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Noise level to which children using cochlear implants and/or hearing aids are exposed in the educational environment: Integrative review

Nível de ruído em que crianças usuárias de implantes coclear e/ou aparelho de amplificação sonora individual são expostas no ambiente educacional: Revisão integrativa

Nivel de ruido al que están expuestos los niños usuarios de implantes cocleares y/o dispositivos individuales de amplificación de sonido en el entorno educativo: Revisión integradora

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Abstract

Introduction: People with hearing loss face significant communication difficulties, especially in noisy environments where speech becomes distorted because of background noise. In the school environment, excessive noise compromises attention, memory and speech recognition, directly interfering with the learning process. **Objective:** To identify, through an integrative review, the impact of different noise levels in classrooms on children who use cochlear implants (CI) and/or hearing aids (HA). **Method:** This review was conducted in national and international health and education databases, such as the Virtual Health

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Library (VHL), PubMed, Scientific Electronic Library Online (SciELO), Scopus (Elsevier), the Brazilian Digital Library of Theses and Dissertations (BDTD), CAPES, and the Education Resources Information Center (ERIC). The studies included were those of any language related to the topic published between 2018 and 2023. **Results:** A total of 2,376 studies were identified. After initial reading and application of the inclusion and exclusion criteria, 6 articles were selected for analysis. **Conclusion:** The noise level present in classrooms makes it significantly difficult for students using HA and CI to understand speech, consequently impairing performance and cognitive development.

Keywords: Education; Noise; Cochlear Implantation; Hearing Aids; Hearing Loss; Noise Measurement.

Resumo

Introdução: Pessoas com deficiência auditiva enfrentam dificuldades significativas de comunicação, especialmente em ambientes ruidosos, onde o discurso é distorcido pelo ruído de fundo. No contexto escolar, o excesso de ruído compromete a atenção, a memória e o reconhecimento da fala, interferindo diretamente no processo de aprendizagem. **Objetivo:** Identificar o impacto dos diferentes níveis de ruído nas salas de aula sobre crianças usuárias de implante coclear (IC) e/ou dispositivo eletrônico de amplificação sonora (DEAS), por meio de revisão integrativa. **Método:** A revisão foi conduzida em bases nacionais e internacionais de saúde e educação, como Biblioteca Virtual em Saúde (BVS), PubMed, Scientific Electronic Library Online (SciELO), Scopus (Elsevier), Biblioteca Digital Brasileira de Teses e Dissertações (BDTD), CAPES e Education Resources Information Center (ERIC). Foram incluídos estudos publicados entre 2018 e 2023, relacionados ao tema, sem restrição de idioma. **Resultados:** Foram identificados 2.376 estudos. Após leitura dos títulos, resumos e aplicação dos critérios de inclusão e exclusão, foram selecionados 6 artigos para análise. **Conclusão:** Os níveis de ruído presentes nas salas de aula dificultam significativamente a percepção auditiva de crianças usuárias de DEAS e IC, prejudicando a compreensão da fala e, consequentemente, impactando negativamente seu desempenho escolar e desenvolvimento cognitivo.

Palavras-chave: Educação; Ruído; Implante coclear; Auxiliares de audição; Perda auditiva; Medição de ruído.

Resumen

Introducción: Las personas con discapacidad auditiva enfrentan dificultades de comunicación, especialmente en entornos ruidosos, donde el ruido de fondo distorsiona el habla. En las escuelas, el ruido puede afectar la atención, el reconocimiento del habla y la memoria, impactando el aprendizaje. **Objetivo:** Identificar, mediante una revisión integradora, el impacto de los diferentes niveles de ruido en las aulas sobre los niños usuarios de implante coclear (IC) y/o dispositivo electrónico de amplificación sonora (DEAS). **Metodo:** Se realizó una revisión integradora de literatura científica nacional e internacional en revistas de salud y educación, consultando bases como BVS, PubMed, SCIELO, Scopus, BDTD, Capes y ERIC. Se eligieron estudios publicados entre 2018 y 2023, relacionados con el objetivo de esta investigación, sin restricción de idioma. **Resultados:** De 2376 estudios encontrados, tras la lectura inicial y la aplicación de los criterios de inclusión y exclusión, se seleccionaron 6 artículos. **Conclusión:** El ruido en las aulas interfiere en la audición de estudiantes que utilizan DEAS e IC, perjudicando su comprensión auditiva y, en consecuencia, su aprendizaje.

Palabras clave: Educación; Ruido; Implante coclear; Audífonos; Pérdida auditiva; Medición de ruido.

Introduction

It is known that in noisy environments speech comprehension is compromised because speech is distorted in the presence of background noise, thus demanding greater cognitive effort and limiting resources for processing and storing information[3].

In addition, the World Health Organization (WHO)[5] points out that exposure to noise may cause cardiovascular diseases, sleep disorders and cognitive impairment, and may also be associated with stomach problems and headaches[6].

These high levels of noise are present in the life of the human population since birth. One place responsible for high levels of noise pollution is the school environment, where these noises can interfere with the learning process of students, and in the health of educators and children. According to studies, noise can have an impact on cognitive processes, language development and emotional issues[4].

In school environments, speech often competes with noises that can interfere with its recognition. Considering the relationship between the acoustic conditions to which students are exposed and the efficiency of teaching[4], these noises are classified as distractors for learning[6], affecting attention, speech recognition and memory[1].

The Brazilian Technical Standard (NBR 10.152/ABNT)[10] recommends that the noise level in a classroom should ideally be 40 to 50 dB(A), in order to provide an adequate acoustic environment for speech understanding.

According to a study, the school environment is permeated by different sources of noise, which can range from nearby vehicle traffic to conversations between students, both inside and outside the classroom. In addition, the architectural characteristics of the space and the coating materials used in the floor, ceiling, and walls can contribute to the increase in reverberation time. The author also highlights that the signal-to-noise relationship is decisive to establish whether the speech signal remains audible amid background noise[7].

Children with hearing impairment may have difficulties in auditory understanding of speech in communication situations when these occur in environments with different competing noises, and this may cause the need for greater effort[1]. For these children, a more favorable signal-to-noise ratio is necessary to achieve speech perception performances similar to those of hearing children. As this relationship increases, speech intelligibility also improves[8]. The related literature indicates that the signal should be at least 10 dB above the noise level to ensure better results[9,6].

The hearing aid (HA) and the cochlear implant (CI), combined with the use of a remote microphone system (RMS) as assistive technology can contribute to the learning process[3,15] and to the improvement of auditory comprehension[3,14] by aiming to minimize adversities related to noise, reverberation and distance, favoring directed auditory attention and improving the signal-to-noise ratio of the environment.

However, with the variation in noise levels present in classrooms, it is observed that students with hearing impairment using hearing aids present greater fatigue and difficulty in concentrating[11]. This occurs because the higher the noise level, the louder the teacher needs to speak to be heard, which adversely affects the signal-to-noise ratio[12]. This condition leads to a decrease in the speed of processing information compared to peers of the same age with normal hearing[13], and thus the school performance of these students is affected.

In view of the above and considering the importance of an adequate environment for learning and access to speech, this study aimed to identify, through an integrative literature review, the impact of different noise levels in classrooms on children using CI and/or HAs enrolled in regular schools.

Objectives

To identify, through an integrative review, the impact of different noise levels in classrooms on children who use CI and/or HA.

Methods

The present study was analyzed by the Research Ethics Committee (REC) of the HRAC-USP Institution and was exempted for not involving human beings, registered under number 23/2024-SVAPEPE-CEP.

This is an integrative study of literature, which enables the synthesis of knowledge and has the potential to incorporate the results of the studies into practice[16].

For the elaboration of this review, a methodological process was followed structured in the following stages: identification of the theme; formulation of the research question and definition of descriptors; establishment of the inclusion and exclusion criteria for the studies; categorization and critical evaluation of the selected publications; and, finally, interpretation and presentation of the results of the integrative review. The development of the review was conducted in accordance with the recommendations of PRISMA-ScR. The guiding question was elaborated based on the PICO (Population, Intervention, Comparison and Outcome) strategy, as shown in Table 1.

Table 1. PICO Strategy

Element	Description	Possible formulation
P (Population)	Children using CI and/or HA	School-aged children with hearing impairment who use CI and/or HA.
I (Intervention / Exposure)	Exposure to noise in educational settings (classrooms, cafeterias, courtyards, etc.).	Evaluation of the noise level present in school environments.
C (Comparison)	Does not apply	Does not apply
O (Outcome)	Impact of the noise level on speech perception, attention, learning, or auditory comfort.	Determine whether the level of noise present in the school environment is adequate or harmful to the auditory and educational performance of students with hearing impairment.

The study sought to answer the following question: "What is the impact of environmental noise present in school contexts on the learning of students using HA and CI?"

The selection of studies was carried out through searches in the international and national scientific literature, as well as in journals specialized in health and education, available in the following databases: Virtual Health Library (VHL), PubMed, scientific Electronic Library Online (SCIELO), Scopus (Elsevier), Brazilian Digital Library of Thesis and Dissertations (BDTD), Capes and Education Resources Information Center (ERIC), from November 2023 to February 2024. Health Sciences Descriptors (DeCS) in Portuguese and their English counterparts in the Medical Subject Headings (MeSH) were used, namely: Education, Noise, Cochlear Implant, Hearing Aids, Hearing Loss and Noise Measurement. The descriptors and words were combined using the Boolean operators "AND" (English), "E" (Portuguese), "OR" (English) and "OU" (Portuguese), as summarized in Chart 1.

Chart 1. Research strategy to be used

Database	Descriptors	Research strategy	Results
BVS/VHI	DeCS	(Education) AND (Noise) AND (Cochlear implant) AND (Hearing Aids) AND (Hearing loss) AND (Noise Measurement).	1296
PubMed	MeSH	(Education) OR ("Education") AND (Noise) OR ("Noise") AND (Cochlear Implants) OR ("Cochlear Implants") OR (Cochlear Implant) OR ("Cochlear Implant")OR (Cochlear Implantation) OR ("Cochlear Implantation")) AND(Hearing Aids) OR ("Hearing Aids") OR (Hearing Aid) OR ("Hearing Aid") AND(Hearing Loss) OR ("Hearing Loss") OR (hearing losses) OR ("hearing losses").	810
SciELO	DeCS MeSH	(Education) AND (Noise) AND (Cochlear implant) AND (Hearing Aids) AND (Hearing loss) AND (Noise Measurement). (Education) OR ("Education") AND (Noise) OR ("Noise") AND (Cochlear Implants) OR ("Cochlear Implants") OR (Cochlear Implant) OR ("Cochlear Implant")OR (Cochlear Implantation) OR ("Cochlear Implantation")) AND(Hearing Aids) OR ("Hearing Aids") OR (Hearing Aid) OR ("Hearing Aid") AND(Hearing Loss) OR ("Hearing Loss") OR (hearing losses) OR ("hearing losses").	54
Scopus (Elsevier)	MeSH	(Education) OR ("Education") AND (Noise) OR ("Noise") AND (Cochlear Implants) OR ("Cochlear Implants") OR (Cochlear Implant) OR ("Cochlear Implant")OR (Cochlear Implantation) OR ("Cochlear Implantation")) AND(Hearing Aids) OR ("Hearing Aids") OR (Hearing Aid) OR ("Hearing Aid") AND(Hearing Loss) OR ("Hearing Loss") OR (hearing losses) OR ("hearing losses").	819
BDTD	DeCS	(Education) AND (Noise) AND (Cochlear implant) AND (Hearing Aids) AND (Hearing loss) AND (Noise Measurement).	116
Capes	DeCS	(Education) AND (Noise) AND (Cochlear implant) AND (Hearing Aids) AND (Hearing loss) AND (Noise Measurement).	74
ERIC	MeSH	(Education) OR ("Education") AND (Noise) OR ("Noise") AND (Cochlear Implants) OR ("Cochlear Implants") OR (Cochlear Implant) OR ("Cochlear Implant")OR (Cochlear Implantation) OR ("Cochlear Implantation")) AND(Hearing Aids) OR ("Hearing Aids") OR (Hearing Aid) OR ("Hearing Aid") AND(Hearing Loss) OR ("Hearing Loss") OR (hearing losses) OR ("hearing losses").	260

Selection Criteria

The eligibility criteria were studies indexed in the previously mentioned databases, whose theme adhered to the objectives of the present investigation. Only articles published in the last five years (period from 2018 to 2023) were included, with no restrictions on language. Duplicate publications, theses, dissertations, annals of scientific events, and monographs were excluded from the analysis, as they did not fit within the scope of the review of the primary scientific literature.

Data analysis

The selected articles were evaluated by two reviewers and followed the following steps: reading of the titles, reading of the abstracts and reading of the texts in full, and were included in this research upon the agreement of the two reviewers. After applying the inclusion and exclusion criteria, the characteristics of the articles were compiled in a table, containing the following information: Authors/Year; Country; Participants; Procedures; Results; Conclusion.

Results

During the search, 3429 studies were found. After an initial analysis, based on the previous reading of the titles and abstracts and applying the inclusion and exclusion criteria, 43 articles were selected for full reading. Of these, six articles were eligible for the study and the others were excluded, as shown in the flowchart of the article selection process that is represented in Figure 1.

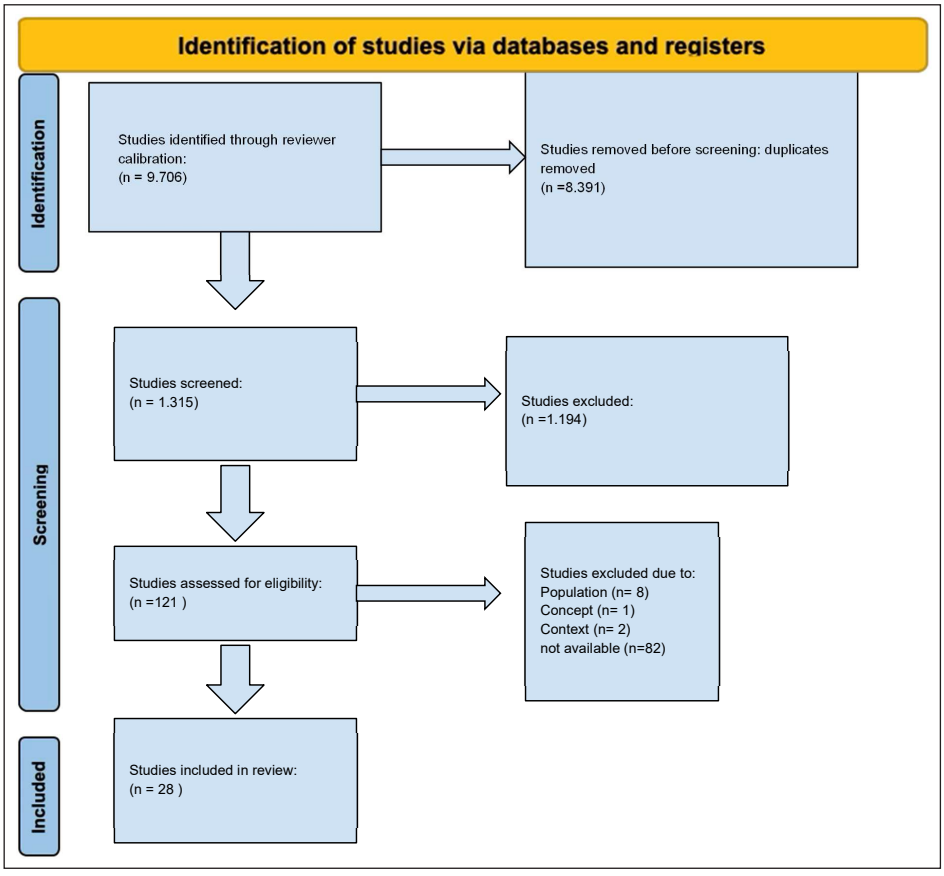
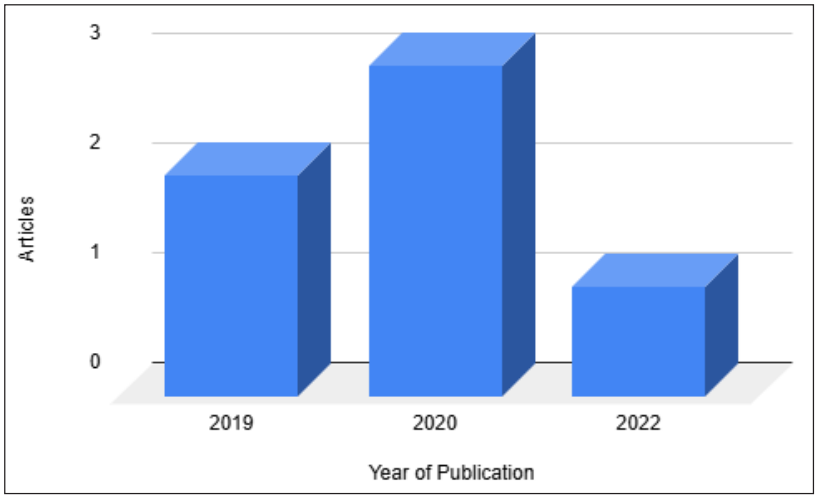


Figure 1. Flowchart of the article selection process

Eligible articles were published in the period from 2019 to 2022, with 2020 being the year in which the highest number of publications occurred, as highlighted in Graph 1.

Graph 1. Number of articles according to the year of publication.



Regarding the origin of publication, the six eligible studies were developed in different countries, such as: Australia, Belgium, United Kingdom, United States, South Africa and Sweden.

All studies are cross-sectional and have shown that children with hearing impairment in school environments face considerable difficulties in speech comprehension and auditory effort.

There are no studies among the eligible articles that seek to measure the level of noise to which students are exposed in school environments (Chart 2).

Chart 2. Results of the selected articles.

Authors/Year	Country	Participants	Procedures	Key results	Conclusion
Krijger, Stefanie; Coene, Martine; Govaerts, Paul J; Dhooge, Ingeborg /2020.	Belgium	19 children using CI (mean age of 13 years 9 months) and 18 teachers.	A cross-sectional study. A hearing inventory was applied with 15 auditory situations experienced by the students in classroom activities and social situations at school. The instrument also included a version for teachers and a screening protocol to identify educational risk.	Children with CI reported more hearing difficulties than their hearing peers. They presented more difficulties in situations of: (1) group work, (2) use of multimedia and (3) large classrooms.	Participants with CI had significant hearing difficulties. Factors such as reduced signal-to-noise ratios, distortions of the speech signal (by multimedia or reverb), greater distance from the sound source, absence of visual support, and the directivity effects of microphones were identified as relevant challenges for children with CI in the classroom environment.
Badajoz-Davila, Javier; Buchholz, Jörg M; Van-Hoesel, Richard/2020.	Australia	12 CI users (age 9 to 12 years).	A cross-sectional study, in which speech intelligibility was unilaterally evaluated in 12 CI users, under conditions of silence and noise, by means of a three-dimensional arrangement of loudspeakers installed in classrooms. The noise consisted of four dialogues between two speakers, reproduced from fixed positions distributed around the participant.	In noise, there is a drop in speech intelligibility, especially over long distances; In small classrooms, what most influenced learning was reverberation.	In environments that have the presence of noise, there is a drop in speech intelligibility, especially over long distances. In small rooms, there is greater reverberation. In addition, intelligibility does not decrease linearly, with increasing reverberation.
McGarrigle, Ronan; Gustafson, Samantha J; Hornsby, Benjamin WY; Bess, Fred H/2019.	United Kingdom	82 children between 6 and 13 years old (37 with normal hearing and 45 with hearing loss using HA).	A cross-sectional study. The children performed a dual-task paradigm. The main task was the recognition of babbling words from several speakers in three individually selected conditions: Easy, Moderate and Hard. The secondary task was a visual monitoring task.	Verbal tasks were slower and considered more challenging compared to children with normal hearing. There was no significant difference in the signal-to-noise ratio during the dual task.	Even in speech tasks, children with hearing loss had slower processing speed than their hearing peers, which can negatively impact learning and academic performance.

Authors/Year	Country	Participants	Procedures	Key results	Conclusion
Nelson, Lauri H.; Anderson, Karen; Whicker, John; Barrett, Tyson; Muñoz, Karen; Branco, Karl/2020.	United States	3,584 school-age participants, with hearing impairment and using HAs or CI.	A cross-sectional study. An electronic survey was applied to analyze, through descriptive statistics, the students' perceptions of hearing difficulties in different classroom situations.	The greatest difficulties reported were: hearing comments from other students and understanding speech in noisy environments. The difficulties were more frequent among students from the 3rd to the 6th grade and increased according to the degree of hearing loss.	Students who are deaf or hard of hearing may face challenges in hearing and comprehension throughout the school day.
Blumenthal, Lior; Sefotho, Máximo M./2022.	South Africa	Six ex-students that use CI	A cross-sectional study. Semi-structured interviews were used.	CI users reported increased cognitive effort, concentration difficulties, and fatigue.	It indicates the need for awareness and training in the education of students with CI to help them achieve their academic potential.
Brännström, K. Jonas; von Lochow, Heikea; Lyberg Åhlander, Viveka; Sahlén, Birgitta/2019.	Sweden	23 children using CI and/or HAs (mean age 9 years).	a cross-sectional study. The children were evaluated for the comprehension of speech passages in four auditory conditions: typical voice, dysphonic voice (hoarse), voice at low volume and babbling noise from multiple speakers.	Noise from multiple voices significantly reduced children's speech comprehension compared to silence.	Children who use HA or CI have difficulties in understanding in acoustically unfavorable environments, which can compromise school learning opportunities.

Discussion

The selected and analyzed articles demonstrate that the level of noise present in the school environment compromises the auditory comprehension of students who use HA and CI, which, consequently, negatively impacts learning, since the transmission of auditory information is essential for the acquisition of new knowledge. However, it is observed that these studies did not use a standardized evaluation method that could justify the different findings.

The results indicate that the speech signal in the classroom is degraded not only by background noise, but also by vocal quality and signal intensity, factors that can be influenced by voice and speech disorders, which are more prevalent among education professionals[17,1]. This condition contributes to the decrease in the speed of processing information[13].

In addition, it was observed that the auditory effort is high: Children with hearing loss have greater cognitive effort even when speech is perceived correctly, compared to their hearing peers, arguing that students who use HA and CI often resort to compensatory strategies, such as orofacial reading and visual cues, although these do not replace environmental adaptations, confirming that auditory barriers persist despite technologies, especially in contexts of multiple sound sources[13,19,11].

That said, when the student cannot properly hear the teacher's instructions, the entire educational process is compromised. In activities that involve listening comprehension, in which linguistic and cognitive skills are directly related, it is observed that the performance of tasks is impaired, giving evidence to the direct relationship between acoustic signal degradation and increased auditory effort. This is because, in order to carry them out, students who use devices require greater effort compared to children who do not use such resources[1,11].

According to the UK study, children aged between 6 and 13 years have a greater auditory effort in double tasks, however, tasks involving verbal aspects are more susceptible to the negative effects of signal-to-noise ratio and auditory impairment than tasks involving visual aspects[13].

Different conditions also influence the occurrence of noise in the classroom, such as the size of the classroom, as well as the covering material of the walls, floor and ceiling in the classrooms, noise from equipment (projectors, fans and computers) and from the hallways. Thus, even when the room is silent, there is noise that ends up influencing and hindering the educational process[18,17], demonstrating that noise and reverberation are determining factors.

There is also evidence that the impact of noise can be directly related to the severity of hearing loss, the type of disability and the fact whether it is bilateral or unilateral[19]. In addition, this impact varies according to the school year in which students are enrolled. For example, students from the 3rd to the 6th grade presented greater difficulty in concentrating, learning and greater fatigue when compared to those from the 7th to the 12th grade[11,20].

Some limitations identified in the development of this study refer to the small number of studies that address the theme of this integrative review and to the restriction of the age group considered to investigate the impact of different noise levels in the school context.

Conclusion

In view of the findings, it is concluded that the different levels of noise to which children using CI and/or ASD are exposed in regular schools can cause learning difficulties and auditory fatigue.

The results of this integrative review reinforce the importance of ensuring adequate access to sound conditions, at all academic levels, for students who use these devices. However, there is little research on the subject and the absence of studies that directly measure the intensity of noise to which these students with hearing impairment are exposed in the school environment, showing the need for further investigations in this area.

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