field	Q	Likert (verbal)	3, 4	No	–	- affective response - frequency-related attributes
[44]	2019	J	Italy	330 (6–7)	Field	Q	Likert (verbal)	3	Yes	T_{mid} (80% OCC) = 0.5–1.4 s T_{mid} = 0.6–1.7 s $C_{50,mid}$ = -2.2–7.6 dB $U_{50,mid}$ = -2.6–4.0 dB $L_{A,eq}$ (OCC, silence) = 45.5–55.9 dB(A) $L_{A,eq}$ (OCC, group work) = 61.8–75.1 dB(A) L_s (OCC) = 60.3–63 dB(A) mL_s (OCC) = -2.4 – −0.8 dB/dd	- disturbance - loudness - speech perception
[45]	2019	J	Netherlands	335 (9–13)	Lab	Q	Likert (verbal)	3, 5	No	T_{mid} = 0.07 *vs* 0.33 s $L_{A,eq}$ (quiet) = 45 dB(A) *vs* $L_{A,eq}$ (sound stimuli) = 60 dB (A)	- affective response - effects on performance - noisiness
[46]	2020	J	China	87 (8–9)	Field	Q	Dichotomous	yes/no	Yes	T_{mid} = 0.55 *vs* 1.20 s $C_{50,\ mid}$ = 5.5 *vs* −1 dB STI = 0.75 *vs* 0.56 $L_{A,eq}$ = 39.6 *vs* 42.1 dB(A)	- affective response - effects on performance - noisiness - reverberance - speech perception
[47]	2020	J	Finland	50 (8–13)	Field	Q	Visual Analog Scale	from 0 to 100	No	$L_{A,eq}$ = 35 dB(A) $L_{A,eq}$ (OCC) = 58–60 dB(A) T_{mid}	- affective response - frequency-related attributes - loudness - noisiness - perceived control - speech perception
[48]	2021	J	Netherlands	250 (9–12)	Lab	Q	Likert (verbal) Likert (emoji)	4 5	No	T_{mid} = 0.22 *vs* 0.70 s $L_{A,eq}$ (quiet) = 45 dB(A) *vs* $L_{A,eq}$ (sound stimuli) = 60 dB (A)	- affective response - sound source detectability
[49]	2022	J	France	112 (8–11)	Field	Q	Likert (verbal) Visual Analog Scale	4 from 0 to 10	Yes	$L_{A,eq}$ = 30–40 dB(A) $L_{A,eq}$ (OCC) = 46–54 dB(A)	- affective response - effects on performance - loudness - noisiness - speech perception
[50]	2023	C	Chile	272 (9–11)	Field	Q	Likert (verbal)	3, 4, 5	Yes	–	- affective response

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Table 2 (*continued*)

Ref.	Year	Pub. type	Country	N (age range)	Study setting	Methodological approach			Context	Acoustic measurements	Perceptual attributes
						Type	Scale type	n. points			
											- speech perception
[51]	2026	J	Italy	229 (11–14)	Field	Q	Likert (verbal)	5	No	$L_{A,eq}$ (quiet) *vs* $L_{A,eq}$ (sound stimuli) = 47 dB (A)	- affective response
[52]	2023	J	China	38 (6–12)	Lab	I	Semi-structured questions		No	$L_{A,eq}$ (quiet) = 21.0–23.2 dB (A) *vs* $L_{A,eq}$ (sound stimuli) = 55 dB(A) Psychoacoustic indicators: FS, loudness, roughness, sharpness	- social interaction
[53]	2023	J	Finland	34 (10–11)	Field	Q	Likert (verbal) Likert (emoji)	4 5	Yes	T_{mid} = 0.32 *vs* 0.54 s STI = 0.80 *vs* 0.76 L_s = 52.3 *vs* 54.7 dB; $L_{A,eq}$ = 29 dB(A) $L_{A,eq}$ (outdoor) < 50 dB(A) $L_{A,eq}$ (OCC, different activities) = 44.1–71.6 dB (A)	- affective response - effects on performance - speech perception
[54]	2023	J	China	188 (7–12)	Field	Q	Likert (verbal) Open-ended questions	5 –	No	–	- health and restoration
				61 (9–11)	Lab		Likert (verbal)	5	Yes	$L_{A,eq}$ (background) = 45 dB (A) *vs* $L_{A,eq}$ (sound stimuli); SNR = −5 to +15 dB	
[18]	2023	J	Italy	130 (8–10)	Field	Q	Likert (pictorial)	9	Yes	$L_{A,eq}$ = 29–48 dB(A) T_{mid} = 1.05–1.58 s $C_{50,mid}$ = −3.2–1.2 dB	- affective response - frequency-related attributes - loudness
[55]	2026	J	Italy	213 (6–11)	Field	Q	Likert (verbal)	3	Yes	T_{mid} (80% OCC) = 0.4–0.5 *vs* 0.7–1.3 s	- speech perception
[56]	2025	J	Egypt	123 (10–11)	Field	Q	Likert (verbal)	5	No	–	- speech perception - sound source detectability
[57]	2025	J	UK	164 (11–12)	Field	Q	Likert (verbal)	5	Yes	$L_{A,\ eq,15min}$ (multiple school locations): baseline (no added sound) = 59.2–71.9 (dB); natural sounds = 61.6–69.3 (dB); music = 67.2–74.4 (dB)	- affective response - frequency-related attributes
[58]	2025	J	Italy	69 (9–11)	Field	Q	Likert (emoji) Dichotomous	5 yes/no	No	$L_{A,eq,2min}$ (OCC) = 81–90 dB (A) T_{mid} = 2.53–4 s	- affective response - noisiness - speech perception
[59]	2025	J	Germany	67 (6–10)	Field	Q	Likert (emoji)	5	Yes	$L_{A,eq,15min}$ (OCC) = 55.5–67.4 dB(A) Psychoacoustic parameters: loudness, sharpness T_{mid} = 0.4–0.51 s $C_{50,mid}$ = 5.1–9.0 dB EDT_{mid} = 0.35–0.52 s STI = 0.74–0.81	- effects on performance - perceived control - speech perception

applied the eight attributes of the circumplex model originally developed for adults in outdoor environments [51] or indoor residential settings [57]. Research examining cognitive responses focused on the perceived impacts of the sound environment on the activities occurring within the learning space: speech perception (n = 19), overall disturbance (n = 6), as well as effects such as attentional capture, distraction, loss of concentration, and impaired performance (n = 12). Additional studies considered the influence of the sound environment on cognitive restoration and health (n = 1) and social interactions (n = 3). Finally, studies addressing behavioural responses focused on coping strategies adopted by children in response to noise (n = 5).

Table 3 presents the 12 macro-categories along with the 55 corresponding attributes, examples of their associated questionnaire items, and the specific study references from which they were derived. The frequency of each attribute across studies was calculated and visualised using a word cloud (Fig. 5).

3.4. RQ2: Methodologies and measurement tools

Table 2 shows that most studies (29 out of 32) employed questionnaires as assessment tools, either in pen-and-paper format or via digital platforms. A single study [31] used individual interviews, in a semi-structured format to accommodate potential variability in responses, with questions progressing from general topics to a specific focus on a

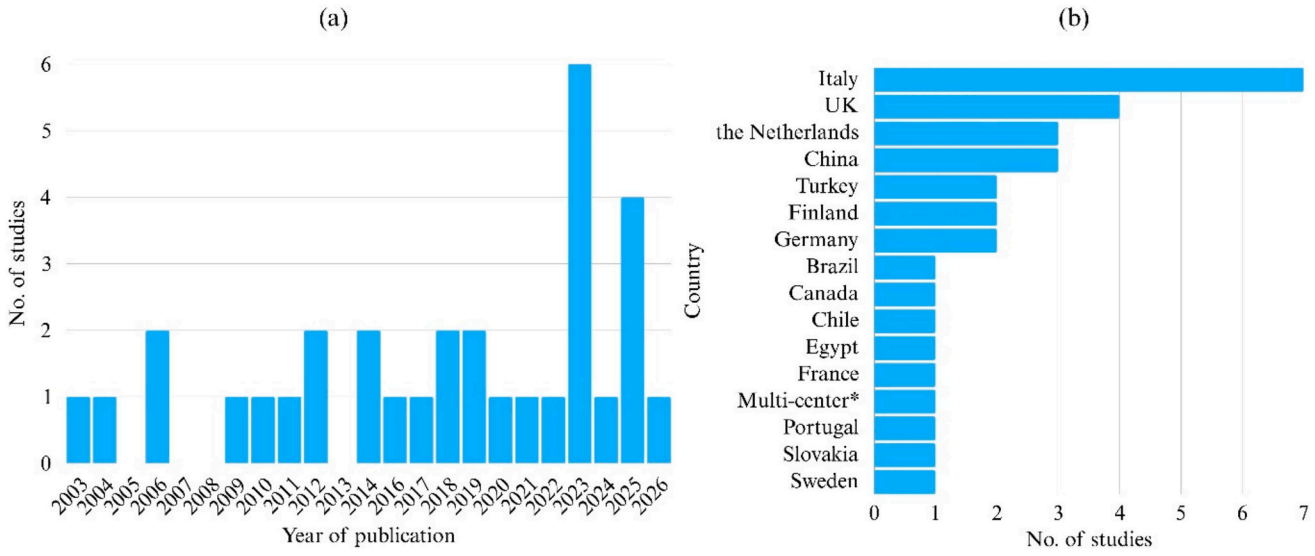

Fig. 2. Distribution of the studies by (a) year of publication, and (b) country.

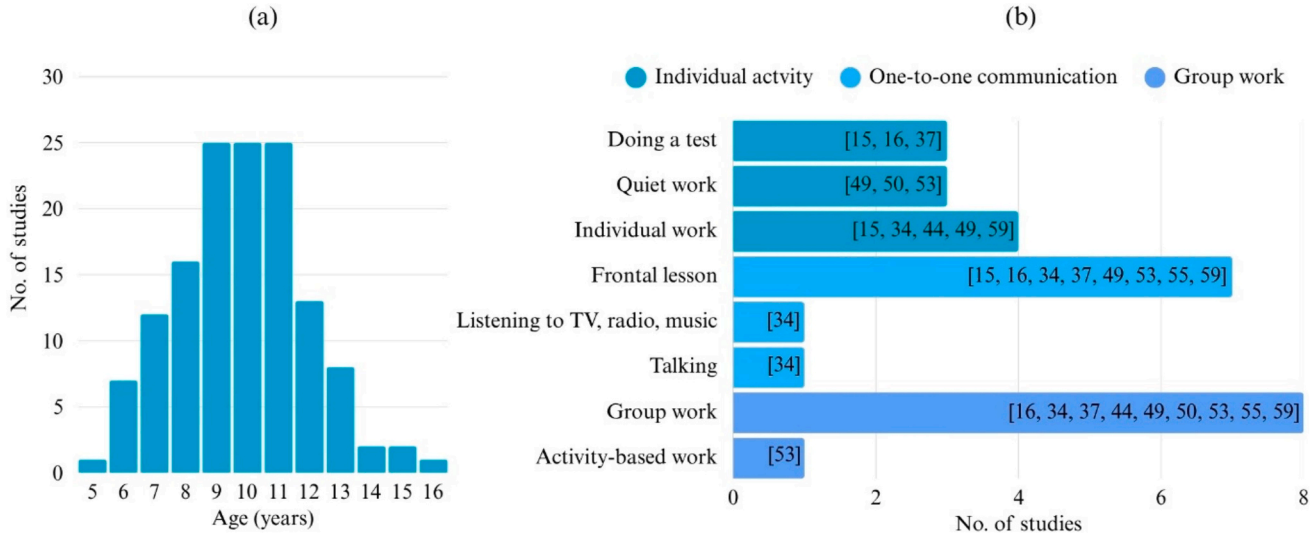

Fig. 3. (a) Distribution of the studies according to children's age. (b) Classroom situations addressed in the studies (context of the perceptual assessment).

particular sound source. Su et al. [52] examined children's social interactions by analysing self-reported behavioural expectations after exposure to different soundscapes in virtual settings. Finally, Rubin et al. [36] based their assessment on observations of students' communicative interactions, complemented by group interviews.

Fig. 6 shows the types of assessment scales used in the 28 studies based on questionnaires. Six studies adopted dichotomous scales (two response options, e.g., yes/no). Only two studies adopted Visual Analogue Scales as an assessment tool (from 0 to 100 in ref. [47], and from 0 to 10 in ref. [49]). Most of the studies used Likert scales to collect information on children's perceptions. While verbal scales were most used, seven studies incorporated pictorial and emoji-based scales [16,18,37,48,53,58,59]. These tools provided visually intuitive formats for expressing perception, such as using smiling/frowning faces or body postures to represent degrees of affective reaction. The 5-point Likert scale was by far the most common, while scales with fewer points, such as 3-point and dichotomous formats, were less frequently used. The 9-point scale was employed in only a single study [18].

3.5. RQ3: Relationships between perceptual assessments and contextual factors

Based on the reviewed literature, contextual factors influencing children's perception of classroom acoustic environments were identified and clustered into broader thematic domains (Fig. 7). The studies were then analysed to determine whether these contextual factors had positive, negative, or neutral reletionships with children's perceptual experiences (see Section 2.6). The findings are summarised in Figs. 8–14 and discussed in detail in the following subsections.

3.5.1. Demographic factors

Demographic factors refer to individual characteristics, such as age and gender, collected through a general questionnaire administered directly to students or teachers or to parents. In the reviewed studies, these factors showed generally limited and outcome-dependent associations with children's perceptions, with age emerging as the most frequently examined variable and the one showing the clearest, although not fully consistent, effects. Results are shown in Fig. 8.

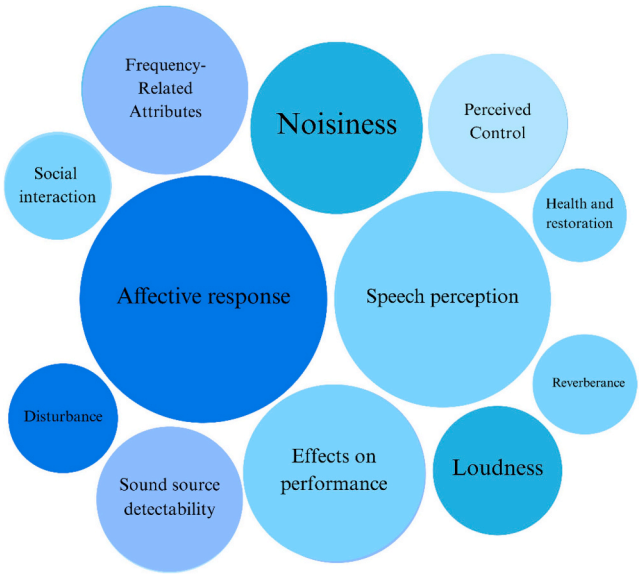

Fig. 4. Overview of the macro-categories of perceptual attributes identified. Bubble size reflects the relative prominence of each category.

3.5.1.1. Age/grade. Ten studies examined the role of children's age (or school grade) in perceptual evaluations, with mixed and outcome-specific findings, suggesting that its effect is strongly moderated by activity type and listening conditions. For affective dimensions, no age-related effects were found for pleasantness or arousal [18]. Results for annoyance were inconsistent: some studies reported a positive association with age [41,47], while others found a negative association [16]. No age-related effects were observed when annoyance referred to specific noise sources such as aircraft or road traffic noise [34].

For speech-related outcomes, age effects appeared to depend on the listening context. Older students generally reported better speech clarity across most classroom activities, although no differences were found during group work [16]. This pattern reversed when visual cues were unavailable, such as when the teacher's face was not visible [16]. In addition, one study found a negative association between grade and perceived performance [15].

3.5.1.2. Gender. Ten studies examined gender as a contextual factor and found that it had little to no effect on the attributes investigated. Emotional responses were largely unaffected by gender, except for the affective response *content*, for which girls reported higher levels than boys [57]. No gender differences were observed for the broader categories of restoration, disturbance, social interaction, and speech perception [44,52,54,56]. Findings on annoyance were mixed. Some studies reported no gender effect [34,41], whereas others found higher annoyance either among boys [41] or among girls [15]. The only study addressing performance-related outcomes found that girls reported lower levels of performance and concentration than boys [15].

3.5.1.3. Other demographic factors. Evidence on other child-specific demographic factors was very limited. Only one study examined native versus non-native speaker status and found no overall effect on perceptual ratings [44]. An exception concerned loudness and overall disturbance, for which classroom activity acted as a mediator: during silent tasks, second-language learners reported higher loudness and disturbance than native speakers. Similarly, special educational needs (SEN) status was assessed in only one study, which showed that students with SEN reported hearing outdoor sounds more frequently than their peers without SEN [52].

One further study investigated ethnicity, maternal education, and duration of school enrolment in relation to annoyance from aircraft and road traffic noise [34]. Ethnicity was not significantly associated with annoyance, whereas higher maternal education was linked to greater annoyance. Duration of school enrolment emerged as a potential confounder for annoyance related to road traffic noise, but not aircraft noise.

3.5.2. Personal factors

Person-related factors, encompassing emotional, cognitive, and behavioural characteristics, and typically assessed using standardised psychometric instruments, were examined in three studies. Four factors were identified: switching skills, mind-wandering, happiness, and noise sensitivity (Fig. 9). Overall, attentional and cognitive characteristics appeared more relevant than traits such as noise sensitivity.

These factors showed selective and context-dependent effects. Children with higher levels of mind-wandering were more susceptible to noise-related distraction, whereas better switching skills were associated with lower distraction and annoyance [49]. Noise sensitivity did not significantly influence affective dimensions such as arousal [18] and eventfulness [51]. However, under playground sound stimuli, children with higher noise sensitivity reported lower pleasantness ratings than their less noise-sensitive peers [51]. Happiness did not directly affect distraction but acted as a moderator: children with lower happiness levels reported higher perceived loudness in acoustically poor classrooms and reduced speech clarity even under favourable acoustic conditions [44].

Taken together, the findings suggest that person-related factors might influence classroom sound perception, but the available evidence remains limited and points to selective rather than generalisable effects.

3.5.3. Acoustic environment

In this review, the acoustic environment is operationalized in three dimensions: type of sound source, sound pressure levels (measured outside or inside the classroom), and room-acoustic parameters.

3.5.3.1. Type of sound source. Five studies examined how different types of sound source influence children's perceptions, either in laboratory settings [48,52,54] or in strictly controlled field conditions [51,57]. Across these studies, sound stimuli with different spectro-temporal characteristics but matched A-weighted levels were compared against a baseline condition, typically a quiet environment or a reference background noise. Results are displayed in Fig. 10.

Overall, adding a sound stimulus tended to produce more positive evaluations than the baseline condition, particularly for affective responses, social interaction, and perceived restoration. However, effects varied by sound type. Sounds from motorised vehicles or electromechanical sources often showed no significant influence [48,52], whereas children's voices were found to reduce pleasantness [48]. Direct comparisons further suggested that, at the same sound level, some sources were perceived as more restorative than others, with music and birdsong ranked highest in restorative potential [54].

3.5.3.2. Outdoor sound levels. Only three studies examined the effects of outdoor sound sources on students' perceptions (Fig. 11). Findings were mixed. One study found no association between the presence of external noise sources, such as traffic or people, and classroom annoyance [43]. In contrast, studies adopting an epidemiological approach reported that higher exposure to specific outdoor noise sources was associated with greater source-related annoyance (in both traffic and aircraft noise [34]) and poorer student performance (aircraft noise alone [31]).

3.5.3.3. Indoor sound levels. Indoor sound levels (Fig. 11) were assessed under either unoccupied condition [18] or during classroom activities [43,44]. Overall, the reviewed studies showed little association with children's perceptual evaluations, including affective dimensions, disturbance, perceived loudness, and speech clarity. Disturbance from

Table 3
Overview of the reviewed studies in terms of the macro-categories and perceptual attributes assessed. Examples of questionnaire items, together with their response scales, are reported in the rightmost column.

Macro- category	Attribute	Refs.	Examples of questions
Noisiness	Noisiness (general)	[39,41,42,45–47,49,58]	Do you think your classroom is noisy?
	Presence of noise	[39]	*(1) Not noisy at all*
	Noisiness from classmates	[46]	*(2) A bit noisy*
	Noisiness (within-school, outside-classroom sources)	[46]	*(3) Quite noisy*
			(4) Very noisy
	Noisiness (internal noises)	[46]	[49]
	Noisiness (external noises)	[46]	Do you perceive too much noise in the canteen?
			yes/no
			[58]
Sound source detectability	Sound source detectability	[16,37,40,41,48,56]	What is the source of the noise?
			(1) Talking of other children
			(2) Traffic
			(3) People
			(4) Other
			[41]
Loudness	Loudness	[18,44,47,49]	Do you think that the noise level in class is…
			(1) Very low
			(2) Quite low
			(3) Quite loud
			(4) Very loud
			[49]
Speech perception	Clarity of target speech	[15,16,33,36–38,40,41,44,46,47,49,50,53,55,56,58]	How well do you hear your teacher's speech in this classroom when everyone is working quietly?
			(1) Extremely well
			(2) Very well
			(3) Moderately well
			(4) Slightly well
			(5) Not at all
			[53]
			Do you hear your teacher's voice during classes?
			yes/no
			[41]
	Listening effort	[59]	How effortful was listening for you during [silent work/interaction/ group work])?
			(1) Not at all exhausting
			(2) Slightly exhausting
			(3) Moderately exhausting
			(4) Rather exhausting
			(5) Very exhausting
			[59]
Disturbance	Disturbance (general)	[31,41,44]	How much traffic noise disturbs you?
	Disturbance (traffic)	[44]	*(1) A little*
	Disturbance (rain)	[44]	*(2) Quite*
	Disturbance (siren)	[44]	*(3) A lot*
	Disturbance (within-school, outside-classroom source)	[44]	[44]
			Is there anything that disturbs you while playing outside or working in the classroom?
			(open-ended question)
			[31]
Effects on performance	Attentional capture	[49]	When the teacher or a classmate talks to the entire classroom. If noise attracts your attention, you lose track of the discussion:
	Distraction	[49]	*(1) Almost never*
	Concentration	[15,46,53]	*(2) Rarely*
	Fatigue	[59]	*(3) Quite often*
	Performance	[15,31,34,36,41,45]	*(4) Very often*
			[49]
			How easy is it to make group work when people move, and many people speak at the same time in this classroom?
			(1) Extremely easy
			(2) Easy
			(3) Neutral / Neither easy nor difficult
			(4) Difficult
			(5) Extremely difficult
			[53]
Frequency-related attributes	Frequency of sounds (in general)	[18,57]	How often do you hear certain sounds during lessons (e.g., students talking loudly, students moving about, sudden unexpected sounds, mobile phones, etc.):
	Frequency of noise	[38,40,43,47]	*(1) Never*
	Frequency (indoor sounds)	[15]	*(2) Rarely*
	Frequency of aircraft noise	[34]	*(3) Sometimes*
	Frequency of road traffic noise	[34]	*(4) Often*
	Frequency (outdoor sounds)	[15]	*(5) Very often*
			[15]

(*continued on next page*)

Table 3 (*continued*)

Macro- category	Attribute	Refs.	Examples of questions
			Is there noise in your classroom? *(1) No* *(2) Sometimes* *(3) Every day* [43]
Perceived control	Coping strategies	[31,38–40,47,59]	What do you do to stop noise affecting you? *(open-ended question)* [31] Would you like to change the noise in your environment, or do you think it is fine as it is *(open-ended question)* [31]
Affective responses	Emotional responses Preference Pleasantness Comfort Arousal Comfortable/Annoying Engaging/Detached Empty/Full of content Private/Intrusive Pleasant/Unpleasant Eventful/Uneventful Monotonous/Vibrant Calm/Chaotic Annoyance (in general) Annoyance from specific sound sources Annoyance due to aircraft noise Annoyance due to road traffic noise	[31,58] [45,46] [18,48] [40,50] [18] [57] [51] [15,16,31,39,41,43,49,50,53,58] [33,53] [34] [34]	What noises do you hear in your environment? How do they make you feel? *(open-ended question)* [31] How much noise annoyed you during this lesson? *(1) Not at all* *(2) Only a little* *(3) To some extent* *(4) A lot* *(5) Extremely* [53] To what extent do you agree or disagree that the sound environment of your school is… *(1) Comfortable* *(2) Engaging* *(3) Full of Content* *(4) Intrusive* *(5) Annoying* *(6) Detached* *(7) Empty* *(8) Private* [57]
Social interaction	Social interaction	[36,52]	In this place, do you want to be with other people, be here alone, or not come? [52]
Reverberance	Reverberance	[46]	Do you think that less echo can be perceived in the present classroom than before the ceiling change? *Yes/no* [46]
Health and restoration	Restoration (need for) Restoration (importance of the sound environment for) Perceived restorative sound scale for children (PRSS-C)	[54]	How important is the sound environment in your restorative experience in classrooms? *(1) Not at all* *(2) A little* *(3) Moderately* *(4) Very* *(5) Extremely* [54]

sirens, traffic, and other indoor and outdoor sound sources during both silent and group activities showed no significant correlations, except for a positive correlation observed between indoor sound levels and traffic disturbance during group activities [44]. Study [45] investigated in a laboratory environment the perceptual effects of increasing sound levels of specific sources from 45 to 60 dB(A). The findings highlighted a distinctive role of "children's talk" as a noise source: perceived noisiness consistently increased with children's speech level, regardless of the presence or not of acoustic treatment in the room.

3.5.3.4. Acoustical parameters. Acoustic characteristics showed relatively few significant associations with students' perceptual outcomes, with most studies reporting non-significant effects. Results are reported in Fig. 12.

Reverberation time was the most frequently examined parameter and was associated with greater perceived noisiness from internal sound sources, higher overall disturbance, and increased disturbance from sounds originating within the school building and from traffic [18,35,44]. In contrast, no significant relationships were found with pleasantness, disturbance from sirens or rain, or perceived target speech clarity, while a negative association was reported with arousal.

Other acoustic indicators, including speech clarity (C50), useful-to-detrimental ratio (U50), target speech level (Ls), and spatial slope of speech level, showed similarly limited and context-dependent effects [44]. Classroom activity appeared to play an important moderating role: longer reverberation times, lower speech clarity, and higher speech levels were associated with greater loudness during group work but not during silent tasks. Disturbance ratings also significantly increased during group activities, when C50 decreased. In contrast, steeper spatial slopes of speech level were associated with higher loudness and disturbance during silent tasks, but not during group work. Overall, the findings suggest that acoustic metrics alone do not consistently predict perceptual outcomes and that their influence is shaped by classroom context.

Finally, only limited attention was given to sound insulation. One study reported that higher façade insulation, assessed indirectly through the outdoor–indoor sound level difference, was associated with better perceived target speech clarity [41]. Another study identified window glazing, used as a proxy for façade insulation, as a potential confounding factor in the relationship between traffic or aircraft noise exposure and annoyance [34].

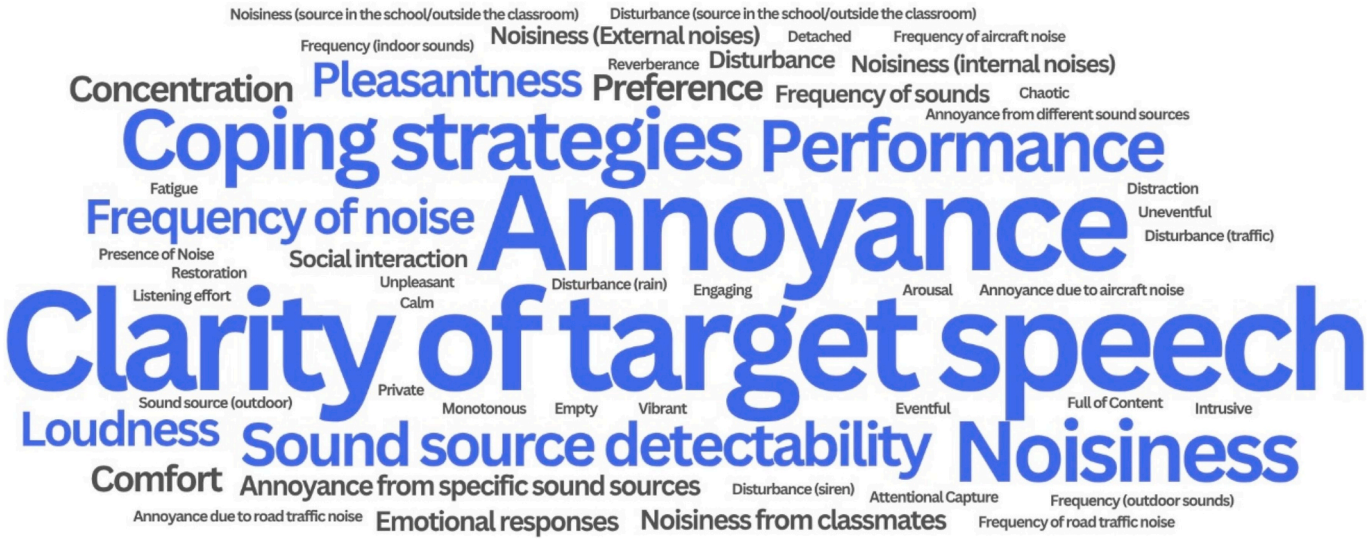

Fig. 5. Word cloud of extracted attributes, with word size indicating frequency of occurrence across studies.

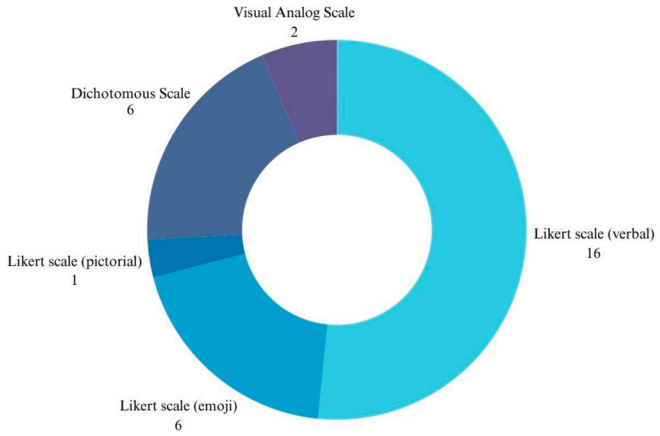

Fig. 6. Types of questionnaire scales used across the reviewed studies (numbers indicate how many studies used each scale).

3.5.4. *Built environment*

Built environment factors included objective characteristics of the school, classroom, and surrounding context that may shape children's perceptions. Across the reviewed studies, fifteen factors were identified and grouped into five categories: urban context (i.e., country, district estate value, school location, traffic volume), building envelope (i.e., glazing percentage, window opening), spatial dimensions (i.e., floor area, height, volume), occupancy and spatial layout (i.e., spatial density, windows proximity, class size, placement in the classroom), and school type. Results are displayed in Fig. 13.

Overall, urban context factors showed mostly non-significant associations with perception. The main exceptions concerned road traffic, whose volume and proximity to school were associated with a higher reported frequency of noise [38] and greater disturbance during silent tasks [44]. Building envelope characteristics also showed limited effects: glazing percentage was not associated with annoyance [50], whereas open-window conditions were linked to higher perceived loudness, but not to pleasantness or arousal [18]. Spatial dimensions such as floor area, height, and volume were examined in only one study and showed no significant relationship with annoyance [50].

In contrast, occupancy and spatial layout factors appeared more influential. Larger class sizes were associated with a lower perceived frequency of outdoor sounds [15], while higher spatial density was linked to greater annoyance [50]. Seating position also mattered: proximity to windows improved perceived speech clarity [50], and front/back seating location affected the reported frequency of outdoor noise [15].

School type was examined in two studies. Public schools were associated with greater perceived noise and annoyance, but also more frequent use of coping strategies, compared with private schools [39]. Flexible learning environments were associated with higher comfort and lower annoyance than traditional classrooms, although no differences were found in perceived speech clarity [50].

Overall, the built environment appeared to influence children's perception mainly through spatial and organisational characteristics rather than through urban or geometric features.

3.5.5. *Pedagogical factors*

Pedagogical factors include teaching approaches, instructional formats, and classroom activity patterns that may shape how children perceive the classroom sound environment. They were examined in only a few studies, but the available evidence suggests that classroom activity and instructional context affect children's perception.

One study found that pupils in non-traditional schools (i.e., those schools adopting educational approaches that differ from conventional instruction, implementing for instance Jena, Montessori, or Dalton theories) were less annoyed by the acoustic environment than those in traditional schools [43], suggesting that more flexible educational approaches may support more positive perceptions.

Classroom activity or lesson type also appeared to matter [16,44,53], although in most studies this variable was treated mainly as a contextual moderator rather than directly compared across instructional formats. The strongest evidence came from study [16], which showed that perceived speech clarity varied across situations, with the most favourable conditions being "no noise outside the classroom" and "doing a test," and the least favourable "noise made outside by other children". Study [53] suggested possible differences between lesson types in annoyance, disturbance, and concentration, but no formal statistical testing was conducted.

3.5.6. *Interventions*

Three types of interventions aimed at improving the acoustic environment were identified in the review: passive acoustic treatments, electroacoustic systems, and behavioural approaches (Fig. 14). Unlike the other contextual factors considered, these interventions represent deliberate strategies to modify classroom acoustic conditions. They were

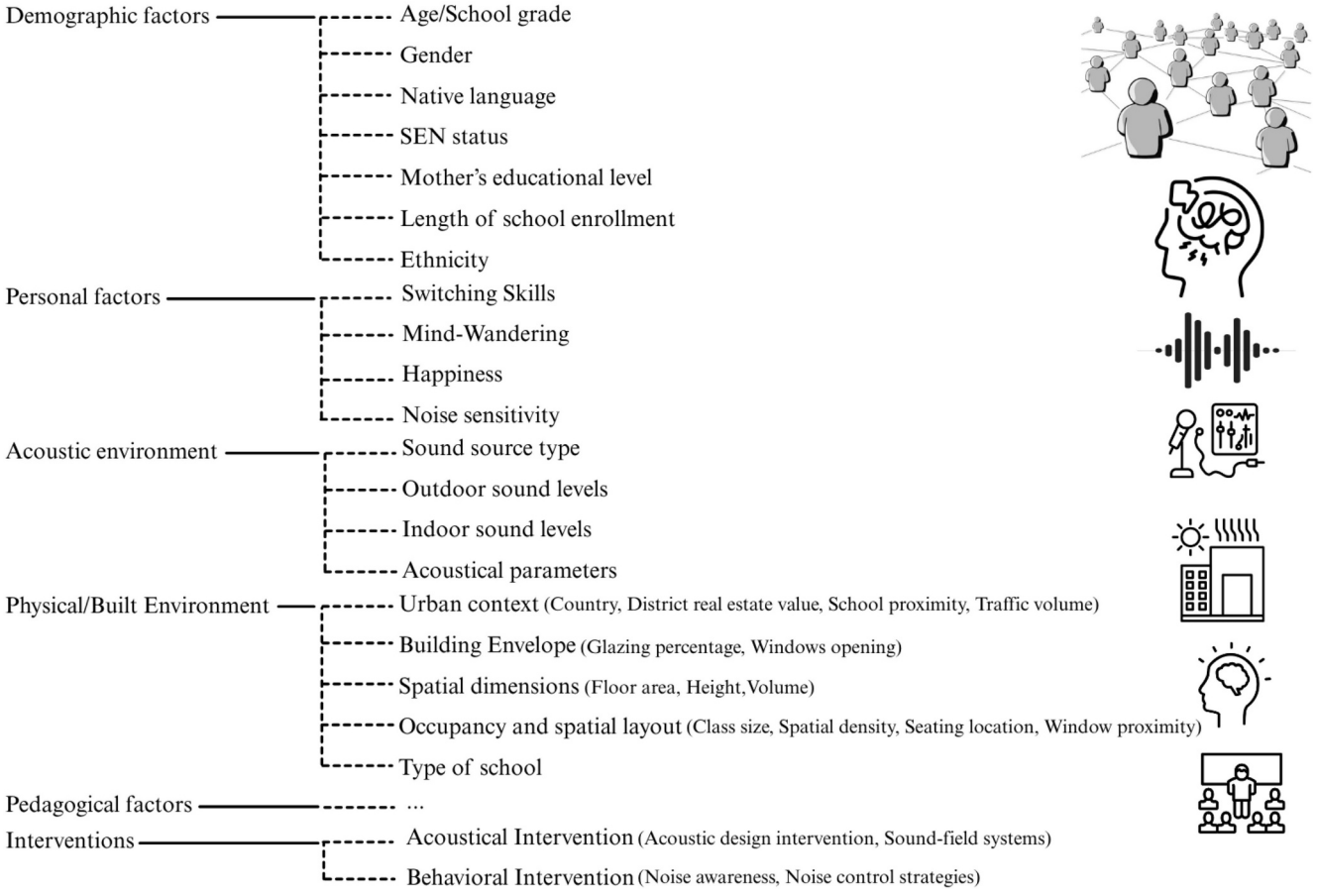

Fig. 7. Contextual factors influencing the children's perception of the school sound environment.

included because changes in children's perceptual responses following their implementation provide useful insight into their effectiveness.

3.5.6.1. Acoustic design interventions. Acoustic design interventions mainly involved the addition of sound-absorbing materials to classroom surfaces, either in real or experimental settings [44,46–48,53,55]. Overall, their effects appeared to depend largely on children's age and classroom activity.

Interventions were generally associated with more positive affective outcomes, including higher pleasantness [48] and lower annoyance among older, but not younger, children [47]. These benefits were most evident during teacher-led or activity-based tasks, whereas no clear effects emerged during quiet work or group activities [53]. Similarly, reductions in broader terms of disturbance were mainly observed during group work rather than silent tasks [44]. Perceived noisiness decreased primarily for internally generated sounds, such as classmates' noise, while effects on external noise and overall noisiness were limited [46,47]. Other outcomes, including reverberance, coping strategies, and perceived noise frequency, were generally unchanged [46,47].

For performance-related outcomes, acoustically treated classrooms were associated with better concentration [44], especially during tasks requiring attention to the teacher or individual desk work [53]. Evidence for speech clarity was mixed, with some studies reporting improvements [46] and others finding no significant effects [44]. However, positive effects on speech clarity appeared more consistently among older students [55] and in situations where listening relied less on visual cues [53].

3.5.6.2. Sound-field systems. Only two studies examined the effects of sound-field systems on students' perceptions, with contrasting findings. Sound-field systems are classroom amplification devices used to improve teacher voice audibility across the room. Originally developed to assist students with hearing impairments, these systems are now increasingly implemented in general education settings to enhance overall learning conditions. One study reported positive effects over time on perceived performance, social interaction, and speech clarity [36]. In contrast, the other study [37] found no significant benefits once exposure duration was considered. Overall, the limited evidence does not allow firm conclusions about the effect of sound-field systems on children's perception in primary school classrooms.

3.5.6.3. Behavioural interventions. Two studies examined behavioural interventions aimed at increasing students' awareness of noise and promoting quieter classroom behaviours. Findings were mixed. A noise-awareness training programme was associated with increased reports of noise presence and annoyance, as well as more frequent teacher-led coping strategies, but no change in student-led strategies [39]. In contrast, a workshop-based intervention implemented after acoustic treatment was associated with reduced annoyance, particularly among younger students and for specific sources such as corridor and furniture noise [47]. However, it did not significantly affect student coping strategies, perceived speech clarity, noisiness, or the perceived frequency of noise.

3.6. RQ4: Linguistic aspects

Table 4 summarises the linguistic characteristics of the assessment tools used across the reviewed studies. The results indicate substantial heterogeneity regarding the linguistic development, translation, and adaptation of questionnaires and interviews administered to children.

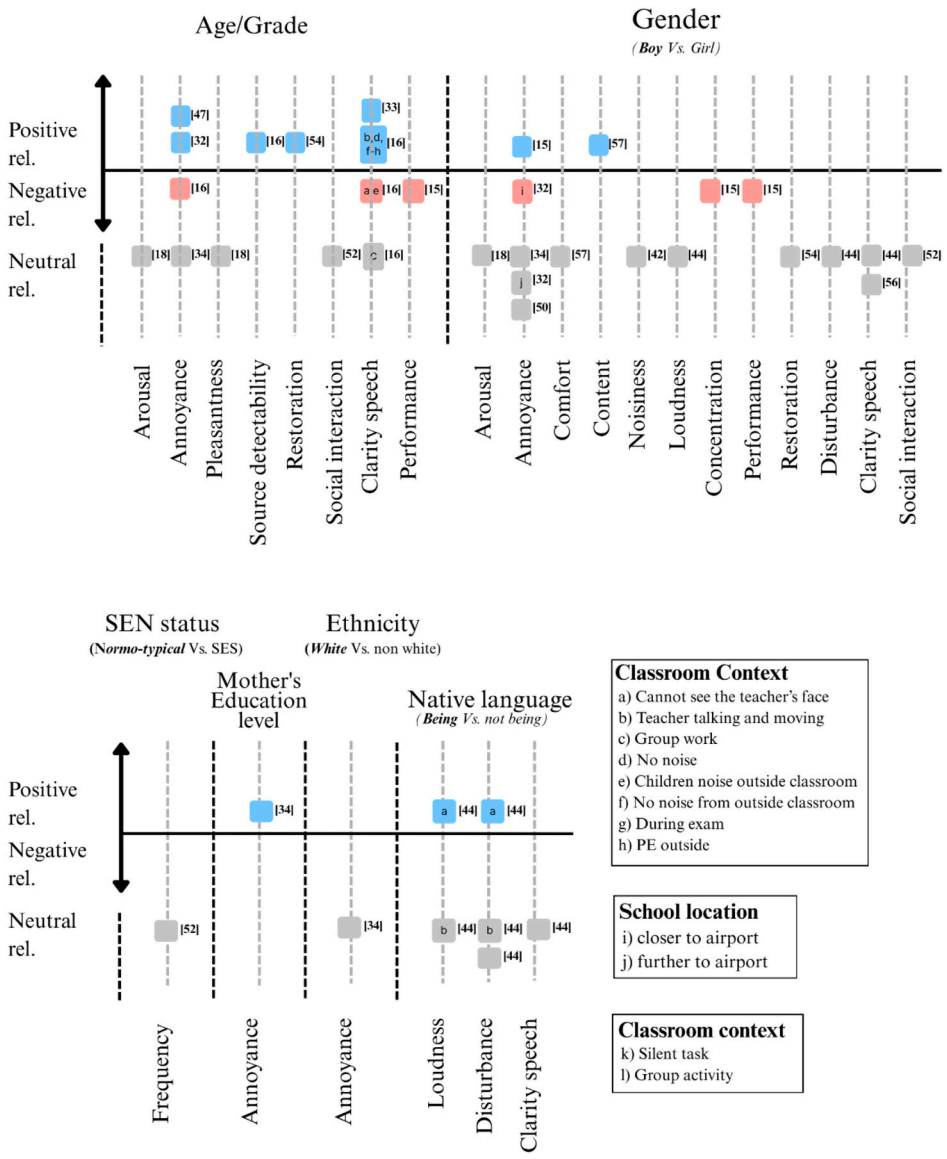

Fig. 8. Distribution of studies reporting relationships between demographic factors and perceptual assessments. Bold terms in parentheses identify the reference category used for categorical comparisons. The y-axis shows the number of studies reporting positive, neutral/no, or negative relationships; numbers indicate study references. Letters within boxes indicate interaction terms reported in the original studies.

All studies administered the assessment tools in the dominant language of the country in which the study was conducted, although this information was often inferred from the manuscript rather than explicitly reported.

Only a minority of studies clearly documented the development and adaptation of the questionnaires. Seven studies replicated or adapted questionnaires previously used in other studies, either without reporting a translation procedure [37,48,57] or through forward- and back-translation approaches [15,34,44,55,59]. Nine studies developed original questionnaires based on previous literature [43,50,53], collaboration with experts such as psychologists or statisticians [38,40,47], or preliminary interviews with children [16,32,35]. Three studies [42,51,54] used standardised or validated instruments, including ISO-based tools and previously validated questionnaires. The remaining 12 studies provided limited or no information regarding the linguistic development, adaptation, or validation of the assessment tools. Moreover, five studies adapted their assessment tools from instruments originally developed for older children or adults [15,51,53,57,59].

The availability of the original wording of questionnaire items also varied substantially across studies. While 18 studies fully reported the administered questions, the others provided only partial examples or no wording at all, making it difficult to compare perceptual descriptors across studies and to evaluate the semantic appropriateness of the instruments for children. To improve transparency, the Supplementary Material reports the questionnaire and interview items from reviewed studies that made the question wording available, grouped according to the perceptual attributes investigated. Finally, only a limited number of studies explicitly assessed children's comprehension of the questionnaire items through pilot studies, preliminary interviews, or iterative revisions based on children's feedback [15,16,34,38,43,44,50,55,59].

4. Discussion

This systematic review examined how children in primary schools perceive classroom acoustic environments, focusing on four main aspects: the perceptual attributes investigated in the literature (RQ1), the methodologies used to assess children's perceptions (RQ2), the contextual factors influencing these evaluations (RQ3), and the linguistic characteristics of the assessment tools (RQ4).

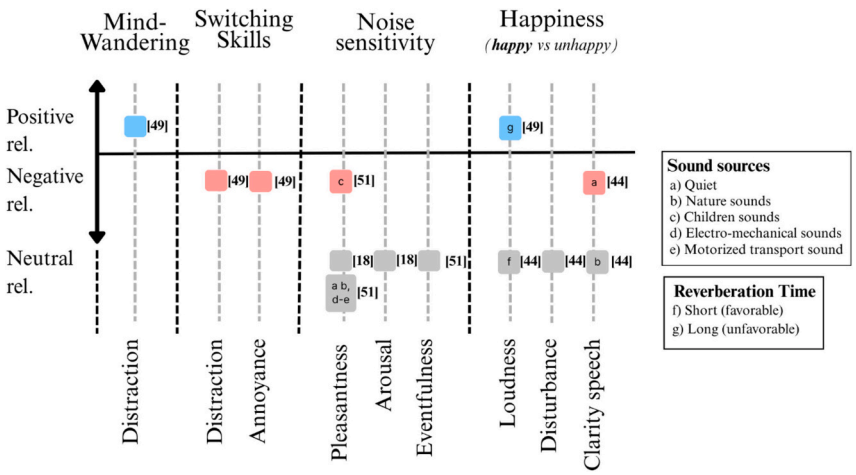

Fig. 9. Distribution of studies reporting relationships between personal factors and perceptual assessments. Bold terms in parentheses identify the reference category used for categorical comparisons. The y-axis shows the number of studies reporting positive, neutral/no, or negative relationships; numbers indicate study references. Letters within boxes indicate interaction terms reported in the original studies.

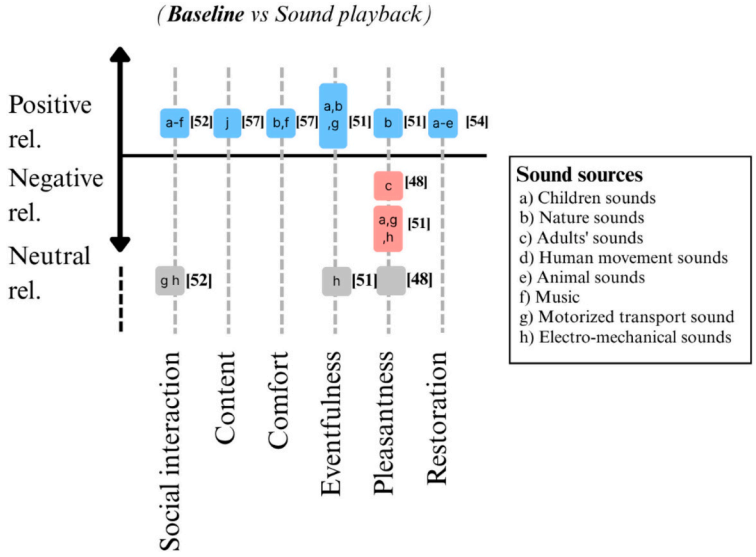

Fig. 10. Distribution of studies reporting relationships between personal factors and the type of sound stimuli. Bold terms in parentheses identify the reference category used for categorical comparisons. The y-axis represents the number of studies reporting positive, neutral/no, or negative relationships; numbers indicate study references. Letters within boxes indicate interaction effects.

4.1. Overview of the evidence

A first finding concerns the perceptual attributes examined in the literature. As displayed in Fig. 5, although the reviewed studies addressed a broad range of outcomes, they were strongly oriented toward negative dimensions (e.g., annoyance, noisiness, disturbance) and cognitive responses (e.g., speech clarity, perceived effects on performance). In contrast, positive or supportive aspects of classroom sound environments, such as pleasantness, comfort, or restoration, as well as other types of positive affective responses (e.g., vibrancy), received comparatively limited attention. This imbalance might stem from the traditional focus of classroom acoustics on noise control. However, the experimental studies reviewed in Section 3.5.3.1 suggest that not all sounds are perceived negatively by children. Certain sound stimuli, such as music or natural sounds, were associated with more positive affective responses [51,57] and higher perceived restoration [54]. This supports an interpretation of classroom acoustic quality that is more closely aligned with an indoor soundscape perspective.

A second finding is that children's perceptions cannot be adequately understood through acoustic metrics alone (Section 3.5.3). Across the reviewed studies, indicators such as sound levels and acoustic parameters showed only limited associations with subjective outcomes. When significant relationships were observed, they were often moderated by contextual variables [44,45]. This suggests that children's perceptions emerge from the interaction between acoustic conditions, the type of learning activity, and individual characteristics. While parameters such as reverberation time and speech clarity remain essential indicators of acoustic adequacy for supporting verbal communication [69], children's perception of classroom sound environments appears to be strongly shaped by pedagogical factors, characteristics of the built environment, and personal attributes (Section 3.5).

This interpretation is further supported by the wide range of significant contextual factors identified across the reviewed studies. Classroom activity emerged as one of the most important aspects [16,44,53]. The same acoustic condition could be associated with different evaluations depending on whether pupils were engaged in silent work, teacher-led instruction, group activities, or more active learning [44,53]. Similarly, built environment factors showed meaningful relationships with

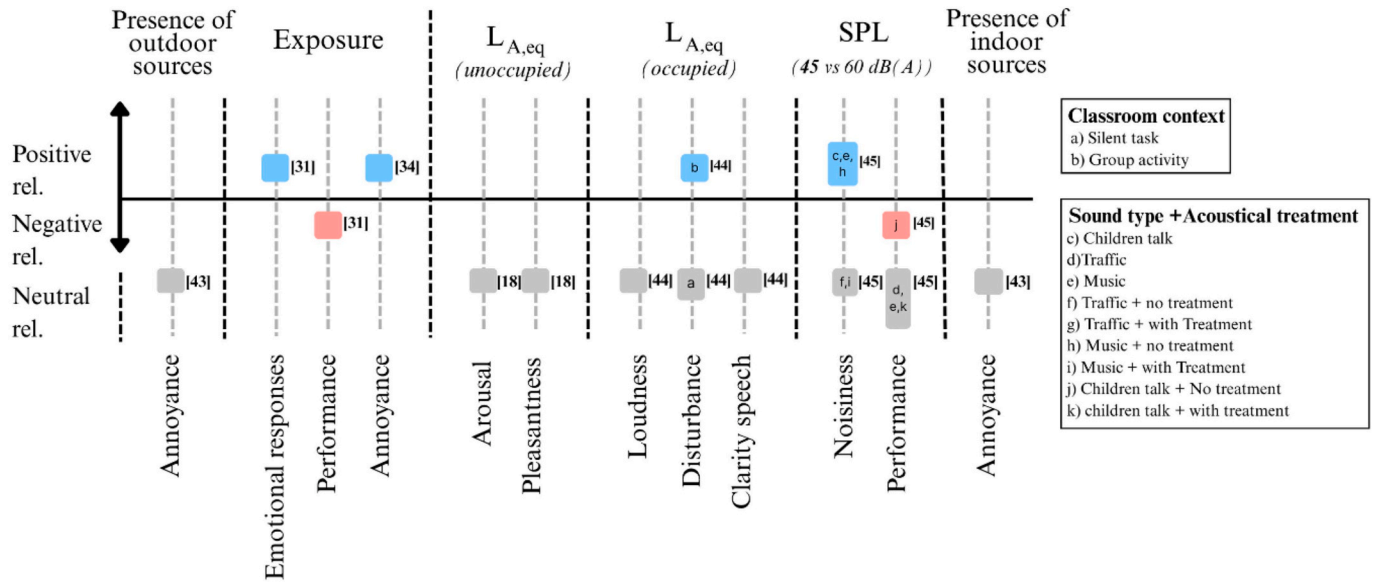

Fig. 11. Distribution of studies reporting relationships between outdoor sound sources (left), indoor sound sources (right) and perceptual assessments. Bold terms in parentheses identify the reference category used for categorical comparisons. The y-axis shows the number of studies reporting positive, neutral/no, or negative relationships; the numbers correspond to the study references. Letters within boxes indicate interaction terms reported in the original studies.

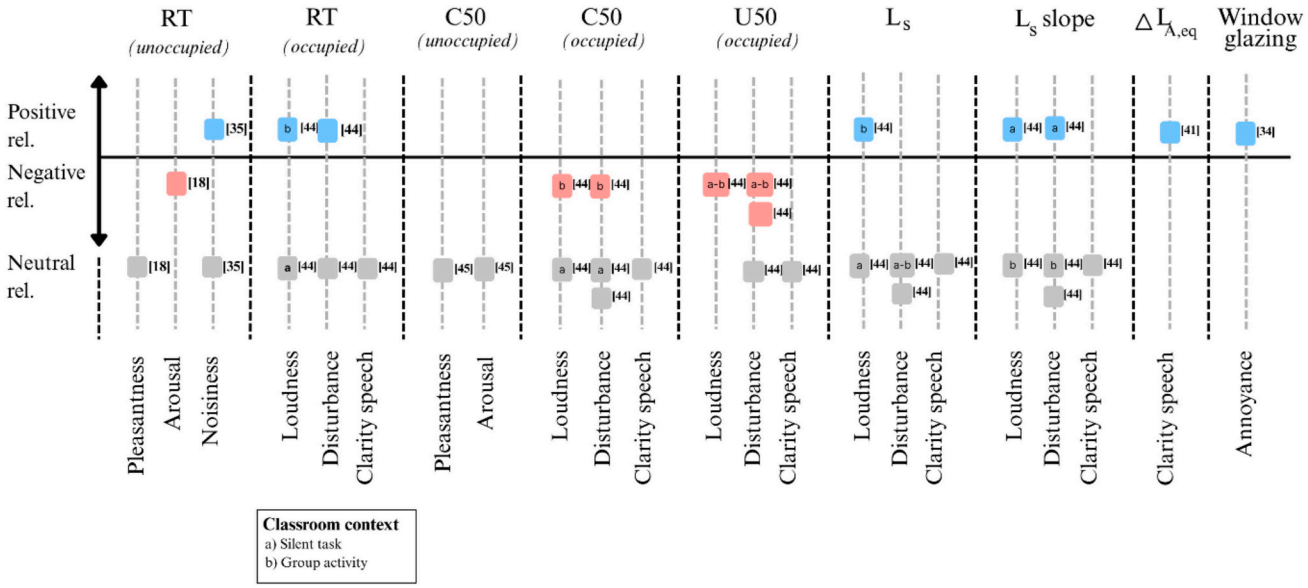

Fig. 12. Distribution of studies reporting relationships between classroom acoustic parameters and perceptual assessments. The y-axis shows the number of studies reporting positive, neutral/no, or negative relationships; the numbers correspond to the study references. Letters within boxes indicate interaction terms reported in the original studies. ΔL_{Aeq}: difference between the outdoor noise (L_{Aeq}) and indoor sound level (L_{A95}).

perception, including spatial density and seating position [15,50], as well as school type [39,50]. Although pedagogical factors were examined in only a limited number of studies, the available evidence suggests that teaching format and classroom organisation are important for understanding how children perceive the classroom sound environment [16,43,53]. These findings are particularly relevant considering contemporary educational practices, which increasingly emphasise collaborative learning, flexible spaces, and student-centred pedagogies [70,71]. In such contexts, acoustic quality cannot be understood solely in terms of reducing overall noise levels. It should also consider whether the sound environment is appropriate and supportive for the activity taking place.

4.2. *Methodological implications for assessing children's perception*

A third finding concerns the methodological limitations of the reviewed studies. Considerable variation was observed in the perceptual outcomes, the wording of questionnaire items, and the response formats used (Section 3.3 and 3.4). In some cases, perceptual attributes were adapted from adult-oriented soundscape frameworks [51,57] or from environmental noise research [53], rather than being developed specifically for primary school children. This is a critical issue, because children differ from adults in emotional vocabulary, abstract reasoning, and metacognitive ability. These differences may influence how they interpret and respond to perceptual questions [27]. Likewise, the absence of standardised and validated assessment tools for this age group reduces comparability across studies and limits the accumulation

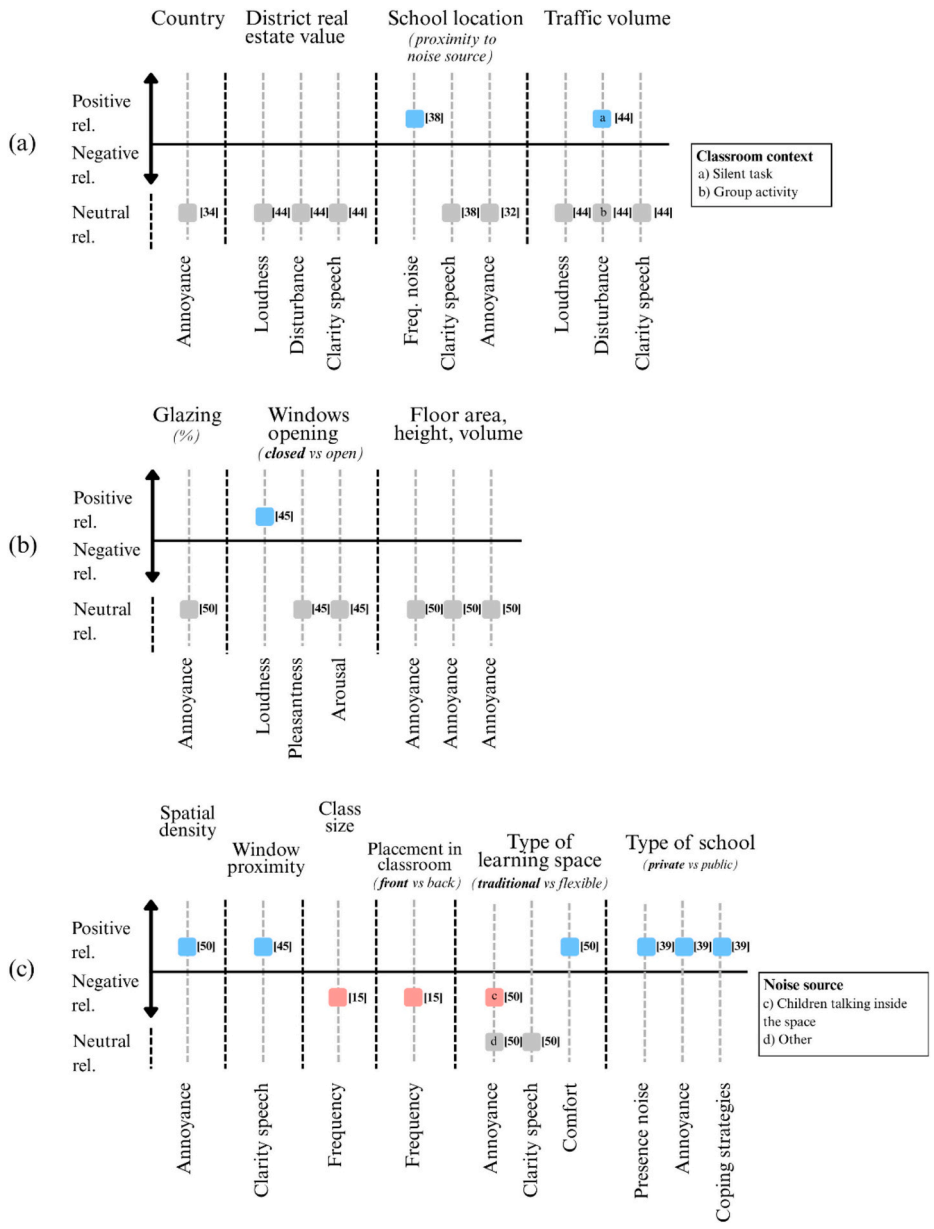

Fig. 13. Distribution of studies reporting relationships between the built environment and perceptual assessments. Bold terms in parentheses identify the reference category used for categorical comparisons. The figure is organised into three panels: (a) urban context, (b) building envelope and spatial dimensions, and (c) occupancy, spatial layout, and school type. The y-axis shows the number of studies reporting positive, neutral/no, or negative effects; the numbers correspond to the study references. Letters within boxes indicate interaction terms reported in the original studies.

of robust evidence. Although some studies used pictorial or emoji-based supports [16,18,37,48,53,58,59], most instruments remain only partially adapted to children's developmental characteristics.

The linguistic analysis further reinforces this methodological concern. As shown in Section 3.6, the reviewed studies varied substantially in the extent to which they reported the origin of the assessment tools and the procedures used for translation or adaptation. In several cases, questionnaires were adapted or translated from previous studies but the semantic adaptation of perceptual descriptors for children was only rarely described. This is particularly relevant because translating attributes for children involves not only interlingual translation, but also developmental and semantic adaptation of descriptors into language that children can understand and use reliably. The limited reporting of wording and comprehension testing (section 3.6; Table 4) reduces the transparency and comparability of the evidence and makes it difficult to assess whether differences across studies reflect actual perceptual differences or differences in how questions were linguistically formulated.

The review suggests that future research should prioritise the development of child-centred, linguistically transparent, and context-sensitive approaches. This includes identifying perceptual dimensions that are meaningful to children, validating age-appropriate response scales, reporting the exact wording of questionnaire and interview items, and documenting translation and adaptation procedures when tools are used across languages. Particular attention should be given to testing children's comprehension of perceptual descriptors, especially when instruments are derived from adult soundscape models or translated from another language. Integrating quantitative and qualitative methods may also help capture aspects such as behavioural responses or social dynamics that may be difficult for children to verbalise directly.

Future research will also require more ecologically valid approaches to the acoustic characterisation of the classroom environment. Several

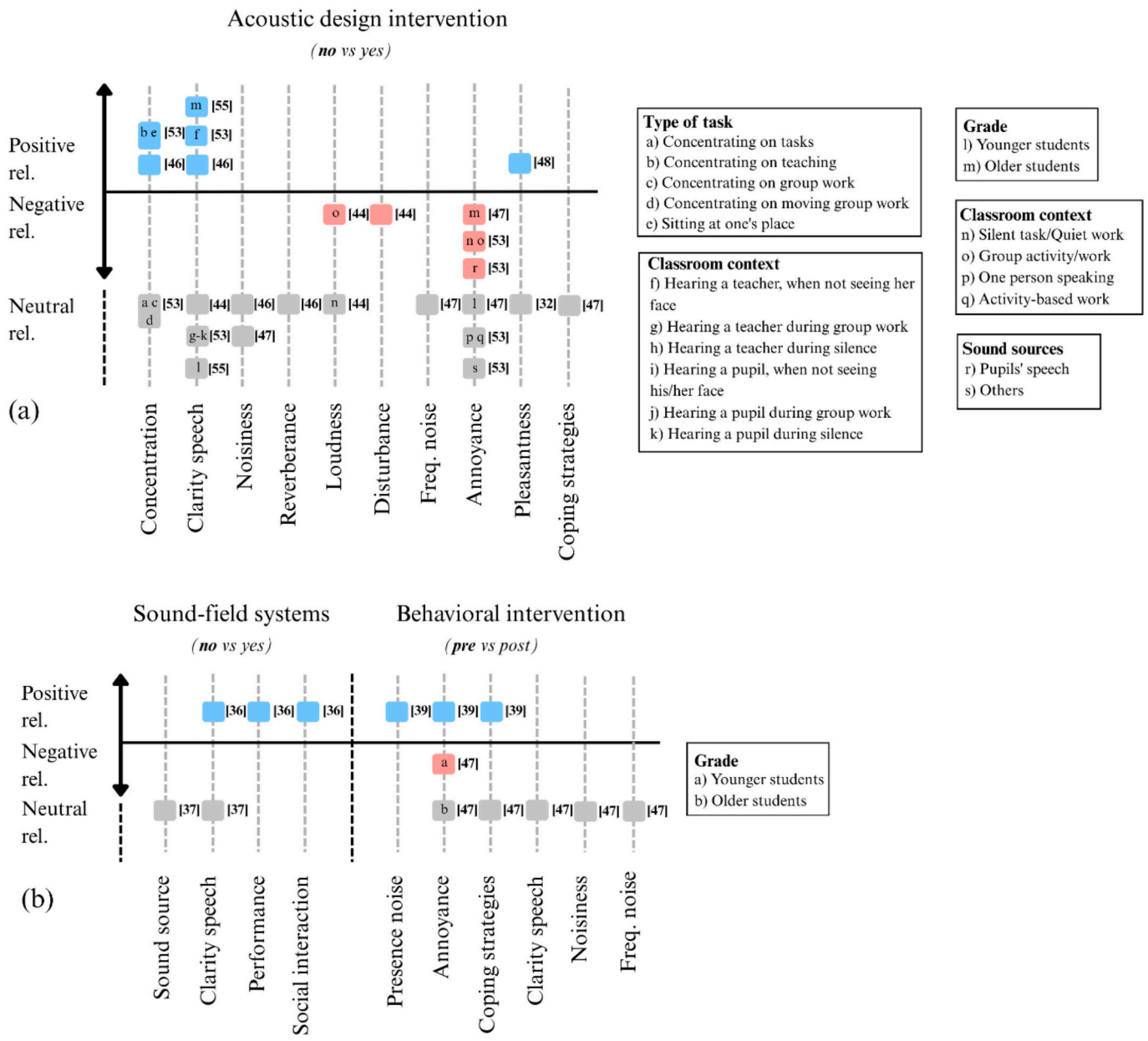

Fig. 14. Distribution of studies reporting relationships between interventions and perceptual assessments. Bold terms in parentheses identify the reference category used for categorical comparisons. The figure is organised into two panels: (a) acoustic design interventions, and (b) sound-field systems and behavioural interventions. The y-axis shows the number of studies reporting positive, neutral/no, or negative relationships; the numbers correspond to the study references. Letters within boxes indicate interaction terms reported in the original studies.

reviewed studies relied on measurements in unoccupied conditions or over short time intervals [18,40,44,46,52,53]. These measures do not capture the dynamic nature of classroom sound environments during actual teaching and learning activities, which are strongly shaped by sounds generated by the children themselves [72]. Integrating room-acoustic, psychoacoustic, and contextual measures would therefore help clarify the relationship between acoustic conditions and children's subjective experiences.

Finally, an important gap concerns the populations included in the reviewed studies. Most samples were concentrated in the upper primary school age range, particularly around 9–11 years, leaving younger pupils underrepresented (Section 3.2). This is particularly important because younger children may be especially vulnerable to adverse acoustic conditions and may also differ in how they understand and report their own experiences [24].

4.3. Implications for classroom design and educational practices

Beyond methodological considerations, the findings of this review also have implications for the design and management of learning environments. These implications are particularly relevant given the increasing recognition that classroom acoustic environments influence not only speech intelligibility but also broader aspects of the learning experience, including comfort, engagement, and social interaction.

The findings concerning interventions (Section 3.5.6) further support the need for an integrated perspective. Although acoustic treatments improve objective acoustic parameters, their perceptual benefits are not always consistent and often depend on contextual factors [44,46–48,53,55]. Similarly, sound-field amplification systems have shown mixed results. While these technologies may support teachers' vocal comfort, electroacoustic interventions alone do not appear to consistently improve students' perceptions [36,37]. At the same time,

Table 4
Summary of the 32 studies with reference to the linguistic aspects. The following information is reported: (1) study reference; (2) year of publication; (3) country in which the study was conducted; (4) assessment type (Q = questionnaire; I = interview); (5) language of study administration (reported or inferred from the text); (6) original language of the questions; (7) source of the questions; (8) availability of the question wording (* indicates availability also in the study's original language, when different from English); (9) assessment of children's comprehension of the questions; and (10) additional notes on the development of the questionnaire.

Ref.	Year	Country	Type	Language of administration	Original language	Instrument origin/ adaptation	Wording available?	Comprehension testing	Notes
[31]	2003	UK	I	English (inferred)	English	original	yes	not reported	
[16]	2004	UK	Q	English (inferred)	English	original	partial	yes	• semi structured interviews for questionnaire development • pilot study with 84 children
[32]	2006	Brazil	Q	Portuguese (inferred)	Portuguese	original	no	not reported	• preliminary interview with children
[33]	2006	Turkey	Q	Turkish (inferred)	Turkish	original	no	not reported	
[34]	2009	UK, Netherlands, Spain	Q	English/Dutch/ Spanish (reported)	English	not reported	yes	yes	• translation and back translation from English • same wording administered to children and parents • pilot study for procedures and materials
[35]	2010	Germany	Q	German (reported)	German	original	partial	not reported	• questionnaire developed ad hoc for children
[36]	2011	Canada	I	not reported		n/a	n/a	n/a	
[37]	2012	UK	Q	English (inferred)	English	previous study	partial	yes	• from study [16]
[38]	2012	Italy	Q	Italian (reported)	Italian	original	partial	yes	• designed in collaboration with psychologists • questions modified according to children's feedback
[39]	2014	Turkey	Q	Turkish (inferred)	Turkish	original	yes	not reported	
[40]	2014	Italy	Q	Italian (inferred)	Italian	original	partial	not reported	• designed with psychologists and statisticians
[41]	2016	Portugal	Q	Portuguese (inferred)	Portuguese	original	yes	not reported	
[15]	2017	Sweden	Q	Swedish (reported)	English	previous study	yes	yes	• from study [61] • original questionnaire piloted in secondary schools • back-to-back translation from English
[42]	2018	Slovakia	Q	Slovak (inferred)	Swedish and English	standardized questionnaire	no	not reported	• MM questionnaires [62]
[43]	2018	Netherlands	Q	Dutch (inferred)	Dutch	original	yes	yes	• questions partly based on study [38] • piloted with children
[44]	2019	Italy	Q	Italian (reported)	English	previous studies	yes	yes	• from studies [16,63] • back-to-back translation from English • questions read aloud with children to check comprehension
[45]	2019	Netherlands	Q	Dutch (inferred)	Dutch	original	no	not reported	
[46]	2020	China	Q	Chinese (reported)	Chinese	original	yes	not reported	
[47]	2020	Finland	Q	Finnish (inferred)	Finnish	original	yes	not reported	• questions based on previous studies and Authors' clinical experience
[48]	2021	Netherlands	Q	Dutch (inferred)	Dutch	previous study			• from study [43]
[49]	2022	France	Q	French (inferred)	French	original	yes*	not reported	
[50]	2023	Chile	Q	Spanish (inferred)	Spanish	original	yes	yes (pilot study)	• questions based on previous studies
[51]	2026	Italy	Q	Italian (inferred)	English	ISO standard	yes	not reported	• from ISO/TS 12913–2 [17] and ISO/TS 12913–3 [64] (for adults)
[52]	2023	China	I	Chinese (inferred)	Chinese	original	yes	not reported	
[53]	2023	Finland	Q	Finnish (inferred)	Finnish	original	yes	not reported	• questions partly adapted from ISO/TS15666 and based on previous studies
[54]	2023	China	Q	Chinese (inferred)	Chinese	standardized questionnaire	partial	not reported	• PRSS-C [65]
[18]	2023	Italy	Q	Italian (reported)	Italian	original	yes	not reported	
[55]	2024	Italy	Q	Italian (reported)	English	previous studies	yes*	yes	• from studies [16,66] • mixed forward-and back-translation • pilot study
[56]	2025	Egypt	Q	Arabic and English (reported)	Arabic and English	original	partial	not reported	
[57]	2025	UK	Q	English (reported)	English	previous study	yes	not reported	• from study [6] (with adults)

(*continued on next page*)

Table 4 (*continued*)

Ref.	Year	Country	Type	Language of administration	Original language	Instrument origin/ adaptation	Wording available?	Comprehension testing	Notes
[58]	2025	Italy	Q	Italian (inferred)	Italian	original	partial	not reported	
[59]	2025	Germany	Q	German (reported)	English	previous studies	yes*	yes	• from study [67] (with children) and study [68] (with adults) • pilot study with five children

the review highlights the potential role of behavioural interventions and educational programmes aimed at promoting noise awareness [39,47].

Overall, these findings suggest that improving classroom acoustic environments cannot rely on a single type of intervention. Architectural measures, electroacoustic systems, and educational strategies should instead be considered complementary components of a broader design and management approach [36,37,39,44,46–48,53,55]. This interpretation is consistent with recent school soundscape literature, which has argued for moving beyond a purely noise-reduction paradigm towards a more holistic perspective that considers positive soundscapes and pupils' well-being [73]. In this sense, the soundscape framework offers a useful conceptual basis, because it draws attention to the overall quality of the learning environment, which can be intentionally designed to support children's learning, well-being, comfort, engagement, and social interaction.

Finally, the relevance of sound type composition (Section 3.5.3) underscores the need for careful consideration of both the external soundscape and ventilation strategies in the design of school buildings. These elements may introduce sounds that evoke opposite perceptual responses, potentially leading either to annoyance or to enhanced comfort and restorativeness, depending on the context [48,52,54,57].

4.4. Limitations

This review has some limitations that should be acknowledged. First, the included studies were highly heterogeneous in terms of design, perceptual outcomes, acoustic metrics, and methods, which limited direct comparison across studies and prevented quantitative synthesis.

Second, although strict inclusion criteria were adopted, some studies included a limited proportion of participants older than the target age range (6–12), which may have introduced a small degree of developmental heterogeneity in the reviewed evidence.

Third, several factors were examined in only one or a few studies, meaning that some conclusions remain tentative.

Fourth, the categorisation of perceptual attributes and contextual factors was based on an interpretative synthesis which, although necessary for organising a fragmented literature, may have introduced some degree of simplification.

Finally, it should be noticed that this study represents a preliminary step towards the development of an initial perceptual model and corresponding assessment scales for school soundscapes for children. Accordingly, in this first phase, the evidence reviewed excluded studies involving children with hearing impairments, sensory disabilities, or neurodivergence. While we fully acknowledge the importance of accounting for aural diversity and adopting a design-for-all perspective, the development of a robust model at this stage requires a relatively homogeneous evidence base. This approach will ensure its applicability to the general target population, while providing a foundation for future work aimed at evaluating and adapting the model for populations with special needs.

A further limitation concerns the language of the literature search, which was restricted to English-language publications. Although the review included studies conducted in several non-English-speaking countries, relevant publications in other languages may have been missed. Future reviews could address this limitation through multilingual searches or cross-linguistic comparisons.

5. Concluding remarks

This systematic review investigates how children perceive the sound environment of primary school classrooms and provides a structured synthesis of a highly fragmented body of literature. Overall, the findings indicate that children can meaningfully report on their classroom sound environment, but that their perceptions are shaped by a complex interaction of acoustic, personal, pedagogical, and environmental factors rather than by acoustic conditions alone.

The review highlights three main conclusions: (i) the literature has focused predominantly on negative and cognitive outcomes, such as annoyance, noisiness, and speech-related performance, while positive and restorative dimensions remain underexplored; (ii) children's perceptions are shaped by the interaction of acoustic conditions with contextual and personal factors, particularly classroom activity, pedagogical context, and age; (iii) the field still lacks standardised, linguistically transparent, and child-centred tools capable of assessing classroom sound perception in developmentally appropriate and comparable ways.

5.1. What's next?

Future research should move towards the systematic development and validation of child-centred soundscape assessment tools. Three main directions appear particularly important.

First, future studies should focus specifically on primary school children, with careful consideration of age-related differences in linguistic, cognitive, and emotional development. Qualitative methods, such as interviews, focus groups, drawing tasks, or participatory activities, could be used to identify the words and meanings that children associate with classroom sounds before these are translated into questionnaire items.

Second, the development of assessment tools should be accompanied by systematic validation through pilot testing, comprehension checks, and cross-cultural translation or adaptation procedures. In this phase, teachers can provide essential insight into pupils' comprehension levels, classroom needs, special educational requirements, survey fatigue, and the suitability of different wording and response formats for specific age groups.

Third, more ecologically grounded studies are needed, in which children's perceptions are assessed during or immediately after real classroom activities and linked to acoustic, pedagogical, social, and spatial conditions.

Addressing these challenges will require interdisciplinary collaboration among acousticians, soundscape researchers, developmental psychologists, pedagogy scholars, linguists, educational researchers, and teachers. Such collaboration would support the development of assessment tools that are not only acoustically meaningful, but also pedagogically appropriate, developmentally accessible, and feasible for use in real classroom contexts.

CRediT authorship contribution statement

Chiara Visentin: Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Shomaila Syed: Writing – review & editing, Writing – original draft, Visualization, Investigation, Formal analysis, Data curation, Conceptualization. **Simone Torresin:** Writing – review & editing, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.apacoust.2026.111471.

Data availability

Data will be made available on request.

References

[1] Schweiker M, Ampatzi E, Andargie MS, Andersen RK, Azar E, Barthelmes VM, et al. Review of multi-domain approaches to indoor environmental perception and behaviour. Build Environ 2020;176:106804. https://doi.org/10.1016/j.buildenv.2020.106804.
[2] World Health Organization, Compendium of WHO and other UN guidance on health and environment, (2024). https://www.who.int/tools/compendium-on-health-and-environment (accessed March 24, 2026).
[3] ISO 12913-1:2014, Acoustics - Soundscape - Part 1: Definition and conceptual framework, (2014). https://www.iso.org/standard/52161.html (accessed March 24, 2026).
[4] Torresin S, Albatici R, Aletta F, Babich F, Kang J. Assessment methods and factors determining positive indoor soundscapes in residential buildings: a systematic review. Sustainability (Switzerland) 2019;11. https://doi.org/10.3390/su11195290.
[5] Axelsson Ö, Nilsson ME, Berglund B. A principal components model of soundscape perception. J Acoust Soc Am 2010;128:2836–46. https://doi.org/10.1121/1.3493436.
[6] Torresin S, Albatici R, Aletta F, Babich F, Oberman T, Siboni S, et al. Indoor soundscape assessment: a principal components model of acoustic perception in residential buildings. Build Environ 2020;182. https://doi.org/10.1016/j.buildenv.2020.107152.
[7] Jo HI, Jeon JY. Influence of indoor soundscape perception based on audiovisual contents on work-related quality with preference and perceived productivity in open-plan offices. Build Environ 2022;208:108598. https://doi.org/10.1016/j.buildenv.2021.108598.
[8] Kurukose Cal H, Kang J, Aletta F. Methodological approaches and main factors considered in school soundscape studies: a scoping review. Build Acoust 2024;31:75–90. https://doi.org/10.1177/1351010X231216016.
[9] Hamida A, Zhang D, Ortiz MA, Bluyssen PM. Indicators and methods for assessing acoustical preferences and needs of students in educational buildings: a review. Appl Acoust 2023;202. https://doi.org/10.1016/j.apacoust.2022.109187.
[10] Klatte M, Bergström K, Lachmann T. Does noise affect learning? A short review on noise effects on cognitive performance in children. Front Psychol 2013;4. https://doi.org/10.3389/fpsyg.2013.00578.
[11] Visentin C, Pellegatti M, Garraffa M, Di Domenico A, Prodi N. Individual characteristics moderate listening effort in noisy classrooms. Sci Rep 2023;13. https://doi.org/10.1038/s41598-023-40660-1.
[12] Thompson R, Smith RB, Bou Karim Y, Shen C, Drummond K, Teng C, et al. Noise pollution and human cognition: an updated systematic review and meta-analysis of recent evidence. Environ Int 2022;158. https://doi.org/10.1016/j.envint.2021.106905.
[13] Benocci E, Alain C, Calcus A. Neural signatures of stream segregation from childhood to adulthood. Sci Rep 2026. https://doi.org/10.1038/s41598-026-38602-8.
[14] Leibold LJ. Speech perception in complex acoustic environments: Developmental effects. J Speech Lang Hear Res 2017;60:3001–8. https://doi.org/10.1044/2017_JSLHR-H-17-0070.
[15] K.J. Brännström, E. Johansson, D. Vigertsson, D.J. Morris, B. Sahlén, V. Lyberg-Åhlander, K.J. Brännström, How Children Perceive the Acoustic Environment of Their School, (2017) 84–94. https://doi.org/10.4103/nah.NAH_33_16.
[16] Dockrell JE, Shield B. Children's perceptions of their acoustic environment at school and at home. J Acoust Soc Am 2004;115:2964–73. https://doi.org/10.1121/1.1652610.
[17] ISO/TS 12913-2:2018, Acoustic - Soundscape - Part 2: Data collection and reporting requirements, (2018). https://www.iso.org/standard/75267.html (accessed March 24, 2026).
[18] Visentin C, Torresin S, Pellegatti M, Prodi N. Indoor soundscape in primary school classrooms. J Acoust Soc Am 2023;154:1813–26. https://doi.org/10.1121/10.0020833.
[19] Tardini V, Fratoni G, D'Orazio D. Survey of national target values on classroom acoustics. Build Environ 2025;283. https://doi.org/10.1016/j.buildenv.2025.113299.
[20] Mega C, Ronconi L, De Beni R. What makes a good student? How emotions, self-regulated learning, and motivation contribute to academic achievement. J Educ Psychol 2014;106:121–31. https://doi.org/10.1037/a0033546.
[21] Kurukose Cal H, Aletta F, Kang J. Exploring the factors influencing school soundscapes: Insights from teachers and acoustic experts. Indoor Built Environ 2025. https://doi.org/10.1177/1420326X251383003.
[22] Peng ZE, Pausch F, Fels J. Spatial release from masking in reverberation for school-age children. J Acoust Soc Am 2021;150:3263–74. https://doi.org/10.1121/10.0006752.
[23] Loh K, Yadav M, Persson Waye K, Klatte M, Fels J. Toward child-appropriate acoustic measurement methods in primary schools and daycare centers. Front Built Environ 2022;8. https://doi.org/10.3389/fbuil.2022.688847.
[24] Mercugliano A, Corbani A, Bigozzi L, Vettori G, Incognito O. The effects of classroom acoustic quality on student perception and wellbeing: a systematic review across educational levels. Front Psychol 2025;16. https://doi.org/10.3389/fpsyg.2025.1586997.
[25] Bjorklund DF, Causey KB. Children's thinking: cognitive development and individual differences. 6th ed.,. SAGE Publications; 2018.
[26] Posner J, Russel JA, Peterson BS. The circumplex model of affect: an integrative approach to affective neuroscience, cognitive development, and psychopathology. Dev Psychopathol 2005;17. https://doi.org/10.1017/S0954579405050340.
[27] Widen SC, Russell JA. Young children's understanding of others' emotions. 3rd ed.,. The Guilford Press; 2008.
[28] Davies WJ, Adams MD, Bruce NS, Cain R, Carlyle A, Cusack P, et al. Perception of soundscapes: an interdisciplinary approach. Appl Acoust 2013;74:224–31. https://doi.org/10.1016/j.apacoust.2012.05.010.
[29] Dokmeci Yorukoglu PN, Kang J. Analysing sound environment and architectural characteristics of libraries through indoor soundscape framework. Arch Acoust 2016;41:203–12. https://doi.org/10.1515/aoa-2016-0020.
[30] Page MJ, Moher D, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. The BMJ 2021;372. https://doi.org/10.1136/bmj.n160.
[31] Haines MM, Brentnall SL, Stansfeld SA, Klineberg E. Qualitative responses of children to environmental noise. Noise Health 2003;19:19–30.
[32] Fernanda M, Nunes O, Sattler MA. Aircraft noise perception and annoyance at schools near Salgado Filho International Airport, Brazil. Build Acoust 2006;13:159–72.
[33] Tamer Bayazit N, Kucukciftci S, Yilmaz Demirkale S, Altun C. A questionnaire survey of elementary school students' and teachers' perception of noise in Istanbul. Proceedings of Internoise 2006 2006.
[34] van Kempen EM, van Kamp I, Stellato RK, Lopez-Barrio I, Haines MM, Nilsson ME, et al. Children's annoyance reactions to aircraft and road traffic noise. J Acoust Soc Am 2009;125:895–904. https://doi.org/10.1121/1.3058635.
[35] Klatte M, Hellbrück J, Seidel J, Leistner P. Effects of classroom acoustics on performance and well-being in elementary school children: a field study. Environ Behav 2010;42:659–92. https://doi.org/10.1177/0013916509336813.
[36] Rubin R, Flagg-Williams JB, Aquino-Russell CE, Lushington TP. The classroom listening environment in early grades. Can J Speech-Lang Pathol Audiol 2011;35:344–59.
[37] Dockrell JE, Shield B. The impact of sound-field systems on learning and attention in elementary school classrooms. J Speech Lang Hear Res 2012;55:1163–76. https://doi.org/10.1044/1092-4388(2011/11-0026).
[38] De Giuli V, Da Pos O, De Carli M. Indoor environmental quality and pupil perception in Italian primary schools. Build Environ 2012;56:335–45. https://doi.org/10.1016/j.buildenv.2012.03.024.
[39] Bulunuz N. Noise pollution in Turkish elementary schools: Evaluation of noise pollution awareness and sensitivity training. Int J Environ Sci Educ 2014;9:215–34. https://doi.org/10.12973/ijese.2014.212a.
[40] Giuli D, Carli D, Bella D. Overall assessment of indoor conditions in a school building: an Italian case study. Int J Environ Res 8 2014:27–38. www.SID.ir.
[41] Silva LT, Oliveira IS, Silva JF. The impact of urban noise on primary schools. Perceptive evaluation and objective assessment. Appl Acoust 2016;106:2–9. https://doi.org/10.1016/j.apacoust.2015.12.013.
[42] Mečiarová Ľ, Vilčeková S, Krídlová Burdová E, Kapalo P, Mihaľová N. The real and subjective indoor environmental quality in schools. Int J Environ Health Res 2018;28:102–23. https://doi.org/10.1080/09603123.2018.1429579.
[43] Bluyssen PM, Zhang D, Kurvers S, Overtoom M, Ortiz-Sanchez M. Self-reported health and comfort of school children in 54 classrooms of 21 Dutch school buildings. Build Environ 2018;138:106–23. https://doi.org/10.1016/j.buildenv.2018.04.032.

[44] Astolfi A, Puglisi GE, Murgia S, Minelli G, Pellerey F, Prato A, et al. Influence of classroom acoustics on noise disturbance and well-being for first graders. Front Psychol 2019;10. https://doi.org/10.3389/fpsyg.2019.02736.
[45] Zhang D, Tenpierik M, Bluyssen PM. Interaction effect of background sound type and sound pressure level on children of primary schools in the Netherlands. Appl Acoust 2019;154:161–9. https://doi.org/10.1016/j.apacoust.2019.05.007.
[46] Peng J, Lau SK, Zhao Y. Comparative study of acoustical indices and speech perception of students in two primary school classrooms with an acoustical treatment. Appl Acoust 2020;164. https://doi.org/10.1016/j.apacoust.2020.107297.
[47] S. Pirilä, J. Jokitulppo, E. Niemitalo-Haapola, A. Yliherva, L. Rantala, Teachers' and Children's Experiences after an Acoustic Intervention and a Noise Controlling Workshop in two Elementary Classrooms, Folia Phoniatr Logop 72 (202AD) 454–463. https://doi.org/10.1159/000503231.
[48] Bluyssen PM, Zhang D, Kim DH, Eijkelenboom AM, Ortiz-Sanchez M. First SenseLab studies with primary school children: exposure to different environmental configurations in the experience room. Intell Build Int 2021;13:275–92. https://doi.org/10.1080/17508975.2019.1661220.
[49] Massonnié J, Frasseto P, Mareschal D, Kirkham NZ. Learning in noisy classrooms: children's reports of annoyance and distraction from noise are associated with individual differences in mind-wandering and switching skills. Environ Behav 2022;54:58–88. https://doi.org/10.1177/0013916520950277.
[50] C. Ipinza-Olatte, M.B. Piderit-Moreno, P. Bluyssen, M. Trebilcock-Kelly, Students' Perceptions of acoustic comfort in traditional and flexible learning environments: a study in Chile, in: J. Phys. Conf. Ser., Institute of Physics, 2023. https://doi.org/10.1088/1742-6596/2600/12/122001.
[51] Pellegatti M, Visentin C, Torresin S, Babich F, Prodi N. The effect of ventilation-related sound stimuli on 11–14 years students' cognition and soundscape assessments. Appl Acoust 2026;245(2026):111206. https://doi.org/10.1016/j.apacoust.2025.111206.
[52] Su H, Ma H, Wang C. Effects of soundscape on Chinese children's social interaction measured by self-reported behavioral expectations. Appl Acoust 2023;207. https://doi.org/10.1016/j.apacoust.2023.109350.
[53] Radun J, Lindberg M, Lahti A, Veermans M, Alakoivu R, Hongisto V. Pupils' experience of noise in two acoustically different classrooms. Facilities 2023;41:21–37. https://doi.org/10.1108/F-03-2022-0036.
[54] Shu S. Exploring the role of soundscape in restorative experience: a pilot study from children's perspective. Front Psychol 2023;14. https://doi.org/10.3389/fpsyg.2023.1131170.
[55] Vettori G, Di Leonardo L, Secchi S, Bigozzi L. The sound of silence: children's own perspectives on their hearing and listening in classrooms with different acoustic conditions. Eur J Psychol Educ 2024;39:3803–23. https://doi.org/10.1007/s10212-024-00819-4.
[56] Afifi S, Kamel T, Ezzeldin S. Indoor environmental quality assessment of naturally-ventilated school classrooms within a dense arid urban setting of Cairo, Egypt. Sci Rep 2025;15. https://doi.org/10.1038/s41598-025-98602-y.
[57] Cal HK, Aletta F, Kang J, Clarke P. Student perception of school soundscapes and wellbeing: a mixed methods examination of natural and musical sounds. Build Environ 2025;277. https://doi.org/10.1016/j.buildenv.2025.112946.
[58] Martellotta F, D'Orazio D, De Carolis D, Liuzzi S, Rubino C. Acoustic comfort in primary- and nursery-school canteens: from measurements to recommendations. Appl Acoust 2025;228. https://doi.org/10.1016/j.apacoust.2024.110324.
[59] Seitz J, Fels J. Activity-based acoustic situations in primary schools: Analyzing classroom noise and listening effort. J Acoust Soc Am 2025;157:1772–83. https://doi.org/10.1121/10.0036129.
[60] Shield BM, Dockrell JE. The effects of environmental and classroom noise on the academic attainments of primary school children. J Acoust Soc Am 2008;123:133–44. https://doi.org/10.1121/1.2812596.
[61] Connolly DM, Dockrell JE, Shield BM, Conetta R, Cox TJ. Students' perceptions of school acoustics and the impact of noise on teaching and learning in secondary schools: Findings of a questionnaire survey. Energy Procedia 2015;78:3114–9. https://doi.org/10.1016/j.egypro.2015.11.766.
[62] K. Andersson, G. Stridh, The MM-questionnaires: A tool when solving indoor climate problems. Örebro, Sweden: Department of Occupational and Environmental Medicine, Örebro University Hospital (1993). https://www.aivc.org/resource/mm-questionnaires-tool-when-solving-indoor-climate-problems (accessed May 22, 2026).
[63] Astolfi A, Pellerey F. Subjective and objective assessment of acoustical and overall environmental quality in secondary school classrooms. J Acoust Soc Am 2008;123(1):163–73. https://doi.org/10.1121/1.2816563.
[64] ISO 12913-3:2025, Acoustics - Soundscape - Part 3: Data analysis, (2025). https://www.iso.org/standard/86955.html (accessed May 22, 2026).
[65] Qin J, Zhao X, He J, Jia X, Zhang B. Development and validation of the perceived restorative soundscape scale for children. Front Psychol 2024;15:1362096. https://doi.org/10.3389/fpsyg.2024.1362096.
[66] L. McFarland, L. Dealtry, Hearing in the early childhood setting: Children's perspectives, Australasian Journal of Early Childhood 42(2) (2017) 105-113. https://doi.org/ 10.23965/AJEC.42.2.13.
[67] C. Visentin, N. Prodi, How reliable are 11-to 13-year-olds' self-ratings of effort in noisy conditions?, Front. Built Env. 7 (2021) 688016. https://doi.org/10.3389/fbuil.2021.688016.
[68] E.M. Picou, T.A. Ricketts, Increasing motivation changes subjective reports of listening effort and choice of coping strategy, International journal of audiology 53 (6) (2014) 418-426. https://doi.org/10.3109/14992027.2014.880814.
[69] UNI 11532-2:2020, Caratteristiche Acustiche Interne di Ambienti confinati - Metodi di Progettazione e Tecniche di valutazione - Parte 2: Settore Scolastico (Acoustics – Acoustical Characteristics of Indoor Environments – Design and Measurement Criteris – Part 2: Rooms for Learning), (2020). https://store.uni.com/uni-11532-2-2020 (accessed August 10, 2025).
[70] Mealings KT, Demuth K, Buchholz JM, Dillon H. The effect of different open plan and enclosed classroom acoustic conditions on speech perception in Kindergarten children. J Acoust Soc Am 2015;138:2458–69. https://doi.org/10.1121/1.4931903.
[71] OECD, The OECD Handbook for Innovative Learning Environments, (2017). https://www.oecd.org/en/publications/the-oecd-handbook-for-innovative-learning-environments_9789264277274-en.html (accessed March 26, 2026).
[72] Visentin C, Prodi N. Let's get loud: how classroom activities influence speech and noise levels during lessons. Build Environ 2026;288. https://doi.org/10.1016/j.buildenv.2025.113959.
[73] H.K. Cal, F. Aletta, J. Kang, From Noise Reduction to Positive Soundscapes: Enhancing Well-Being in Schools, Noise and Health 27 (2025) 805-810. https://doi.org/ 10.4103/nah.nah_161_25.