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Impact of the auditory environment on cognitive performance and behaviour in schools/workplaces: Methodological review 2023-2026

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ABSTRACT

Our auditory environment can impact our cognitive performance and behaviour. In academic research, a multitude of measures can be used to assess performance and behaviour, and a diversity of sounds can be generated, recorded, and manipulated. This paper addresses the question: What methods were used in the research published between 2023-2026 that examine the impact of the auditory environment on performance and behaviour? It uniquely covers both school environments (with participants under 18) and workplaces (with adults). Following the scoping review PRISMA protocol, four databases were searched (MEDLINE Complete, PsychInfo, Scopus, Web of Science). Selected articles had to: (1) be peer-reviewed journal articles published in English; (2) include at least one objective measurement of sound; (3) present at least one experimental comparison which varied the characteristics of the stimulus; (4) report at least one quantitative or qualitative measure of cognitive performance/process. Articles that only reported neurophysiological measures, focused on cochlear implants, or measured speech intelligibility/listening comprehension were excluded. 105 papers met inclusion criteria: 18 about schools, 87 about workplaces. Participants, sound conditions, performance measures, study design were charted and summarised. Studies investigating the impact of chronic (long-term) exposure to sounds had larger sample sizes compared to studies on acute (short-term) exposure. There is a balanced use of environmental and speech sounds in school and workplace studies, with artificial sounds being more frequently used in workplace studies. Recommendations for future studies are to embrace neurodiversity instead of excluding participants with neurodevelopmental conditions, and to consistently compare objective and subjective performance measures.

INTRODUCTION

This review is led by the International Commission on Biological Effects of Noise (ICBEN) Team 4. The team focuses on understanding the impact of noise on performance and behaviour [1-2].

ICBEN defines noise as a sound that is unwanted and/or harmful due to its intensity [3]. In schools and workplaces, unwanted sounds include people passing by, overheard conversations, sounds from mechanical devices (e.g. printers, ventilation, fridge) and tools (e.g. keyboards, jackhammers). Noise is partly subjective which is why a more neutral concept of "sound" will instead be used throughout the review. Sound is defined as mechanical vibrations that are travelling through the air and can be heard [4]. This neutral term offers the opportunity to express: (1) complexities about what features of the auditory stimulations may affect performance and behaviour; (2) situations in which subjective and objective effects do not align.

The aim of the review is to provide a methodological overview of the literature published in the field between 2023 and 2026, extending [1-2]. The paper addresses the following research question: What methods were used in the research investigating the impact of the auditory environment on cognitive performance and behaviour, between 2023-2026? Methods include: participants, sound conditions, performance measures, and study design. For the first time, the ICBEN Team 4 review includes studies with children under 18 in school settings as well as adults in the workplace.

METHODS

The search terms were replicated from [1], with the last keywords being adapted to represent the school/workplace contexts:

ALL=("Noise" OR "Sound") AND

ALL=("Cognitive Performance" OR "Cognitive work" OR "Cognitive activity" OR "Cognitive ability" OR "Cognitive task" OR "Mental work" OR "Mental task" OR "Mental processing" OR "Memory task" OR "Working memory" OR "Executive function" OR "Attentional focus" OR "Attentional capture" OR "Problem solving" OR "Adaptive behaviour" OR "Human behaviour" OR "Speech intelligibility" OR "Coping") AND

[For children's review:] ALL=("School" OR "Classroom")

[For adults' review:] ALL= ("Work" OR "Job" OR "Public place" or "In public" OR "dwelling" OR "Building acoustics")

The search was carried out on MEDLINE Complete, PsychInfo, Scopus, Web of Science. It covered the period from 3rd March 2023 to 1st February 2026. Only peer-reviewed journal articles published in English were included. Papers on school settings must have included participants under 18 years of age. Papers on workplaces must have participants above 18 years of age.

In addition, papers must have reported:

- At least one objective, replicable measure of sound (this included either: the sound pressure level, spectral characteristics, frequency, source of noise, content of noise)
- At least one quantitative or qualitative (interview, observation) measure of cognitive performance (as defined by the keywords) - objective or subjective

- At least one experimental comparison which varies the characteristics of the stimulus, either within or between subjects

Additional exclusion criteria were: (1) Papers already included in [1]; (2) Papers which only reported neurophysiological measures; (3) Papers which solely focused on cochlear implants, speech perception, speech intelligibility, which fall within the remit of ICBEN Teams 1 and 2.

For the review on school settings, the database searches retrieved 886 papers, leading to 813 after duplicates were removed on Zotero. Following abstract screening, 63 papers met the criteria for full-text screening, of which 18 papers met the criteria to be included in the review.

For the workplace review, database searches retrieved 1,260 papers, leading to 1,178 after duplicates were removed on Zotero. Following abstract screening, 143 papers met the criteria for full-text screening, of which 87 papers met the criteria to be included in the review.

RESULTS

Children's performance in noise in school settings

Participants. As shown in Table 1, the majority of studies covered primary school years.

Table 1: Age of the participants included in the studies.

Pre-primary (3-5)	Primary (6-11)	Secondary (12-17)	Longitudinal	Cross sectional wider ranges
[5]	[6-12]	[13-15]	Covering 3-17 [16] Covering 0-13 [17]	Covering 6-13 [18] Covering 8-21 [19] Covering 8-17 [20] Covering 7-14 [21]

Age bands corresponding to school levels were taken from UNICEF [22].

The majority of studies ensured that participants did not have a hearing impairment [6-13], [18], [20-21], [23]. Six studies excluded data from children with neurodevelopmental conditions [5-6] [10-11], [13], [19]. Other exclusion criteria were learning disabilities [8], [11]; language delays [6], [18], [20]; epilepsy [9]. Three studies checked that children had a certain level of cognitive abilities [12], [18-19] and normal or corrected-to-normal vision [7], [11-12]. Two studies explicitly compared autistic and non-autistic children [18], [21]. One study compared children with and without Attention Deficit Hyperactivity Disorder (ADHD) [12]. Special schools were included in [16] and no exclusion was reported in [5], [14-15], [17]. Sample sizes ranged from 35 [9] to 12 130 [5]. Sample sizes varied according to study design. Studies focusing on acute sound exposure involved 108 children on average (median: 114, min: 35, max: 229). Studies looking into chronic sound exposure involved more participants: 4 863 on average (median: 1524, min: 131, max: 12 159).

Sound conditions. Eleven studies focused on acute sound exposure, using short-term experiments to expose participants to various sound conditions [6-7], [9-13], [18-21]. The most commonly used sound stimulus was multi-talker babble noise [6], [9-11], [20]. Also in use were single-talker speech [7], [18], [21]; classroom noise [18]; environmental sounds [7], ventilation [13], music [21]; animal sounds [21]; white noise [18]; pure tones [12] and stimuli of varying emotional intensity [19]. The sound stimuli ranged from 33dB [10] to 77dB [19]. The majority of the 11 experimental studies included a quiet control condition [6-7], [9-11], [13], [18], [20].

Seven studies looked at chronic sound exposure, meaning long-term exposure corresponding to real-life conditions [5], [8], [14-17], [23]. Among these, three studies focused on the association between exposure to traffic sounds [16-17], residential sounds [5] and performance outcomes. Four studies adopted a semi-experimental design, investigating the impact of sound amplification systems implemented in classrooms [23], or comparing prevailing sound conditions in classrooms with a quieter [14-15] or louder [8] condition.

Measures of performance and behavior. The studies which focused on chronic exposure to transportation sounds and did include children with neurodevelopmental conditions used extensive cognitive test batteries as outcome variables [5], [14-17]. The other two studies looking into long-term sound exposure in the classroom measured reading fluency [23], working memory and long-term memory [8].

Experiments with acute sound exposure used: calculation [13]; listening comprehension [10]; reading comprehension [10], [13], [18]; recall [6-7], [9], [11], [18]; attention [11-12], [20]; auditory emotion recognition [19]; change deafness [21] tasks as outcome variables.

Adult performance in noise

Participants. The average number of participants in laboratory studies was 49 (median: 40; min: 10; max: 192) while it was 199 for field studies (median: 119; min: 31; max: 828).

Sound conditions. Of 87 studies, 72 were laboratory studies examining mostly the acute effects of the sound environment and 15 were field studies examining mostly chronic effects. Table 2 reports the studies per sound type – see Figure 1 for overall numbers. The most common sound types were environmental sound (42 studies), speech (39 studies) and artificial sounds (32 studies). Environmental sounds consisted of everyday life sounds, such as occupational noise, which were examined in field [24-32] and laboratory studies [33-48]. Traffic noise was another common noise type examined mostly in laboratory studies ([35], [37], [49-58]) but also field studies ([25], [77], [59]). Artificial sound conditions were used mainly in basic research studies investigating the effects of sound type and sound pressure level, typically by comparing specific sound environments with white, pink, or speech-shaped noise [36-37], [51-52], [60-73], [79].

Table 2. Sound conditions used in laboratory and field studies with adults.

Sound condition type	Laboratory studies	Field studies
Environmental sound	[33-58], [60], [66], [74-77]	[24-32], [59], [77]
Speech	[35], [37], [39], [40], [42], [45-46], [50-51], [53-55], [66], [68-70], [72], [74], [78-93] [110]	[30], [61], [94-95]
Artificial sound	[36-37], [51-52], [60], [62-73], [79], [91], [93], [96-105]	[61], [95]
Music	[59], [64], [67], [71], [74], [97], [106-108]	[30], [59], [109]
Nature sound	[52], [55], [60], [71]	

Measures of performance and behavior. The cognitive performance types identified were memory (39 studies), perception (30 studies), attention (30 studies), problem solving/processing (26 studies), subjective experience related to performance (26 studies) and psychomotor performance (7 studies) (see Table 3 and Figure 1). Memory performance was most examined, especially in laboratory studies. Memory performance included mostly working memory tasks

[32-33], [35], [40-41], [55-56], [59], [63], [69], [70-71], [74], [79], [81-85], [94], [96-99], [105] or free recall [45-46], [50-52], [55-56], [62], [64], [67], [72], [78], [80], [84], [106-107]. Attention was often examined in laboratory tasks for example with tests examining sustained attention [37-38], [43], [45], [47], [50], [53], [57], [60], [90-92], [97], [103-104] or Stroop or other tests measuring inhibition [24], [40], [56], [65], [74], [90], [92]. Seven out of the 15 field studies only used subjective experience as a performance measure [25-26], [28-29], [77], [95], [109]. Perception consisted mostly of detection tasks [24], [38], [44-45], [50], [54].

Table 3. Performance measures used in laboratory and field studies with adults.

Performance measure type	Laboratory studies	Field studies
Memory	[33], [35], [40], [41], [45-46], [50], [51], [52], [55-56], [60], [62], [63], [64], [67], [69], [70-72], [74], [78-79], [80-85], [96-99], [105-107]	[32], [59], [94]
Perception	[37-39], [44], [45], [47-48], [50], [53-55], [68-69], [72-73], [78], [86],-90], [96], [100-102], [108]	[24], [27], [62], [94]
Attention	[37], [38], [40], [43-45], [47], [50], [53], [55-57], [60], [65], [70], [74]-75], [76], [90-93], [97-98], [101], [103-104]	[24], [27], [30]
Problem solving/ processing	[34], [35], [36], [37], [38], [42], [45], [46], [47], [48], [49], [50], [55], [60], [68], [70], [72], [74], [83], [84], [86], [92], [106]	[24], [32], [61]
Subjective experience	[33-35], [39], [41], [45-46], [50], [55-58], [65-66], [71], [73-74], [85], [89]	[25-26], [28-29], [77], [95], [109]
Psychomotor	[36], [50], [54], [63], [87], [106], [108]	

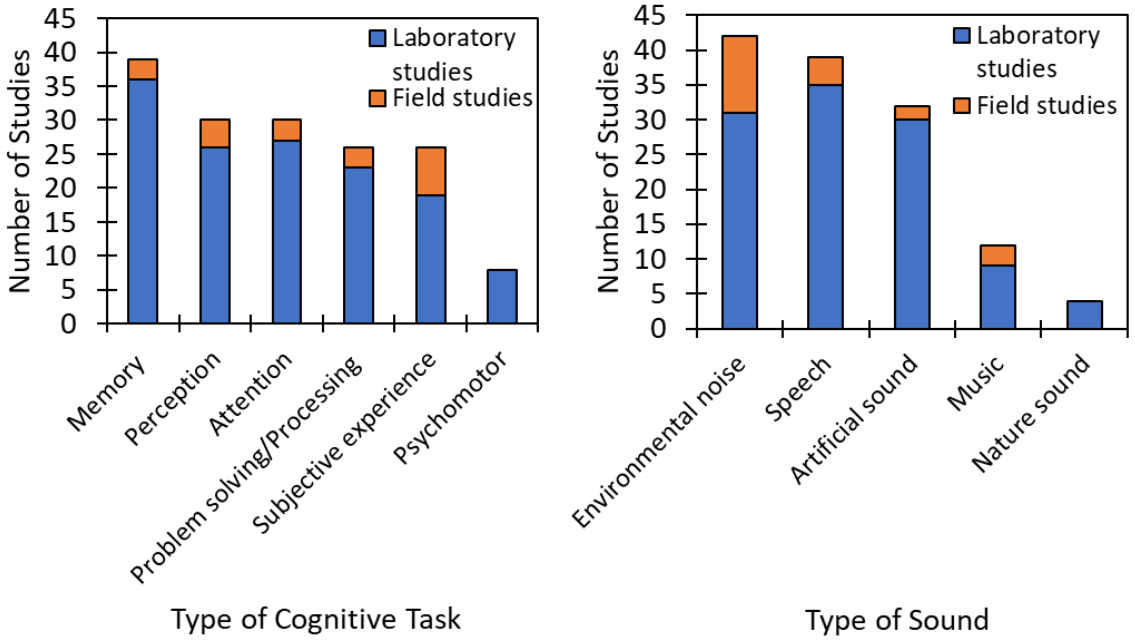

Figure 1: Number of studies per type of cognitive task and type of sound, for laboratory and field studies with adults.

CONCLUSIONS

Children

Studies focusing on the chronic impact of sounds on performance have larger sample sizes, are more likely to include children with neurodevelopmental conditions and to use extensive batteries of cognitive tests. Studies using acute sound exposure need to include more children with neurodevelopmental conditions, cognitive and language delays. This gap in the literature had already been identified three years ago [111-113].

Adults

Memory was the most examined cognitive function with both working memory and free recall being emphasized. The most common combination was examining memory performance in relation to speech sound, but only in laboratory studies. Attention and perception as well as problem solving or processing had a wider variety of tasks included.

In field studies, subjective experience was still the most common performance measure. Subjective experience related to performance was less often examined in laboratory studies which concentrated on objective performance measures. Similar results were reported in the last ICBEN Team 4 review [1]. Methodologically, this discrepancy may reflect the tradition in basic research of addressing research questions using objective measures as the preferred source of evidence [1]. It is advised to combine both objective and subjective measures in future research, in order to have a full picture of the impact of sounds on adults' performance and subjective experience.

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