Effects of noise on the cognitive performance of primary school children

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Classroom acoustic environments often fail to meet standards, and noisy environments can not only affect children's listening abilities but also lead to a decline in cognitive performance. This study examines how background noise influences primary school children's cognitive processes. Children from two primary schools underwent testing in their classroom environments under both quiet and noisy conditions, with students performing neuropsychological tests to assess executive functions and learning tasks. Preliminary findings only partially support the hypothesis that noise negatively impacts cognitive performance. Noise was found to adversely affect children's performance on attention tasks in the first school, whereas in the second school, children performed better in noise on both attention and inhibition tasks, as well as on a writing task. Unlike the first school, the second school had a reverberation time that did not meet regulatory standards. These initial findings suggest interesting hypotheses and directions for future research. However, they also reveal some weaknesses in the experimental protocol that need to be addressed to further investigate the emerging hypotheses.
Keywords: classroom acoustics, noise, cognitive performance, acoustic measurements, children

Gli effetti del rumore sulle prestazioni cognitive dei bambini di scuola primaria

Gli ambienti acustici delle classi spesso non rispettano gli standard e ambienti rumorosi non solo possono influenzare le capacità di ascolto dei bambini ma anche portare a un declino delle prestazioni cognitive. Questo studio esamina come il rumore influenzi i processi cognitivi dei bambini di scuola primaria. I bambini di due scuole hanno svolto in aula una serie di test per valutare le funzioni esecutive e brevi compiti di lettura e scrittura. Tutte le prove sono state svolte sia in condizioni di quiete che di rumore. I risultati preliminari supportano solo parzialmente l'ipotesi che il rumore abbia un impatto negativo sulle prestazioni cognitive. Le performance dei bambini nei compiti di attenzione sono infatti risultate peggiori in rumore rispetto alla condizione di quiete nella prima scuola, mentre nella seconda scuola i bambini hanno ottenuto risultati migliori in rumore nelle prove di attenzione, di inibizione e nel compito di scrittura. A differenza della prima scuola, nella seconda il tempo di riverbero non rispettava gli standard normativi. I risultati iniziali suggeriscono interessanti ipotesi e direzioni per future ricerche. Tuttavia, rivelano alcune debolezze nel protocollo sperimentale, da superare al fine di approfondire le ipotesi formulate e trovare nuove evidenze.
Parole chiave: acustica scolastica, rumore, performance cognitiva, misurazioni acustiche, bambini

1 | Introduction

The examination of the effects of noise has been extensive, particularly regarding auditory perception and listening effort. The term "auditory perception" refers to the ability to recognize and understand auditory stimuli, such as discerning characteristics like frequency, pitch, timbre, and loudness, as well as comprehending speech and music. It also encompasses the capability to spatially locate sounds, analyze their temporal patterns, and perceptually organize auditory information [1]. Listening effort refers instead to the attention and cognitive resources needed to overcome obstacles during a listening task. It can be evaluated through various methodologies, including self-report, behavioral, and physiological measures [2]. Despite the increasing research in recent years on the consequences of noise in relation to cognitive fatigue [3], the impact of noisy environments on cognitive performance and brain activity has often been neglected, and most studies still focus on the perceptual effects of noise.

The consequences of noise exposure in terms of cognitive fatigue can, however, be particularly negative, and in the case of chronic exposure, long-term effects may also occur.

These consequences include annoyance, perceived disturbance, as well as impairments in concentration, productivity, and executive functioning [4, 5].

Executive functions (EFs) are higher-order cognitive skills that enable top-down control and regulation of thought processes and associated actions [6]. They consist in three primary components: inhibition (including selective attention, cognitive inhibition, and self-control), working memory, and cognitive flexibility. These components give rise to higher-order functions such as problem-solving, reasoning skills, and planning. They play a crucial role in both physical and mental health, contributing to cognitive and psychological development, reflective capacity, mental agility, and the self-regulation of emotions and behaviour. Therefore, EFs are considered pivotal in the development of academic skills, as the range of cognitive functions involved in the learning process primarily includes attention, memory, inhibition, concentration, and reaction time [7]. So, particularly in children, exposure to noise can have lifelong implications for both health and academic outcomes. Children are in fact particularly sensitive to noise, as they lack fully developed cognitive skills and coping strategies to counteract its effects [8]. Although children start to develop the ability to ignore distractions in their early years, their executive functions are still undergoing full development [9-10]. The maturation of their auditory pathway is not yet complete, and their phonological processing skills have not been fully achieved [11]. Consequently, children exhibit greater sensitivity to noise-induced interference than adults, impacting both auditory and non-auditory tasks [12]. Moreover, a considerable part of their educational experience occurs within complex and unfavourable acoustic settings.

According to the World Health Organization (WHO, 2014) [13], the physical environment within schools plays a significant role in promoting health. Among the stressors, elevated noise levels can lead to irritation, foster aggressiveness, diminish both physical and mental performance, and induce discomfort and headaches [14].

And there is evidence of how classroom noise can significantly impair children's academic performance [15]. Additionally, children with learning difficulties, are generally reliant on a favorable acoustic environment for optimal functioning [14].

Classrooms are almost always noisy environments, due to external noise sources, such as traffic and outdoor play areas, as well as internal noise sources, such as noise from chairs being moved or children talking [15]. In particular, the primary sources of noise reported as most bothersome by both students and teachers include classroom chatter and sounds from movement, such as those originating from the corridor and the scraping of chairs and tables [16].

Children-generated classroom noise was identified as having the most adverse effects on speech perception, listening comprehension, and performance in verbal and mathematical tasks. This phenomenon can be attributed to auditory distraction mechanisms. The impact depends on the spectro-temporal characteristics and informational content of the background noise, which may lead to domain-specific interference, attentional capture, or a combination of both mechanisms [17].

The World Health Organization [18] sets specific guidelines for classroom acoustics, recommending background noise levels not exceeding 35 dB(A) and a reverberation time (RT) of no more than 0.6 seconds.

In this regard, the UNI 11532-2 "Internal Acoustic Characteristics of Confined Spaces – Design Methods and Evaluation Techniques – Part 2: School Sector" has been recently published. This standard identifies the limit values to be respected in school environments for parameters such as reverberation time (T), Speech Transmission Index (STI), clarity (C50), and system noise. The document also specifies how to carry out on-site checks [19].

Evaluating and monitoring the acoustics of classrooms is particularly important because it has been observed that inadequate classroom acoustics are associated with increased perceptions of noise intensity and disturbance. Additionally, extended reverberation times, which often indicate poor classroom acoustics, lead to higher noise levels and reduced speech intelligibility. Consequently, students may experience diminished feelings of enjoyment and self-satisfaction [14].

However, schools and classrooms often fail to meet these acoustic standards [20] and even when attempts are made to improve the environment, they hardly ever mitigate the effects of background noise caused by children's chatter and classroom activities.

A recent monitoring report for the school year 2020/2021 [21] has concluded that only 11% of Italian school buildings are equipped with specific measures for protection against noise. Of these, the majority (79%) have adopted measures to isolate external noises, while few have reduced internal reverberation.

This study aims to investigate how different types of noise affect various verbal and nonverbal executive functions, as well as learning activities. Children's cognitive performance is assessed in both quiet and noisy conditions using a set of non-auditory tasks. The evaluation involves examining perceived cognitive effort and measures of the classroom acoustic environment.

The following findings present preliminary results based on the data collected to date.

2 | Material and Methods

2.1 | Participants

The study involved 74 fourth-grade students from two public primary schools in the Padua province of Italy.

- School A: two classrooms, 31 children (18 female), with a mean age of 9.2 years ± 0.4 years.
- School B: two classrooms, 43 children (28 female), with a mean age of 9.1 years ± 0.4 years.

None of the children had been diagnosed with cognitive, learning, or sensory disabilities, according to their class teachers. Both schools share similar outdoor noise conditions, as they are situated in low-traffic residential areas with comparable socioeconomic characteristics. All parents provided informed consent for their children's participation in the study.

This research received approval from the Ethics Committee of the Human Inspired Technology Research Centre at the University of Padua (protocol number 2020_92R1).

2.2 | Materials and Procedures

2.2.1 | Children's Cognitive Measurements

Cognitive assessment: CoEN App

Children's cognitive abilities were assessed using an iOS app called "CoEN – Cognitive Effort in Noise" [22]. Developed by a research team from the University of Padua and Venice, this app employs game-like tasks to evaluate verbal working memory, visual attention, and cognitive inhibition. CoEN comprises five tasks, including adaptations from standardized neuropsychological tests such as the Digit Span Test (Forward and Backward), a visual attention test from the WISC-IV (cancellation subtest), a visual attention test from the NEPSY-II (visual search of faces), a Reading Span Test, and the Cognitive Inhibition Task, adapted from Diamond et al. [23].

In the Digit Span Test, verbal working memory is assessed by requiring the child to recall a series of digits either in the same order (forward subtest) or in reverse order (backward subtest) as they are presented by the examiner. In the CoEN version, digits are visually presented on the screen, and the child types the series of digits in either direct (forward span) or reverse (backward span) order on a keyboard.

The Visual Attention Test (NEPSY-II) is a visual search task where the child is required to identify target faces from a page displayed on the tablet screen in CoEN, that also contains distractors. This timed test must be completed within three minutes [24].

The Cancellation Test (WISC-IV) is similar to the NEPSY-II visual attention test but has a shorter duration. The child identifies and marks targets (e.g., animals) among various stimuli within 45 seconds [25].

The Reading Span Test [26] evaluates the ability to simultaneously hold and manipulate information in working memory. Children are presented with a series of sentences and asked to recall the final word of each sentence.

The inhibition task [23] assesses inhibitory control by displaying a red heart or a flower on either side of the tablet screen. The child must touch the arrow that corresponds to the heart's side (congruent condition) or the opposite side when a flower appears (non-congruent condition).

Assessment of learning abilities: Text comprehension task & Writing task

The children were then tasked with completing the following assessments:

A comprehension task [27] in which they read age-appropriate passages and answered a series of multiple-choice questions. This test allows for the assessment of reading and comprehension abilities.

A writing task, specifically the Sentence Generation Test [28]. In this test, children were instructed to write as many sentences as possible within a 5-minute timeframe, each containing two pairs of given words. This task aids in evaluating verbal fluency and writing ability.

Following the testing session, children were given a self-report questionnaire, drawing from the Bess et al. fatigue scale [29]. This questionnaire was administered to assess their cognitive effort during the tasks. It consists of six items (e.g., "Do you feel tired?" and "Was it difficult to remember?") rated on a 5-point Likert scale, ranging from "not at all" to "very much".

During the sessions in schools, the children performed all the tests twice, once in quiet conditions and once in noisy conditions. To minimize any potential learning effects, all the tasks were administered with a minimum two-week interval between the two trials. In school A, the order of the task condition was counterbalanced across children. However, in school B, this was not feasible due to organizational issues, and both classes performed the tests in quiet during the first trial and in noise during the second trial.

Furthermore, in school A, both classes alternated: while half of the class performed the tests using the app, the other half completed the paper-based tasks, and then they switched roles. In school B, on the other hand, all children began with the app-based tests, and once completed, they proceeded to the paper-based ones.

The quiet condition was characterized by the classroom's natural acoustic environment, with noise levels being carefully controlled by instructing the children to remain as quiet as possible. Additionally, detailed instructions were provided to the children before the tests, encouraging them to remain quiet during testing.

For the noise condition, multi-talker babbling was introduced to simulate ambient noise, similar to what is typically found in classroom environments.

In each classroom, a talkbox placed on the teacher's desk introduced the following signals:

- School A: multi-talker babble noise [30].
- School B: multi-talker babble noise along with intermittent transient noises such as door slamming, knocking, ambulance sirens, etc.

2.2.2 | Acoustic Measurements

All acoustic assessments were conducted in empty classrooms, adhering to standard protocols. The Reverberation Time (RT) and Speech Transmission Index (STI) were measured, as they are commonly used objective parameters for evaluating classroom acoustic quality.

RT was measured according to ISO 3382 norms [31], at three different positions in each classroom for both sound source locations. The mean values of the six RT measurements were compared with the normative data in the frequency of 250, 500, 1000 and 2000 Hz. Additionally, RT values corresponding to an occupancy level of 80% were estimated based on empty-room RT measurements, following the UNI 11532-2 standard [18].

STI was measured using a TalkBox by NTi Audio, which has a polar directivity diagram similar to that of the human voice. The TalkBox was positioned at the teacher's location and placed at a height of 1.50 m.

These assessments were conducted in unoccupied classrooms during school closures to determine compliance with normative references. This involved selecting three positions in a line at the talkbox, with one point placed 1 meter away and another at the least favorable position. Additionally, in School B, the measurement protocol included STI index measurements on all desks in the classroom.

In order to assess the impact of the different sound signals used in the two schools (multitalker babble noise in school A, and multitalker babble noise supplemented with transient noises in school B), measurements were conducted to determine the sound power emitted by the Talkbox under each scenario. This assessment was carried out by comparing the emitted sound against a reference sound source and following the protocols outlined in ISO 3747 [32].

Precisely, sound pressure levels were measured at six microphone positions arranged in a circular configuration at a distance of 50 cm from the Talkbox. This arrangement ensured comprehensive coverage of each signal emitted by the Talkbox, as well as the reference sound source and the background noise. Subsequently, sound power was calculated based on these measurements.

An omnidirectional calibrated microphone (model XL2 by NTi Audio) was used, positioned at a height of 1.2 m in the centre of the classroom, both in quiet and noisy conditions.

During cognitive testing in the classroom, the equivalent continuous sound level (LAeq,1s) was recorded.

The acquisitions are carried out throughout the entire duration of the testing session, starting from the distribution of materials and the explanation of the tests to the children, for a total of approximately 1 hour and 30 minutes. From all this acquired data, only the samples related to the actual test execution are processed (calculated from the moment when the children start the first test until the last child has completed all the tests).

Finally, since the overall test execution time may vary from child to child and therefore from class to class, the equivalent sound level (SEL) values were calculated for each classroom under both conditions, in order to compare the measured values among the different classes.

3 | Results

3.1 | Acoustic Measurements

The volumes of the classrooms where the tests were conducted are: 149 and 155 m³ for School A, and 142 and 140 m³ for School B.

- School A: The RT was measured in both classrooms, resulting in average values of 0.51 and 0.49 seconds, respectively. These measurements were found to comply with normative standards.

Similarly, the average STI values were calculated for both classes, measuring at 0.70 and 0.74, respectively. These values are considered satisfactory when compared to the standard scale outlined in ISO 9921 [33].

- School B: The average RT in both classrooms were found to be 1.55 and 1.36 seconds, respectively. These values exceeded the regulatory limit for each analyzed frequency.

However, the average STI values for both classes were found to be acceptable compared to the ISO 9921 standard scale, with at 0.56 and 0.54, respectively.

The measured RT values in empty classrooms and the estimated optimal RT values, considering 80% occupancy, are summarized in the following tables (Tab. 1 for School A and Tab. 2 for School B) and represented in the following graphs (Fig. 1 for School A and Fig. 2 for School B)

Tab. 1 – Measured Reverberation Time (RT) values in both classes (RT-1 and RT-2) and tolerance interval for the optimal RT at different frequencies – School A

Valori misurati del Tempo di Riverbero (RT) in entrambe le classi (RT-1 e RT-2) e intervallo di tolleranza per il valore di RT ottimale alle diverse frequenze – Scuola A

School A					
Freq [Hz]	*Optimum RT [s]*	*Optimum RT (superior) [s]*	*Optimum RT (inferior) [s]*	*RT-1 [s]*	*RT-2 [s]*
125	0.53	0.76	0.34	0.58	0.58
250	0.53	0.63	0.42	0.50	0.51
500	0.53	0.63	0.42	0.46	0.44
1000	0.53	0.63	0.42	0.55	0.48
2000	0.53	0.63	0.42	0.52	0.51
4000	0.53	0.63	0.34	0.47	0.45

Tab. 2 – Measured Reverberation Time (RT) values in both classes (RT-1 and RT-2) and tolerance interval for the optimal RT at different frequencies – School B

Valori misurati del Tempo di Riverbero (RT) in entrambe le classi (RT-1 e RT-2) e intervallo di tolleranza per il valore di RT ottimale alle diverse frequenze – Scuola B

School B					
Freq [Hz]	*Optimum RT [s]*	*Optimum RT (superior) [s]*	*Optimum RT (inferior) [s]*	*RT-1 [s]*	*RT-2 [s]*
125	0.52	0.75	0.34	2.25	1.75
250	0.52	0.62	0.42	1.80	1.41
500	0.52	0.62	0.42	1.48	1.39
1000	0.52	0.62	0.42	1.37	1.35
2000	0.52	0.62	0.42	1.30	1.23
4000	0.52	0.62	0.34	1.07	1.05

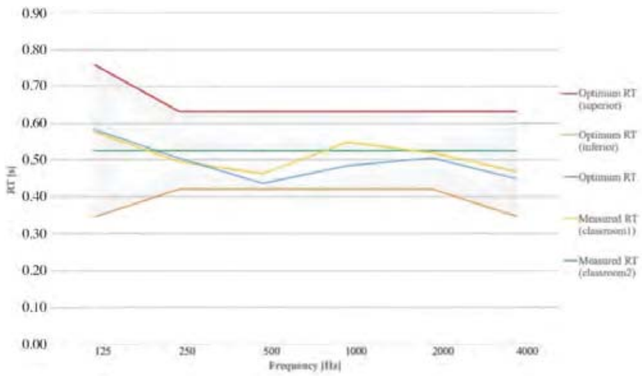

Fig. 1 - Graphical representation of the Measured Reverberation Time (RT) values and tolerance interval for the optimal RT at different frequencies – School A

Rappresentazione grafica dei valori del tempo di riverbero misurato e dell'intervallo di tolleranza per il tempo di riverbero ottimale a diverse frequenze – Scuola A

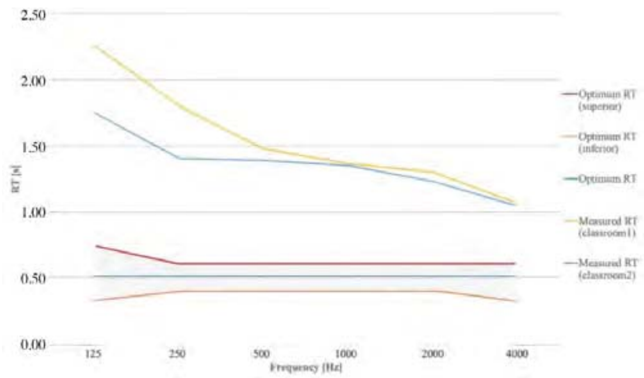

Fig. 2 – Graphical representation of the Measured Reverberation Time (RT) values and tolerance interval for the optimal RT at different frequencies – School B

Rappresentazione grafica dei valori del tempo di riverbero misurato e dell'intervallo di tolleranza per il tempo di riverbero ottimale a diverse frequenze – Scuola B

The calculated values of the equivalent sound level (SEL) are provided below (Tab. 3), and in the following (Tab. 4), the duration of the test execution and the corresponding individual SEL levels measured, for each class, in quiet and in noise, are reported. Specifically, for school A, the values related to the phase during which half of the class performed the cognitive tests using the CoEN app and the other half the paper-based tests are reported, and then the subsequent phase during which the tablet-paper tests were reversed. For school B, instead, the SEL values for each of the tests (conducted simultaneously by the entire class) are reported.

Tab. 3 – Sound Equivalent Level (SEL) values for each classroom (SEL-1 and SEL-2) in each school, measured in both noisy and quiet conditions

Valori di Livello Sonoro Equivalente per ogni aula (SEL-1 e SEL-2) in ciascuna scuola, misurati in condizioni di quiete e di rumore

	School A		**School B**	
	SEL-1 [dBA]	*SEL- 2 [dBA]*	*SEL-1 [dBA]*	*SEL- 2 [dBA]*
"Quiet"	83.3	77.6	92.4	88.5
"Noise"	92.9	93.4	105.0	101.5

Tab. 4 – SEL values and test execution duration for each class: cognitive tests on tablets (memory, attention, and inhibition) and paper-based tests (text comprehension and sentence generation)

Valori di SEL e durata dell'esecuzione dei test per ciascuna classe: test cognitivi su tablet (memoria, attenzione e inibizione) e test su carta (comprensione del testo e generazione di frasi)

	Test	*Test duration [min]*	*SEL [dBA] Quiet*	*Test duration [min]*	*SEL [dBA] Noise*
School A 1	CoEN app – Learning abilities	19	91.8	21	93.4
School A 1	Learning abilities – CoEN app	17	83.3	23	92.9
School A 2	CoEN app – Learning abilities	28	88.0	18	92.0
School A 2	Learning abilities – CoEN app	18	77.6	21	93.4
School B 1	CoEN app	36	92.4	30	105.0
School B 1	Learning abilities comprehension task	10	85.4	10	96.8
School B 1	Learning abilities writing task	12	94.4	10	99.3
School B 2	CoEN app	26	88.5	23	101.5
School B 2	Learning abilities comprehension task	10	86.0	10	97.7
School B 2	Learning abilities writing task	25	88.0	10	99.0

Finally, Regarding the sound power levels, the following values were obtained: Lw=77.5 dB(A) for the signal used in School A, and Lw=76.0 dB(A) for the signal used in School B.

3.2 | Children's Cognitive Measurements

Due to some technical issues in acquiring scores related only to the inhibition test, which were later resolved through a series of modifications and an update of the App, it was not possible to consider the data from the inhibition test in the first school (A).

- School A: The paired t-test findings indicated that under noisy conditions, children exhibited significantly poorer performance on the Cancellation Test ($t=1.704$, $p<0.05$) and reported higher levels of cognitive fatigue ($t=-2.408$, p<0.05) compared to quiet conditions. These results are summarized in the following table (Tab. 5).

Tab. 5 – Children's performance on the CoEN tasks across acoustic conditions – School A
Prestazioni dei bambini: prove dell'app CoEN nelle diverse condizioni acustiche – Scuola A

School A					
(n=31; 18 girls)					
	"Quiet"		"Noise"		
Variable	*Mean*	*SD*	*Mean*	*SD*	*t*
Digit Span Forward (accuracy)	6.04	1.40	6.15	1.89	−0.259
Digit Span Backward (accuracy)	5.27	2.05	5.85	1.29	−1.364
Reading Span (accuracy)	2.00	1.69	2.23	1.97	−0.507
Visual attention (accuracy)	14.69	9.75	11.65	17.41	1.194
Cancellation (accuracy)	26.42	10.71	22.69	10.74	1.704*
Comprehension	9.36	2.97	9.96	2.80	−0.742
Writing	13.40	4.89	12.36	5.65	0.783
Cognitive Effort Self Report	1.73	0.57	2.10	0.69	−2.408*

*p<.05; **p<.01; ***p<.001

- School B: The analysis showed significant differences between the quiet and noise conditions in the visual attention (t=−2.382, p<0.05; t=−3.426, p<0.001), inhibition (t=−3.295, p<0.01) and writing (t=−4.915, p<0.001) tasks, with better scores observed under the noise condition, as shown in the following table (Tab. 6).

Tab. 6 – Children's performance on the CoEN tasks across acoustic conditions – School B
Prestazioni dei bambini: prove dell'app CoEN nelle diverse condizioni acustiche – Scuola B

School B					
(n=43; 28 girls)					
	"Quiet"		"Noise"		
Variable	*Mean*	*SD*	*Mean*	*SD*	*t*
Digit Span Forward (accuracy)	5.65	1.84	5.91	1.58	−0.851
Digit Span Backward (accuracy)	5.29	1.96	5.53	2.12	−0.569
Reading Span (accuracy)	2.03	1.66	2.24	1.71	−0.879
Visual attention (accuracy)	13.16	13.59	18.29	8.73	−2.382*
Cancellation (accuracy)	18.92	15.04	26.87	9.44	−3.426***

Tab. 6 – continued

School B					
(n=43; 28 girls)					
	"Quiet"		"Noise"		
Variable	*Mean*	*SD*	*Mean*	*SD*	*t*
Cognitive inhibition Congruent (accuracy)	18.45	3.60	18.50	3.69	−0.071
Cognitive inhibition Incongruent (accuracy)	13.92	8.38	18.24	4.08	−3.295**
Cognitive inhibition Mixed (accuracy)	15.47	4.55	16.45	4.45	−1.593
Comprehension	9.11	7.74	8.99	3.01	0.30
Writing	10.82	5.71	15.47	8.43	−4.915***
Cognitive Effort Self Report	1.67	0.46	1.73	0.58	−1.083

*p<.05; **p<.01; ***p<.001

4 | Discussion

The results partially supported the hypothesis that babble noise has an adverse effect on children's cognitive performance.

In the case of School A, it was observed that noisy conditions led to a deterioration in the visual attention test and an increased perception of cognitive fatigue among children. The compromised performance in visual tasks can be attributed to noise, as it redirects attention partially from relevant visual information to the auditory signal, resulting in disruption of the task. This finding is consistent with previous research indicating that babble noise can significantly impact children's attention [34].

Contrary to expectations, results from School B did not align with those of School A. Despite the initial expectation that noise, including transient noises, would be more disruptive for the children, the findings demonstrated the opposite effect. Interestingly, there was a significant improvement in performance under noisy conditions for both visual attention and inhibition tasks, as well as for the writing task.

Regarding this last task, in particular, although it may seem counterintuitive, a similar result has already been found in a study by Dockrell & Shield [35], where children scored higher in reading and writing tasks in the babble noise condition with the addition of transient noises compared to quiet and babble noise conditions without transient noises. Furthermore, it's crucial to emphasize that the writing task involves creativity, and several studies [36] argue that the presence of moderate-intensity noise during the execution of a creative task can actually promote a positive outcome.

The results in School B regarding cognitive tests of attention and inhibition may be in line with the theory of stochastic resonance, which suggests that noise within a nonlinear system can enhance the quality of the output signal compared to situations with no noise present [37]. This phenomenon has been observed across various physiological systems, where noisy stimulation can potentially improve cognitive functions [38]. The addition of randomized noise can activate additional cognitive resources, potentially leading to improved attentional performance, especially in individuals with attention deficits or ADHD [38, 39].

For instance, research has shown that white noise can effectively enhance attention performance by improving the ability to distinguish between targets and non-targets and by reducing omission errors. Moreover, it has been found to alleviate extrinsic hyperactive behaviors in children with ADHD [40]. And there is evidence that white noise therapy could be beneficial for children with ADHD [41].

It should be noted, however, that when discussing stochastic resonance, white noise or noise with similar characteristics is the most commonly studied form, whereas, in our study, a babble noise was used.

Furthermore, the results from the second school suggest that contextual factors could play a role in modulating the impact of noise on cognitive performance. The RT measurements varied significantly between the two schools. School A, which had a sound-absorbing ceiling, exhibited values within the standard range, whereas school B showed much longer reverberation times that exceeded the normative standard. The variation in classroom acoustics between the schools could have influenced the divergent reactions to noise observed in the study. A plausible hypothesis is that due to prolonged exposure to inferior acoustic environments in school B, students might have developed more adept coping mechanisms to mitigate noise disturbances compared to those in school A.

And it is important to highlight how some studies also show how children might use compensatory strategies to reach the same level of performance in both silence and noise [42].

However, these hypotheses are preliminary and require further investigation. Methodological differences between the schools could have influenced the results.

The primary distinction lays in the experimental setup: in school A, the order of quiet and noisy conditions was alternated between the two classes, whereas in school B, both classes undertook tests in quiet followed by noise. Despite maintaining a minimum two-week interval between each test, it is possible that the children were more familiar with the tasks during the second trial, which could have provided an advantage to the children in both classes of school B during the tests conducted under noisy conditions.

5 | Conclusions

In conclusion, the study offered intriguing insights into the effects of noise on children's cognitive performance, particularly in varied school environments. While noisy conditions in School A were associated with decreased visual attention and increased cognitive fatigue, contrasting outcomes were observed in School B, where noise seemed to improve performance on various cognitive tasks.

However, there were some weaknesses in the experimental protocol that need to be addressed and corrected in future evaluations.

It is important, therefore, to further investigate these research questions. Future research should aim to establish clear causal relationships between observed effects and noise or room acoustics. This could be achieved by consistently counterbalancing acoustic conditions and evaluating children's baseline cognitive abilities in noise-free environments before analysing the impact of noise on groups with comparable performance levels. Additionally, exploring different types of noise could provide valuable insights into their effects on cognitive performance.

Conclusioni

In conclusione, lo studio ha fornito interessanti spunti sugli effetti del rumore sulle prestazioni cognitive dei bambini. Se da un lato nella Scuola A in condizione di rumore è stato rilevato un peggioramento delle performance nei compiti di attenzione visiva e a un aumento dell'affaticamento cognitivo percepito, un risultato diverso e per certi aspetti inatteso è stato osservato nella Scuola B, dove in condizione di rumore i bambini hanno ottenuto punteggi più alti in diverse prove.

Diventa quindi ancora più importante approfondire ulteriormente queste domande di ricerca, risolvendo in primo luogo quelle che sono state le principali problematiche dal punto di vista del protocollo sperimentale.

Una delle prospettive future di questo studio sarà certamente quella di provare a stabilire relazioni causali più evidenti tra gli effetti osservati, la presenza di rumore e l'acustica delle aule scolastiche. Ciò potrebbe essere realizzato innanzitutto attraverso un contro bilanciamento delle condizioni acustiche, e in secondo luogo andando a valutare le abilità cognitive di base dei bambini in ambienti privi di rumore, al fine di analizzare l'impatto del rumore su gruppi di bambini con livelli di prestazioni comparabili. Infine, analizzare gli effetti di diverse tipologie di rumore potrebbe fornire ulteriori evidenze e nuovi spunti di ricerca.

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