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A SYSTEMATIC REVIEW OF PERCEPTUAL ATTRIBUTES FOR INDOOR SOUNDSCAPE ASSESSMENT IN PRIMARY SCHOOL CLASSROOMS

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ABSTRACT

This study investigates semantic attributes and evaluation methods used in the literature to assess children's perception of the sound environment in primary school classrooms. While existing research on indoor soundscapes in educational settings has focused mainly on high schools and universities, there is a significant gap in understanding how younger children (ages 6–10) perceive and interact with classroom acoustic environments. Tools, attributes, and methodologies developed for adults may not be completely relevant or comprehended by children, due to their developing cognitive and linguistic abilities. Consequently, child-centric approaches are required for evaluating the auditory perception of children and designing educational spaces accordingly. To address this gap, a comprehensive review of existing research was conducted to identify key semantic attributes and tools, such as visual scales and pictorial representations. The preliminary insights from this ongoing work highlight the existing methodologies and will inform future research towards standardized frameworks for children.

Keywords: classroom acoustics, indoor soundscape, primary school, comfort.

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1. INTRODUCTION

The acoustic environment of primary school classrooms plays a central role in children's cognitive, academic, and social development [1,2]. Key factors include speech intelligibility, reverberation time, and background sound levels, as well as the type of sounds that make up such background sounds. While research on the acoustic impact of the classroom acoustic environment of the occupants has typically focused on disturbing sound sources (such as traffic), recent interest has shifted toward the potential of sound to be pleasant and, possibly, enhance students' cognitive performance, driven by developments in soundscape research [3,4,5].

Existing research on indoor soundscapes has primarily focused on high schools and universities, with limited studies exploring how younger children aged 6–10 years perceive and interact with classroom acoustics [5, 6]. The attributes, tools, and methodologies used in previous studies are often designed for adults and may not accurately capture children's auditory perception, or may not be properly understood by children, due to their developing cognitive abilities [7,8,9,10]. Visentin et al. [5] investigated the ideal and actual soundscape in primary school classrooms, highlighting how, in the studied context, the former differs significantly from the latter. However, little research is available on which methodologies and perceptual attributes are most relevant to children's perception of the classroom environment. Such knowledge would be useful to understand their preferences and needs, better characterize the impacts of the acoustic environment, and translate this into design strategies.

To this end, the present study presents a review that maps the perceptual attributes and assessment tools used in previous literature to investigate children's perception of

classroom soundscapes. This information is instrumental in developing perception models and soundscape assessment tools tailored for children.

2. METHODOLOGY

A systematic literature review was conducted following the PRISMA protocol across three databases, namely "Scopus," "APA," and "Web of Science," using a tailored search string to extract conference papers and journal articles focusing on classroom acoustics, sound perception, soundscape, and young students. A structured set of inclusion and exclusion criteria was defined. These criteria focused on studies investigating classroom acoustics using keywords from respective domains such as Site of study (school), Perceptions (comfort), Acoustics (noise), Population (student). The initial search retrieved approximately 6800 articles.

A two-step filtering process was applied to refine the dataset of studies. First, a title-based screening process was conducted. Papers that were clearly outside the scope of the study, such as those focusing on children outside of the targeted age group, children with any sensory disability and neurodivergent conditions, or online learning environments, were systematically removed. This process reduced the total number of papers from 6800 to approximately 400. Second, abstract-based filtering was performed. Studies that did not align with the review aim, such as those lacking a perceptual evaluation or focusing solely on objective acoustic measurements, were excluded. The final set of studies consisted of 30 papers.

From the final dataset, the following information was initially extracted: age of the students, sample size, complete list of the questions used to assess subjective perception, and type of answer scale (e.g., Likert scale, visual scale, emoji scale). Afterward, each question was associated with a specific attribute within a preliminary list defined by the Authors. Agreement about the association between the questions and the attributes was discussed and solved together by the three Authors. In the case no pre-defined attribute was found to be suitable for a question, a new attribute was added to the list. As a final step, the attributes were grouped into macro-categories.

3. RESULTS AND DISCUSSION

Table 1 reports the frequency table of the reviewed studies, categorized by attributes and macro-categories. A graphical representation of the reviewed attributes is also provided in Figure 1, by means of a word cloud.

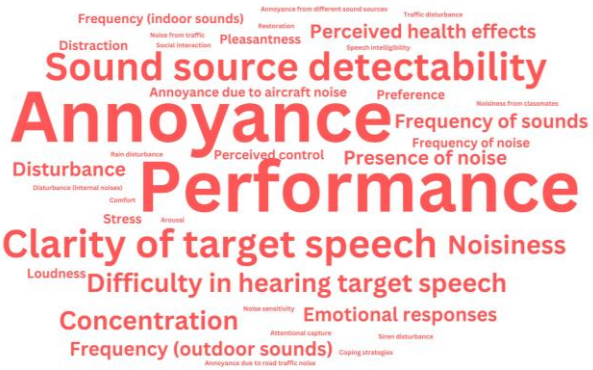


Figure 1. Word cloud representing the frequencies of the attributes used in the reviewed studies

Results indicated an emphasis on perceptual attributes focusing on the negative effects of sound stimuli in the classroom, such as noise-related (7 studies) and annoyance-related attributes (14 studies). Further among the most studied attributes were those related to the effects of the sound environment on the learning and cognitive performance of the students: performance (11 studies), difficulty in hearing the target speech, and concentration (4 studies each). Affective responses were evaluated in only five studies. Less frequently used attributes were those related to physiological responses (e.g. stress, health) and changes in social interactions. Overall, the questions differed in their focus, and some inquired about the frequency of noise occurrences, such as how frequently a particular sound was heard during class, while others assessed the intensity or magnitude of a specific acoustic characteristic, like how loud a classroom was perceived. This difference is critical in understanding the persistence and intensity of various noise sources, as well as their effects on students.

In terms of assessment, the vast majority of the studies used Likert scales based on sematic attributes or categories for the answers, allowing for an organized assessment of the perceptual responses. A few studies [5,15] used pictorial scaling, either emoji or full body images, which gave young respondents visual and immediate tools for expressing their perceptions.

4. FINAL REMARKS

This research provides insight into how the students' perception of the classroom environment was evaluated in previous studies. The findings indicate research gaps in emotional, cognitive, and social assessments while

underlining the negative effects of sound stimuli in the classroom.

5. ACKNOWLEDGMENTS

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Table 1. Frequency table of the perceptual attributes used in the reviewed studies, together with macro-categories.

Category	Attribute	References	Examples of questions
Noisiness	Noisiness	[2, 8, 11, 12]	• Do you think your classroom is noisy? (1) Not noisy at all (2) A bit noisy (3) Quite noisy (4) Very noisy [11] • Is there noise in your classroom? (1) Every day (2) Sometimes (3) No [1] • In general, in class, you find your classmates... (1) Not at all noisy (2) A bit noisy (3) Quite noisy (4) Very noisy [11] • During the lessons, I can hear the traffic from outside. (1) yes, correct (2) no, not correct [2]
	Presence of noise	[1, 13, 14]	
	Noisiness from classmates	[11]	
	Noise from traffic	[2]	
Sound source detectability	Sound source detectability	[1, 12, 15, 16, 17, 18]	• "What is the source of the noise? (1) Talking of other children (2) Traffic (3) People (4) Other [12] • Where does the noise come from (1) Inside the classroom (2) Outside the classroom [16]
Loudness	Loudness	[5, 11]	• Do you think that the noise level in class is... (1) Very low (2) Quite low (3) Quite loud (4) Very loud [11]
Speech perception	Clarity of target speech	[6, 10, 12, 16, 17, 19]	• 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 [19] • "Do you hear your teacher's voice during classes? "Yes/No" [12] • How do you hear the teacher's voice if you

	Speech intelligibility	[20]	are in silence while she is talking? (1) Good (2) Quite good (3) Bad [6] • How does noise affect your speech intelligibility? (1) No Effect / Never Experienced (2) Low / Rarely Experienced (3) Moderate / Sometimes Experienced (4) High / Often Experienced (5) Very High / Always Experienced [20]
Disturbance	Disturbance	[6, 12, 18]	• How much traffic noise disturbs you? (1) A little (2) Quiet (3) A lot [6] • How much ambulance, firemen and police sirens disturb you? (1)A little (2) Quiet (3) A lot [6] • Is there anything that disturbs you while playing outside or working in the classroom? (open-ended question) [18] • How often do you feel sensitive or bothered by the noise around your school?" (1) No Effect / Never Experienced (2) Low / Rarely Experienced (3) Moderate / Sometimes Experienced (4) High / Often Experienced (5) Very High / Always Experienced [20]
	Traffic disturbance	[6]	
	Siren disturbance	[6]	
	Disturbance (internal noises)	[6]	
	Rain disturbance	[6]	
	Noise sensitivity	[20]	
Effects on performance	Difficulty in hearing target speech	[11, 21, 22, 27]	• When the teacher or a classmate talks to the entire classroom: 1-You have difficulties hearing what the person says. (1) Almost never (2) Rarely (3) Quite often (4) Very often [11] • If noise attracts your attention, you lose track of the discussion (1) Almost never (2) Rarely (3) Quite often (4) Very often [11] • How often sounds distract you (1) Almost never (2) Rarely (3) Sometimes (4) Often (5) Several times during a lesson
	Attentional capture	[11]	
	Distraction	[20, 21]	
	Concentration	[19, 20, 21, 22]	

	Performance	[6, 8, 12, 14, 18, 19, 20, 21, 22, 23, 24]	[21] • How easy it is 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 [19]
Frequency-Related Attributes	Frequency of sounds	[1, 5, 22]	• How often do you hear certain sounds during lessons (e.g., students talking loudly, students moving about, sudden unexpected sounds, mobile phones, etc.) (1) Never (2) Rarely (3) Sometimes (4) Often (5) Very often [22] • Is there noise in your classroom? (1) No (2) Sometimes (3) Every day [1] • Do you hear noise from [aircraft/road traffic] when at [school/home]? (1) Never (2) Sometimes (3) Often (4) Always [24]
	Frequency of noise	[12, 16]	
	Frequency (indoor sounds)	[5, 22]	
	Frequency (outdoor sounds)	[5, 22, 24]	
Perceived control	Perceived control	[18, 21]	• Opportunity to control the noise (1) Very strong possibility (2) Some possibility (3) Little possibility (4) No possibility [21] • What do you do to stop noise affecting you? (open-ended question) [18] • What do you do to block out aircraft noise? (open-ended question) [18] • Would you like to change the noise in your environment, or do you think it is fine as it is? [18]
	Coping strategies	[18]	
Affective response	Emotional responses	[15, 18, 21]	• What noises do you hear in your environment? How do they make you feel? (open-ended question) [18] • What is it about plane noise that you find annoying? Do you feel anger, fear, or bothered? [18] • 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 [19] • Thinking about the last year, when you are
	Preference	[5, 18]	
	Pleasantness	[5, 15]	
	Comfort	[26]	
	Arousal	[5]	
	Annoyance	[1, 11, 13, 14, 17, 18, 19, 20, 22, 9]	

	Annoyance from different sound sources	[19]	at [school/home], how much does the noise from [aircraft/road traffic] bother, disturb, or annoy you? (1) Not at all (2) A little (3) Quite a bit (4) Very much (5) Extremely [19]
	Annoyance due to aircraft noise	[24, 28]	
	Annoyance due to road traffic noise	[24]	
Social interaction	Social interaction	[7]	• In this place, do you want to be with other people, be here alone, or not come? [7]
Health and restoration	Perceived health effects	[9, 21, 24]	• Pupils rated the frequency of experiencing the following symptoms (a) Irritation (b) Headache (c) Tension (d) Tiredness (e) Tinnitus (f) Sleeping problems (g) Concentration problems (1) Never (2) Rarely (3) Sometimes (4) Often (5) Very often [21] • Children's restoration needs in their everyday life: Stress reduction: (1) Not at all (2) A little (3) Moderately (4) Very (5) Extremely [29] Fatigue recovery: (1) Not at all (2) A little (3) Moderately (4) Very (5) Extremely [29] (h) How often do you feel stressed because of noise? (1) No Effect / Never Experienced (2) Low / Rarely Experienced (3) Moderate / Sometimes Experienced (4) High / Often Experienced (5) Very High / Always Experienced [20]
	Restoration	[29]	
	Stress	[18, 20]	