Speech perception in noise in children with learning difficulties: A scoping review

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Abstract

Background**:** Children with learning difficulties (LD) face multiple challenges in classrooms settings while having to meet various auditory demands, such as understanding verbal instructions in the presence of background noise. These challenges pose a risk for academic failure, underachievement, and underemployment. Well-developed skills regarding speech perception in noise promote learning, communication, and academic success. These skills need further investigation to promote evidence-based practice and intervention within the audiological and educational fields.

Objective: To identify and review published literature on the speech perception in noise abilities of children with LDs.

Design**:** A systematic search strategy was used to identify literature on five electronic databases using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR). Literature from 2011 to 2021 reporting on speech perception in noise in children with LDs was included.

Results: Of 1295 articles identified, five articles met the inclusion criteria and were included in this scoping review. All studies used comparative study designs to determine the speech perception in noise skills of children with LDs. Results indicated that children with LDs have poorer speech perception in noise skills when compared to typically developing children. Trisyllabic words were better perceived in noise than monosyllabic and disyllabic words.

Conclusion: Children with LDs require greater signal-to-noise ratios if they are to be given the same academic opportunities as typically developing (TD) children. Future studies can investigate the functional outcomes of children with LDs to promote evidence-based practice and intervention.

Keywords: Speech perception; Background noise; Learning disability; Learning difficulty; Signal-to-noise ratio (SNR); Scoping review

1. Introduction

The term learning difficulty (LD), often used interchangeably in literature with the terms “learning disability”, “specific learning difficulty”, “specific learning disorder”, and/or “learning disorder”. An LD refers to difficulties relating to a child's ability to acquire and use various skills [[1], [2], [3]]. These skills include listening, speaking, reading, writing, reasoning, and mathematical abilities [4]. An LD is a significant, lifelong condition that is most often diagnosed or identified in school-aged children and continues into adulthood [5]. A learning disability is a neurodevelopmental disorder presumably caused by a dysfunction within the central nervous system [3,4]. For this study, the term LD will be used to indicate the condition interchangeably referred to in the literature as "learning difficulty", "learning disability", "specific learning difficulty", "specific learning disorder", and/or "learning disorder".

The three identified types of learning disability are dyslexia, dysgraphia, and dyscalculia. Dyslexia refers to difficulties concerning reading, as well as reading accuracy and spelling. Dysgraphia refers to difficulties with putting thoughts on paper. Dyscalculia refers to difficulties with mathematical calculations, specifically with memorizing, reasoning, and problem-solving skills [3].

It is estimated that five to fifteen percent of school-aged children struggle with some form and severity of learning disability [3,6]. Dyslexia may be found in 80% of those children and may be regarded as the most common form of learning disability [3]. Children with learning difficulties are more likely to experience underachievement, underemployment, and social challenges [7].

Research has shown that children with learning disabilities have difficulties with speech recognition and perception, particularly in noise [8,9]. This negatively impacts children's school performance, as they need to have access to speech signals to comprehend and follow verbal instructions [10]. Background noise and prolonged reverberation time (RT) has been proven to have a detrimental effect, especially in younger children, on understanding verbal instructions [10,11]. The signal-to-noise ratio (SNR) is determined by the difference between the level of the speaker's voice and the level of background noise. RT refers to the time required for the sound in a room to decay over a specific dynamic range, usually taken to be 60 dB when the source is interrupted [11]. If sound takes too long to decay, it can cause an echo effect, ultimately degrading the speech signal [11]. This, in turn, has a significant impact on children's learning ability and, therefore, overall academic success [12]. In addition to auditory distractions, classrooms have visual distractions that further hinder children's ability to focus on verbal instructions or even on the task required to complete [13].

A study by Akbari and colleagues in Iran indicated that children with reading impairments presented with lower recognition of words-in-noise than their peers with typical reading skills [8]. Another study in Australia showed that children with dyslexia obtained significantly lower average scores than good readers on auditory processing tests in the presence of noise [14]. Therefore, children with LDs require lower background noise levels and, ultimately, larger SNR to perform to the best of their ability [8,14,15].

Children with LDs face multiple classroom challenges while having to meet various auditory demands [[10], [11], [12], [13]]. These challenges pose a risk for academic failure, underachievement, and underemployment [10,16]. Well-developed speech perception in noise promotes learning, communication, and academic success. Skills relating to speech perception in noise need to be further investigated to promote evidence-based practice and intervention within the audiological and educational fields. This, in turn, will encourage and support enhanced teaching for children with LDs, as well as learning within the classroom. This scoping review was conducted to determine how much relevant literature is available on speech perception in noise skills of children with LDs and to describe the literature findings. Research findings regarding speech perception in noise abilities of children with LDs were summarized to draw conclusions and identify gaps in knowledge to determine how future researchers can continue to contribute to this important field.

2. Methods

2.1. Reporting standard

A guideline, namely the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) checklist, was used to conduct this scoping review [17]. The PRISMA-ScR checklist provides a set of 20 essential reporting items and two optional reporting items [17]. This checklist aims to provide guidelines on improving reporting in scoping reviews and increase the relevance of decision-making [17].

2.2. Eligibility criteria

The search was limited to studies conducted over the last ten years (2011–2021). This allowed the researcher to include the most relevant and recent literature in this study. A PIO framework was adopted for this study, where P (patient) referred to school-going children with learning difficulties, I (intervention) was the assessment measure(s) for speech-in-noise skills, and O (outcome) was the speech-in-noise skill.

2.3. Information sources and search

Five electronic databases were used to identify relevant publications, namely Academic Search Complete, MEDLINE (Proquest), PubMed, Scopus, and Taylor and Francis (Journals). These databases were accessed through the University of Pretoria's library website. They were selected based on their relevance to the current scoping review topic. The researcher searched these databases in June 2021, with the last search being conducted in August 2021. Key search terms were identified from the research aim. Synonyms and abbreviations of the identified key search terms were used to ensure that all relevant publications were included. These five databases were consistently searched using the following combination of key search terms: (“speech perception” OR “speech” OR “speech recognition”) AND (“noise” OR “background noise” OR “signal-to-noise ratio” OR “SNR”) AND (“child*” OR “learner*” OR “adolescent*” OR “teen*”) AND (“learning difficulty” OR “learning disability” OR “learning disorder”).

2.4. Study selection

Throughout the study selection, Distiller Systematic Review (DistillerSR) was used. The primary researcher hand-searched five different databases, namely Academic Search Complete, MEDLINE (Proquest), PubMed, Scopus, and Taylor and Francis (Journals). The studies identified by the key search terms were screened for duplication before the studies were screened further for relevance. Firstly, a title and abstract screening were conducted where duplicate studies were removed. Studies were also excluded if they did not relate to the research topic. Secondly, the remaining related studies underwent full-text reviewing, which was in accordance with the eligibility criteria that the primary researcher set out. Studies were only included if the participants were diagnosed with any type of LD, between the ages of four and 18 years of age if they reported on speech perception in noise skills if they were published in English, if they were published between 2011 and 2021 and if they were peer-reviewed journal articles. The primary researcher hand-searched the four reference lists to ensure that all relevant studies would be included in this study. Through the reference search, an additional study was identified and included.

2.5. Data collection process

A data extraction form was used to extract relevant data from the included studies. This data sheet was used to tabulate, analyze, and categorize the information that the primary researcher extracted from the publications included in this study. The data extraction sheet was drawn up to include the following variables of each publication: title, author, year, study design, study population; study setting; assessment measures used; results found; key findings, and gaps and limitations. A second and third researcher was consulted throughout the reviewing process to discuss the findings at each stage and to resolve any discrepancies.

2.6. Assessment of risk of bias

The risk of bias assessment was not included in this study due to the scoping nature of the review.

3. Results

3.1. Study selection

A total of 1337 studies were found through the chosen databases, and one study was identified through another source. Fig. 1 shows the process and outcome of the search according to the PRISMA-P statement of the selection process in detail. After removing the duplicates and conducting a title and abstract screening, only 14 articles remained. These 14 articles were further assessed using the eligibility criteria. Nine studies were excluded after full-text reviewing. These included studies that did not involve participants diagnosed with LDs (n = 2); that reported on participants older than 18 years and/or participants under four years (n = 1); where participants' SPIN skills were not measured (n = 4); that was not available in English (n = 1); and/or in which participants had an additional diagnosis (n = 1). The key characteristics of each study included in this review are tabulated in Table 1.

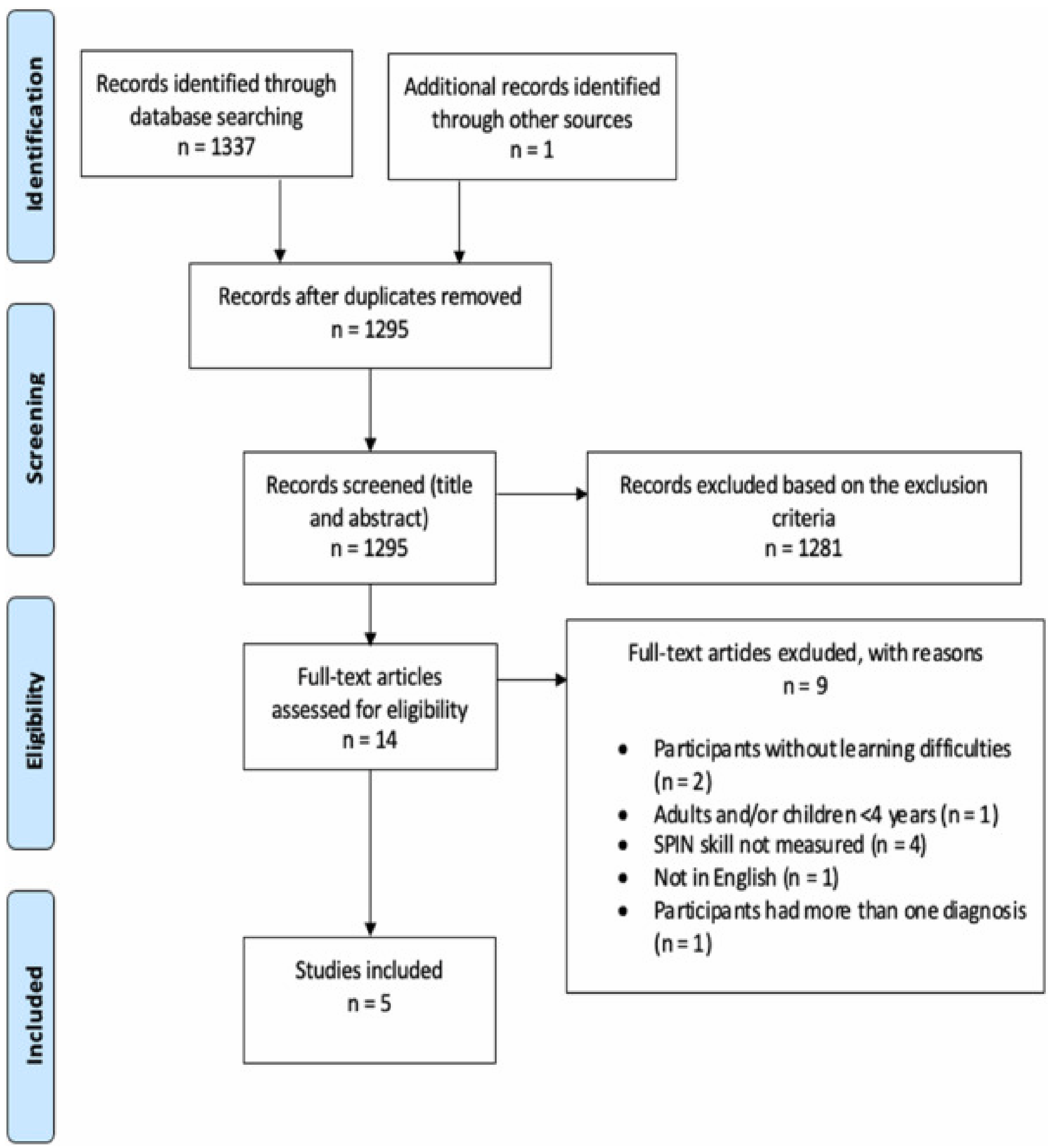

Fig. 1. Process and outcome of the search according to the PRISMA-P statement.

3.2. Study characteristics

The selected studies (n = 5) reported on 348 participants, ranging from five to 12 years of age. The sample sizes in the studies ranged from 40 to 113 children, with each study including a control group (including typically developing children) as well as a research group (including children with LDs). The total number of children with LDs that participated in the selected studies was 124. Table 1 describes the key characteristics of each study included in this scoping review.

Table 1. Key characteristics of the included studies.

Title	Authors	Study design	Study sampling (Patient)	Assessment measure (Intervention)	Outcome of the study (Outcome)
Central auditory processing functions in learning disabled children assessed by behavioural tests.	Ghannoum, Shalaby, Dabbous, Abd-El-Raouf & Abd-El-Hady (2014) [19]	Comparative study design	30 children with LDs and 30 typically developing (TD) children aged 6–12 years	Central auditory testing, including the speech intelligibility in noise test (SPIN) test.	Statistically significant lower scores were found in the 8–10 years subgroup in the SPIN test; however, there were no statistically significant differences in the 6–8 years subgroup and 10–12 years subgroup.
Speech Perception in Noise among Children with Learning Disabilities	Punnoose, Arya & Nandurkar (2017) [22]	Comparative study design	30 children with LDs and 45 TD children aged 9–12 years	WRS in quiet, at +15 dB SNR, at +8 dB SNR and 0 dB SNR.	Poorer WRS in children with LDs when compared to the control group. Both groups' WRS reduced with a decrease in SNR.
Comparative Study of the ability of selective attention and speech perception in noise between 6 to 9 year old normal and learning disabled children	Jarollahi, Aarabia & Jalaeib (2019) [21]	Comparative study design	24 children with LDs and 89 TD children aged 6–9 years	Persian version of the mSAAT test	Children with LDs' test scores differed significantly from those of TD children. Tests scores improved with age in both groups.
Speech Perception in Quiet and in Different Types of Noise in Children with Learning Disability	Apeksha, Aishwarya & Spandita (2019) [18]	Comparative study design	20 children with LDs and 20 TD children aged 5–10 years	Word identification scores in quiet and in the different types of noise at 0 dB SNR.	Children with LDs performed more poorly than TD children in quiet, as well as in the presence of speech babble and speech noise. Trisyllables yielded the best results.
Pattern Perception in Quiet and at Different Signal to Noise Ratio in Children with Learning Disability	Apeksha, Mahadevaswamy, Mahadev & Shivananda (2019) [20]	Comparative study design	20 children with LDs and 40 TD children aged 7–11 years	Speech perception (with word varying in syllable length) in quiet, at 0 dB SNR and +5 dB SNR.	Speech perception is affected in children with LDs compared to TD children. Speech perception was best in the quiet condition. Trisyllables showed the best results.

3.3. Key findings

Ghannoum et al. [19] reported that there were no statistically significant differences in SPIN test scores between the youngest and oldest age groups (6–8 years and 10–12 years) in the children with LDs and the TD children. In the 8–10-year age group, a statistically significant lower score was found in the SPIN test between the children with LDs and the TD children. Punnoose et al. [22] found that children with LDs show increased speech recognition in the presence of noise. A moderate amount of background noise can interfere with speech perception and impair educational outcomes in children, with a greater effect on younger children [22]. Jarollahi et al. [21] reported that children with LDs have difficulty with speech perception in the presence of competitive noise and have reduced selective auditory attention. Apeksha et al. [18] showed that children with LDs have poor phonological processing and that noise influences speech perception. It also indicates that children with LDs have poor pattern perception [18]. Lastly, Apeksha et al. [20] found poor pattern perception in children with LDs compared to TD children. The length of the stimuli and the SNR had a significant impact on the performance of children with LDs [20].

3.4. Synthesis of results

3.4.1. Study sampling

The five studies reported on two datasets, including a study group and a control group [[18], [19], [20], [21], [22]]. The selection criteria, age of participants, and how participants with LDs were diagnosed differed between articles. In all the studies, participants had to have bilateral normal hearing thresholds. However, each study had different interpretations of normal hearing threshold. Two studies, Apeksha et al. [18] and Ghannoum et al. [19] interpreted normal hearing thresholds as 15 dB HL or less at 250 Hz–8000 Hz. The other study by Apeksha et al. [20] mentioned that they deemed hearing thresholds at 15 dB HL normal as well, although they did not specify which frequencies were tested. Jarollahi et al. [21] and Punnoose et al. [22] interpreted normal hearing thresholds as 20 dB HL, but the latter study only required thresholds at 500 Hz to 4000Hz, whereas the former study required thresholds from 250 Hz to 8000Hz. The sample ages ranged from five to 12 years. Ghannoum et al. [19] reported on 60 children, 30 children with LDs and 30 typically developing (TD) children, divided into three equal sub-groups according to age: 6–8 years, >8–10 years and >10–12 years [19]. Punnoose et al. [22] reported on 75 children, 30 children with LDs and 45 TD children, divided equally into three age groups: 9–10 years, 10–11 years and 11–12 years. Jarollahi et al. [21] reported on 113 children, 24 children with LDs and 89 TD children, from 6 to 9 years. Apeksha et al. [18] reported on 40 children, 20 children with LDs and 20 TD children, ranging from 5 to 10 years of age. In a different study, Apeksha et al. [20] reported on 60 children, 20 children with LDs and 40 TD children, ranging from 7 to 11 years of age. All studies included an age-matched control group of TD children [[18], [19], [20], [21], [22]].

3.4.2. Selection criteria for children with LDs

All the articles included in this scoping review included children with LDs. However, they all differed in their selection criteria for children with LDs. The study by Jarollahi et al. [21] selected children with LDs based on their medical records and confirmation from a clinical psychologist. Punnoose et al. [22] identified their children with LDs from local municipal hospitals and excluded children with a previous history of otologic disease, neurologic disease, vascular disease, metabolic problems, Attention Deficit Hyperactivity Disorder, Pervasive

Developmental Disorders, Cognitive Sub-normality, Visual problems, syndromes, and Neuro-motor Disorders. Apeksha and colleagues [18,20] diagnosed children with LDs based on language tests, a linguistic profile test, and early reading skills test. Lastly, Ghannoum et al. [19] selected children with LDs from the Clinic of Learning Disabilities and Related Behavioural Disorders, Centre of Excellence of Medical Research, National Research Centre, and the Unit of Hearing, Balance and Speech disorders in Kasr Al-Ainy University Hospital in the Faculty of Medicine of Cairo University.

3.4.3. Speech perception in noise (SPIN) measures

Various measures were used across the studies to determine speech-in-noise perception abilities of children with LDs. While Ghannoum et al. [19] used a central auditory processing test battery for children, including the low pass filtered speech test (LPF), speech intelligibility in noise test, pitch pattern sequence test (PPS), dichotic digit test (DDT), memory tests and the auditory fusion test (AFT), only the SPIN test results were included in this study to determine the speech-in-noise perception abilities of children with LDs. One study by Jarollahi et al. [21] used the Persian version of the monaural selective auditory attention test (P-mSAAT) to determine the SPIN in children with LDs. Punnoose et al. [22] reported on the word recognition scores (WRS) in quiet, +15 dB, +8 dB and 0 dB Signal to Noise Ratios (SNR) of children with LDs. Apeksha et al. [18] assessed pattern perception in three different listening conditions (in quiet, in the presence of speech noise, and speech babbles), using stimuli comprised of monosyllabic, bisyllabic, and trisyllabic English words. Finally, Apeksha et al. [20] assessed pattern perception in three different listening conditions (in quiet, at 0 dB SNR, and -5dB SNR), using stimuli comprised of monosyllabic, bisyllabic, and trisyllabic English words.

3.4.4. Stimuli

Jarollahi et al. [21] used the P-mSAAT comprising of monosyllabic words in the presence of competing noise. Apeksha and colleagues [18,20] used stimuli comprising not only monosyllabic words but also bisyllabic and trisyllabic words. Phonetically balanced words were the stimuli used by Punnoose et al. [19] and Ghannoum et al. [22] used 20 meaningful Arabic sentences, ranging from four to eight words within the children's vocabulary.

3.4.5. Speech perception in noise (SPIN) skills

Children with LDs obtained significantly lower scores than TD children on all SPIN tasks. However, Ghannoum et al. [19] found no statistically significant difference between the SPIN abilities of children with LDs and TD children in the 6–8 year and 10–12 years age groups. Trisyllables words were better perceived in noise than monosyllabic and disyllabic words [18,20].

4. Discussion

Various definitions and interchangeable terms for LDs are found in the literature, possibly causing a lack of consensus between researchers on aspects to be included. This results in the limited volume of research available on SPIN in children with LDs. The interchangeable terms include “learning disability”, “specific learning difficulty”, “specific learning disorder”, and/or “learning disorder”. The U.S. Department of Education's Individuals with Disabilities Education Act (IDEA) defines “specific learning disability” that has not changed since 1975. It refers to the disability as a disorder in 1 or more of the basic psychological processes involved in understanding or in using language, spoken or written, which disorder may manifest itself in the imperfect ability to listen, think, speak, read, write, spell, or do mathematical calculations. It includes various conditions such as perceptual disabilities, brain injury, minimal brain dysfunction, dyslexia, and developmental aphasia. However, it *does not* include a learning problem primarily the result of the visual, hearing, or motor disabilities, of intellectual disabilities, of emotional disturbance, or environmental, cultural, or economic disadvantage. According to the Diagnostic and Statistical Manual of mental disorders (DSM; 5th edition), a specific learning disorder is a disability that encompasses deficits in reading, writing and mathematics [23]. The National Joint Committee on Learning Disabilities (NJCLD) (2016) proposed one of the more recent definitions of a learning disability. It refers to a learning disability as a heterogeneous group of disorders. The disability hinders children from learning and using various skills, namely, listening, speaking, reading, writing, reasoning and mathematical abilities. Children with learning disabilities may also present self-regulatory behaviour and social interaction difficulties [4].

Although there was consensus among the studies about the SPIN abilities in children with LDs compared to TD children, various SPIN measures were used to determine these skills. This indicates that there is currently minimal research on all SPIN skills of children with LDs and no specific protocol to test and/or determine these skills in children with LDs. The various SPIN measures used in the articles included WRS, speech intelligibility in noise test, and the P-mSAAT. The P-mSAAT assesses SPIN abilities as well as selective auditory attention abilities. This may be a beneficial tool as SPIN often correlates with auditory attention [24,25]. Speech perception has been proven to become more accurate with better auditory attention skills [25]. The study by Jarollahi et al. [21] found that SPIN difficulty is accompanied by reduced selective auditory attention in children with LDs. These skills are crucial for academic success, as children are expected to selectively attend to and focus on a target signal in competing background noise [[25], [26], [27]].

Various stimuli were used in the five studies included in this scoping review. Two studies reported using stimuli comprised of English monosyllabic, bisyllabic, and trisyllabic words [18,20]. Trisyllabic words were reported to be better perceived, not only by children with LDs but also by the TD children. Apeksha et al. [18] mention that trisyllabic words may be better perceived due to longer durational cues. This allows the listener to obtain more information from the word, whether it is perceived in quiet or in the presence of background noise. However, studies have shown that children with LDs present with not only auditory and visual impairments but cognitive and linguistic impairments as well [28].

Phonological awareness and phonological working memory impairments occur when linguistic information cannot be analyzed, synthesized, manipulated, stored, and recalled through the activation of cognitive mechanisms [28]. This, in turn, could cause difficulties in the perception and the production of speech [28]. Speech perception, particularly in noise and phonological awareness, are often based on linguistic factors and ultimately rely on a child's linguistic abilities [[29], [30], [31]]. If children with LDs have linguistic impairments, their SPIN test results could have been affected. Therefore, it is recommended that non-linguistic stimuli be used to assess SPIN abilities to eliminate the effect that linguistic impairments or lack of language experience may have on the results.

This scoping review was conducted to identify the available literature on SPIN in children with LDs. This review has not only identified the relevant literature on this topic but has also shown the scarcity of such literature. The review showed that children with LDs have poorer SPIN abilities when compared to TD children. This, in turn, can negatively impact selective auditory attention. Both of these skills are essential for academic success. Therefore, children with LDs require greater SNRs and lower RTs if they are given the same academic opportunities as TD children.

4.1. Strengths

To the knowledge of the author(s), this is the first scoping review that was conducted to determine how much relevant literature is available on the SPIN abilities of children with LDs. In this scoping review 1295 articles were screened, of which only five were included. These five articles contained research on the speech perception in noise in children with LDs [[18], [19], [20], [21], [22]]. This review highlights the scarcity of research in this field, with only a few articles explicitly exploring this skill in children with LDs. We believe that our comprehensive search strategy and the scoping nature of this review allowed all available relevant literature to be included. This highlights the strength of this scoping review, along with the fact that more than one researcher was involved in the reviewing process. The limited available studies show a consistent deficit in the SPIN abilities of children with LDs.

4.2. Limitations

Although we believe that this scoping review was comprehensive, it does have multiple limitations. Firstly, only literature published in English was included. This could have created language bias, and relevant articles not written in English could have been missed. Secondly, a critical appraisal of the research was not done as this is the first scoping review that we know of that was conducted to determine how much relevant literature is available on the SPIN abilities of children with LDs. Lastly, non-peer-reviewed and grey literature was not included in this scoping review. This could have led to publication bias, and many relevant publications could have been excluded.

5. Conclusion

This review has identified the relevant literature on this topic and has shown the scarcity of such literature. The review emphasized that children with LDs have poorer SPIN abilities than TD children. Further and more in-depth research is needed to fully understand the effect LDs have on SPIN skills. It is recommended that future researchers determine speech perception in noise skills with less linguistically loaded stimuli to understand the actual impact that LDs have on speech perception in noise, whether a child has poor linguistic abilities or not. Future studies can investigate the functional outcomes of children with LDs to promote evidence-based practice and intervention within the audiological and educational environments. This, in turn, will encourage and support enhanced teaching for children with LDs, as well as learning within classrooms.

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Declarations of competing interest

None.

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