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

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MA Audiology

In the Department of Speech-Language Pathology and Audiology
Faculty of Humanities
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Declaration of originality

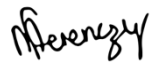
UNIVERSITY OF PRETORIA
FACULTY OF HUMANITIES
DEPARTMENT OF SPEECH-LANGUAGE PATHOLOGY AND AUDIOLOGY

DECLARATION

Full name: Marcelle Lesley Ferenczy
Student number: 16002602
Degree: MA Audiology

I declare that this research report is my own original work. Where secondary material is used, this has been carefully acknowledged and referenced in accordance with university requirements.

I understand what plagiarism is and am aware of the University of Pretoria's policy in this regard.



SIGNATURE

09 December 2021
DATE

Acknowledgements

My heart rejoices in my Heavenly Father, for this amazing opportunity that He has given me and His unconditional love and guidance. "'For I know the plans I have for you,' declares the Lord, 'plans to prosper you and not to harm you, plans to give you hope and a future.'" – Jeremiah 29:11

This dissertation would not have been possible were it not for the following individuals who have changed my life for the better and who will always have a special place in my heart:

- Prof. Lidia Pottas and Prof. Maggi Soer, thank you for all your kindness, knowledgeable guidance, and support over the last two years. I am extremely grateful for all your encouragement and assistance through the difficult times. Thank you for helping me to achieve my academic goals.

- My parents, Richard and Adéle, and my sister, Robyn, I have been so blessed to have you all as my incredible support system. Thank you for all your love, understanding, and reminders that I can get through anything I put my mind to. I will never be able to put into words how grateful I am for everything you have ever done for me.

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- My friends and colleagues, thank you for your willingness to listening to me vent and for motivating me through it all. I sincerely appreciate every single one of you who helped me through this journey.

List of figures

List of abbreviations

AFT	Auditory fusion test
APA	American Psychiatric Association
DDT	Dichotic digit test
DSM-V	Diagnostic and Statistical Manual of mental disorders
LD	Learning difficulty
LDA	Learning Difficulties Australia
LPF	Low pass filtered sequence test
NJCLD	National Joint Committee on Learning Disabilities
PA	Phonological awareness
P-mSAAT	Persian version of monaural selective auditory attention test
PPS	Pitch pattern sequence test
PRISMA-ScR	Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews
RT	Reverberation time
SA	South Africa
SLD	Specific learning disorder
SNR	Signal-to-noise ratio
SPIN	Speech perception in noise
TD	Typically developing
USA	United States of America
WRS	Word recognition score

Abstract

UNIVERSITY OF PRETORIA
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Supervisors	Prof. Lidia Pottas Prof. Maggi Soer
Date	December 2021
Title	Speech perception in noise in children with learning difficulties: A scoping review

Abstract

Background: Individuals with learning difficulties (LDs) face multiple challenges in classroom 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 promotes 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 (Appendix A). 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 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

Chapter 1: Introduction

Chapter aim:

This chapter offers a brief overview of the literature on speech perception in noise abilities of children with learning difficulties. The chapter provides the clarification of terminology and explains the importance of a scoping review of this research topic. Chapter 1 ends with the rationale and research aim for this study.

1.1. 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”, refers to difficulties relating to an individuals' ability to acquire and use various skills (Hostutler et al., 2018; Learning Difficulties Australia [LDA], 2012; Penesetti, 2018). These skills include listening, speaking, reading, writing, reasoning, and mathematical abilities (National Joint Committee on Learning Disabilites [NJCLD], 2016). It is a significant, lifelong condition which is typically diagnosed or identified during the early years of schooling and continues into adulthood (Altarac & Saroha, 2007). A learning disability is a neurodevelopmental disorder that is presumably caused by a dysfunction within the central nervous system (NJCLD, 2016; Penesetti, 2018). Individuals with learning disabilities experience difficulties in acquiring various skills (NJCLD, 2016; Penesetti, 2018). For this study, the term LD will be used to refer to the interchangeable terms in literature, namely “learning difficulty”, “learning disability”, “specific learning difficulty”, “specific learning disorder” and/or “learning disorder”.

The National Joint Committee on Learning Disabilities (NJCLD) (2016) describes learning disability as a heterogeneous group of disorders. The disability holds individuals back from learning and using various skills, namely, listening, speaking, reading, writing, reasoning, and mathematical skills (NJCLD, 2016). Individuals with learning disabilities may also present with self-regulatory behaviour and social interaction difficulties (NJCLD, 2016). A learning disability may co-occur with other conditions such as non-verbal learning disabilities, executive functioning deficits,

attention-deficit hyperactivity disorder, visual processing disorder, and/or auditory processing disorder (Cortiella & Horowitz, 2014). It has been found that the cognitive abilities of children with a learning disability might not match the cognitive abilities of their typically developing peers, despite adequate educational opportunities (Hostutler et al., 2018).

According to the Diagnostic and Statistical Manual of Mental Disorders (DSM; 5th edition), specific learning disorder is a disability that encompasses deficits in reading, writing, and mathematics (American Psychiatric Association [APA], 2013). These deficits prevent the acquisition of foundation skills to support reading, writing and mathematics skills upon entering school (Penesetti, 2018). The three identified types of learning disabilities are dyslexia, dysgraphia, and dyscalculia. Dyslexia refers to difficulties with regard to reading (Cortiella & Horowitz, 2014; Hall, 2008; Penesetti, 2018). Individuals with dyslexia often show difficulties with reading accuracy and spelling (Cortiella & Horowitz, 2014; Hall, 2008; Penesetti, 2018). Reading activities are, therefore, avoided and other mediums (e.g. pictures, videos and/or audios) are generally preferred and adopted (Cortiella & Horowitz, 2014; Penesetti, 2018). Dysgraphia refers to difficulties with putting thoughts on paper (Cortiella & Horowitz, 2014; Hall, 2008; Penesetti, 2018). Individuals with dysgraphia often struggle with spelling, grammar, punctuation, and handwriting (Cortiella & Horowitz, 2014; Penesetti, 2018). Dyscalculia refers to difficulties with mathematical calculations, specifically with memorizing, reasoning, and problem-solving skills (Cortiella & Horowitz, 2014; Hall, 2008; Penesetti, 2018).

In terms of the prevalence of LDs it is estimated that five to fifteen percent of school-aged children struggle with some form and severity of learning difficulties (Penesetti, 2018; Wiguna et al., 2012). Dyslexia may be found in 80% of those children, and may therefore be seen as the most common form of learning difficulty (Penesetti, 2018). A study by Nel and Grosser (2016) considered the prevalence of intellectual/learning difficulties in South Africa (SA), which were found to affect 68 550 children. It was also shown that males have a higher prevalence of intellectual/learning difficulties than females (Nel & Grosser, 2016). There are, to the author's knowledge, no prevalence studies for adults with LDs. However, it is reported that in the United States of America (USA), there is a prevalence of 5% of children in public schools and 1.7% of the total

USA population with learning disabilities (Cortiella & Horowitz, 2014). There is a higher incidence of learning disabilities among individuals who live in poverty in the USA. These individuals often have a high rate of involvement with the criminal justice system (Cortiella & Horowitz, 2014). Individuals with learning difficulties are more likely to experience underachievement, underemployment, and social challenges (Cortiella & Horowitz, 2014). They may present with many challenges regarding their academic performance including various cognitive factors, namely attention, memory, and fatigue, which may negatively affect their ability to perceive speech in the presence of noise (Dole et al., 2012; Lewis et al., 2010).

Phonological processing is considered to be related to the speech perception difficulties found in children with LDs, and is influenced negatively by noise (Breier et al., 2002; Shamir & Shlafer, 2011). Phonological awareness (PA) refers to the ability to recognize, discriminate, and manipulate phonemes (the perceptually distinct units of sound that distinguish one word from another) (Goldstein et al., 2017; Webb & Lederberg, 2014). The ability to store and access the constituent phoneme representations and phoneme combinations of words and the associated phonetic specifications of phonemes are important for perceiving speech (Chung et al., 2013; Preston & Edwards, 2010). Phoneme-grapheme knowledge development is dependent on speech perception and speech perception is in turn dependent on access to phonological representations (Boets et al., 2011; Chung et al., 2013; Preston & Edwards, 2010). It is clear that speech perception and PA share internal phonological structure, and are therefore closely related (Boets et al., 2011; Chung et al., 2013).

Individuals with LDs who have difficulties with speech perception and PA may experience additional challenges in the presence of background noise (Akbari et al., 2020; Dole et al., 2012). The level of challenge becomes evident when it is considered that children are required to participate in listening activities up to 75% of the school day (Nelson & Blaeser, 2010; Van Reenen & Karusseit, 2017), and that speech perception rarely occurs in favourable listening environments due to high levels of noise within typical classrooms (Dole et al., 2012; Lewis et al., 2010). This has a significant impact on the learning ability of children with LD and, therefore, on their overall academic success (Shield & Dockrell, 2003). Background noise has been

proven to have a detrimental effect on understanding verbal instructions, especially in younger children (Van Rooyen & Jordaan, 2009). Children with normal hearing may develop deficits in sustained attention, auditory discrimination, speech perception, memory, reading ability, and school performance as a result of chronic exposure to noise (Shield & Dockrell, 2003). These deficits, if not remediated, can continue into adulthood, and affect the individual's quality of life. Factors that influence classroom acoustics within educational settings include noise levels and reverberation (Dockrell & Shield, 2006). Reverberation time (RT) refers to the time required for the sound in a room to decay when the source is interrupted (Gheller et al., 2020). If the RT is prolonged it can affect speech perception by imposing an echo effect on the speech signal (Gheller et al., 2020). Noise level refers to the signal-to-noise ratio (SNR) between the level of the speaker's voice and the level of background noise (Gheller et al., 2020). 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 that they are required to complete (Stevens et al., 2009).

A study by Akbari et al. (2020) indicated that children with reading impairments presented with lowered recognition of words-in-noise than their peers with typical reading skills. This was confirmed by Gokula et al. (2019), who reported that children with dyslexia obtained significantly lower average scores than good readers on tests of auditory processing (Gokula et al., 2019). Children with learning disabilities, including dyslexia, were found to perform more poorly than children with typical development on the sentence perception in noise task (Gokula et al., 2019). Therefore, children with LDs require lower background noise levels and ultimately larger SNR (Akbari et al., 2020; Gokula et al., 2019; Koiek et al., 2018). Listening difficulties can be identified when individuals struggle to listen to speech in their daily environments, and they experience even more difficulty when the speech signal is degraded (Magimairaj & Nagaraj, 2019).

Listening difficulties, also referred to as "auditory processing disorder" (APD) in literature, may present in individuals with LDs (De Wit et al., 2017; Gilmore & Vance, 2007; Iliadou & Kiese-Himmel, 2018). A study by Del Zoppo et al. (2015) reported a continuation of listening and communication difficulties into early adulthood in the case of individuals referred as children for an auditory processing assessment. It was also

reported that these difficulties restricted various opportunities, including education, vocational, and social prospects. These restrictions resulted in significant underachievement (Del Zoppo et al., 2015).

1.2. Rationale

Children with LDs face multiple challenges in classroom settings while having to meet various auditory demands (Gheller et al., 2020; Shield & Dockrell, 2003; Stevens et al., 2009; Van Rooyen & Jordaan, 2009). These challenges pose a risk for academic failure, underachievement, and underemployment (Del Zoppo et al., 2015; Van Rooyen & Jordaan, 2009). Well-developed speech perception in noise promotes learning, communication, and academic success. These skills 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, to assess the quality of the research, and to identify conflicting evidence. Research findings with regard to speech perception in noise abilities of children with LDs will be summarized to draw conclusions and to identify gaps in knowledge, in order to determine how future researchers can continue to contribute to this important field. This scoping review aims to investigate literature over the last ten years (2011-2021) regarding the speech perception in noise abilities of children with learning difficulties.

Chapter 2: Method

Chapter aim:

This chapter outlines the method used in this study. It highlights the research aim of the study and includes the research design, ethical considerations, eligibility criteria, search strategy, and study selection, as well as the data extraction and analysis process.

2.1. Research aim

The main aim of this study was to identify and describe literature pertaining to the speech perception in noise abilities of children with LDs, with the use of a scoping review of the relevant literature over the past 10 years (2011-2021).

2.2. Research design

In order to achieve the aim of this study, a scoping review was conducted. The purpose of a scoping review is to identify and map the available evidence in a particular field, to clarify key concepts and/or definitions in the literature, and to identify gaps in a specific field (Munn et al., 2018). In this case, the scoping review was used to assess the emerging evidence of the size and scope of available research literature on speech perception abilities of children with LDs (Manchaiah et al., 2020). This scoping review provided a broad overview of the research topic and aided in the process of determining whether a systematic review is necessary (Manchaiah et al., 2020). A reporting tool, namely the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) checklist, was used to conduct the scoping review (Appendix A). The PRISMA-ScR checklist provides a set of 20 essential reporting items and two optional reporting items (Tricco et al., 2018). This checklist endeavours to provide guidelines on improving reporting in scoping reviews, as well as to increase the relevance of decision making (Tricco et al., 2018).

2.3. Ethical considerations

Ethical clearance for this study (reference number: HUM026/0621) was obtained from the Research and Ethics Committee of the Faculty of Humanities at the University of Pretoria, (Appendix B).

This study is a scoping review, and therefore required published studies and no involvement of human participants. Thus, ethical considerations regarding human research participants were not required.

The following ethical principles were observed:

2.3.1. Honesty and plagiarism

The findings of this study were not altered in any way and were reported in an honest manner. The written work that was produced for this study, namely a journal article and a dissertation, was the primary researcher's original work. All secondary sources used in this study were referenced according to the APA 7th edition manuscript format and referencing guidelines. A detailed reference list was included at the end of the article manuscript and this dissertation. This study did not claim any ownership of any work that was not the primary researcher's own. The primary researcher adhered to the University of Pretoria's Policy on Plagiarism (University of Pretoria, 2019). A declaration of originality was signed by the primary researcher and can be found at the beginning of this paper.

2.4. Reliability and validity

Reliability and validity are important aspects of a research study to ensure that the study will yield meaningful conclusions (Leedy et al., 2021). Reliability refers to the consistency of measurements, as well as the conditions in which these measurements take place (Leedy et al., 2021). Validity in qualitative research refers to the 'appropriateness' of the tool/s, processes, and data involved (Leung, 2015).

Reliable and valid results were ensured throughout the study by consistently using the same reporting tool, namely the PRISMA-ScR checklist, for all the articles that were included in this study. All publications in this study had to meet the inclusion criteria. Different keywords and/or phrases and search strategies were used to search multiple databases, namely Academic Search Complete, MEDLINE (Proquest), PubMed, Scopus, and Taylor and Francis (Journals), to ensure that all relevant publications were identified and included in this study. Reliability and validity were ensured through requesting the supervisors' opinion in cases where inclusion of an article was queried.

2.5. Data collection procedures

2.5.1. Inclusion criteria

In the current scoping review, the search was limited to studies that were conducted over the past 10 years (2011-2021). This was done in order 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.

2.5.1.1. Study design

Only peer reviewed publications were included in this scoping review. The studies that were included also had to be available in English. This was to ensure that all articles were interpreted appropriately by the primary researcher, since a translator was not available. Manual translation by the primary researcher may have led to misinterpretation of some of the information.

2.5.1.2. Participants

Studies for this scoping review were selected if participants were diagnosed with a learning difficulty. Participants were required to be between the ages of four and 18 years, as this is the typical age range of children who are exposed to formal schooling. Speech perception in noise is particularly important during school years and is often a reflection of academic success (Van Rooyen & Jordaan, 2009).

2.5.2. Exclusion criteria

Studies were excluded if:

- There was no indication of specific keywords and/or phrases that were used in the study
- The study was not available in English
- The study was not published between 2011 and 2021
- The study reported on children younger than four years of age or adults (persons over 18 years of age); and
- The study was not peer reviewed.

2.5.3. 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 and were selected based on their relevance to the current scoping review's topic. These databases were searched by the primary researcher 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 are included. The 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"). Figure 1 indicates the number of studies obtained from each database.

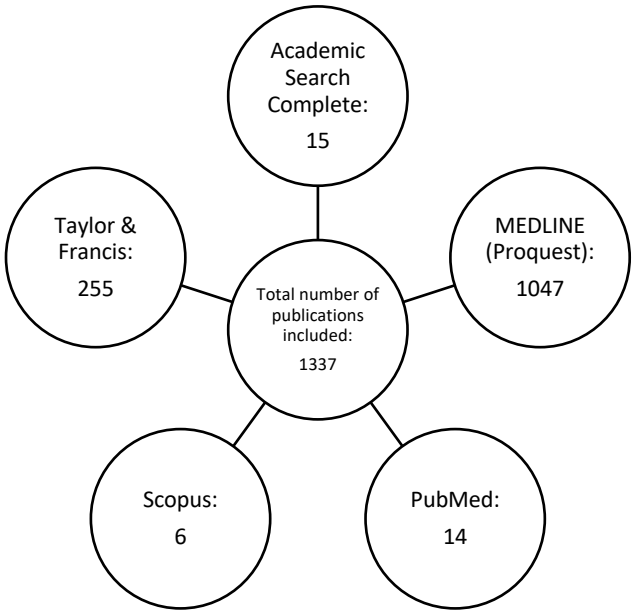

Figure 1: Number of publications obtained from each database.

2.5.4. Study selection

Items nine and ten of the PRISMA-ScR checklist were involved in the final study selection. Throughout the study selection Distiller Systematic Review (DistillerSR) was used (Evidence Partners, 2020). The primary researcher 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 from duplicates before being screened further for relevance. Firstly, a title and abstract screening was 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 was set out by the primary researcher. The reference lists of the included studies were searched by the primary researcher to ensure that all relevant studies would be included in this study. Through the reference search another study was found and included. Nine studies were excluded after full-text reviewing. These included studies (n=2) that did not involve participants diagnosed with LDs; a study (n=1) that reported on adult participants and/or participants under four years; studies (n=4) where participants' speech perception in noise (SPIN) skills were not measured; a study (n=1) that was not available in English; and a study (n=1) in which participants had an additional diagnosis.

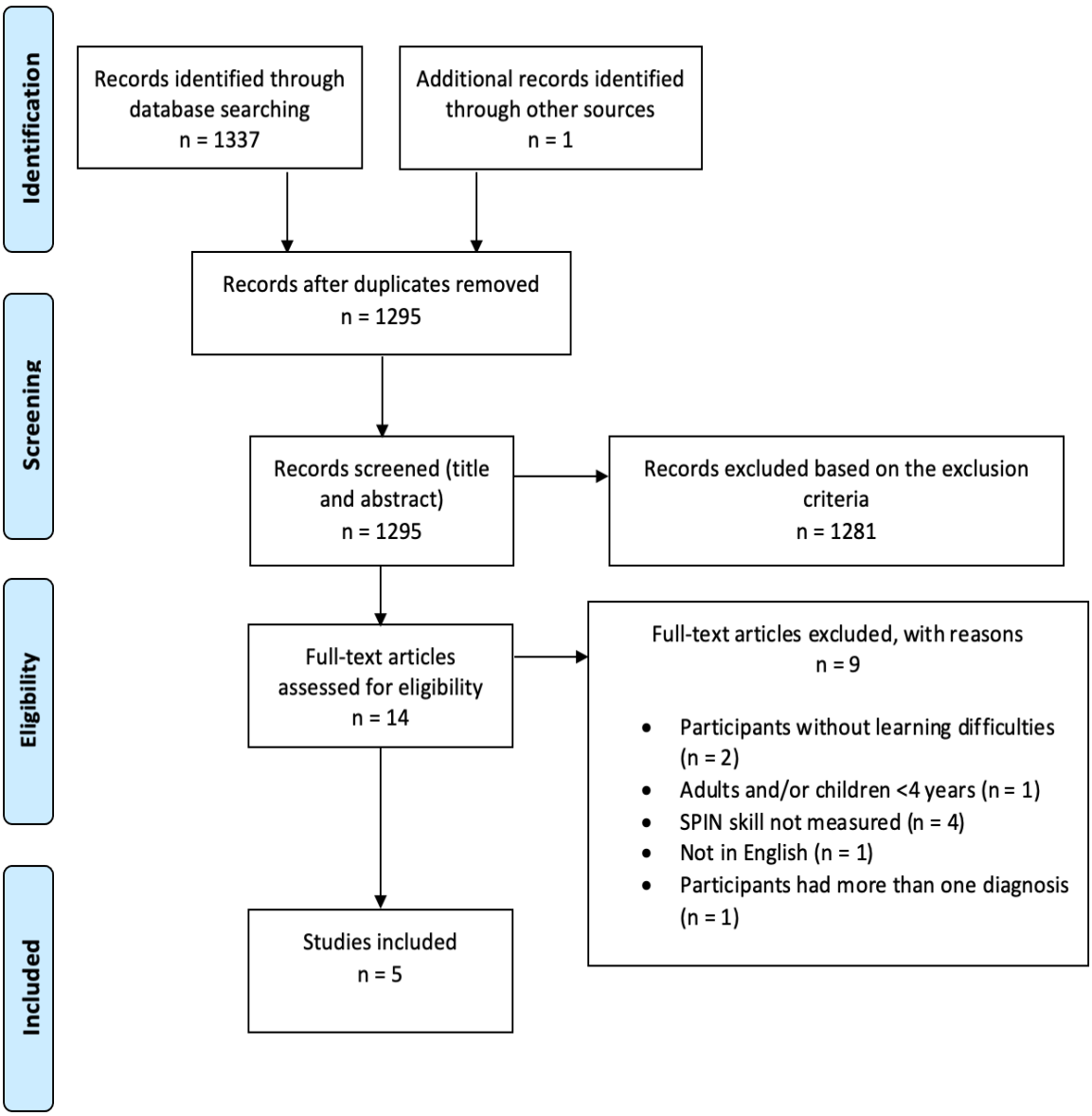

Figure 2: Process and outcome of the search according to the PRISMA-P ScR statement

Figure two summarizes the process and outcome of the search according to the PRISMA-P ScR statement. Of 1295 studies, 1281 studies were excluded based on the eligibility criteria and a further nine studies were excluded after the full text was screened according to the eligibility criteria. This left a total of five studies to be included in this scoping review.

2.5.5. Data extraction and analysis process

An online software program, DistillerSR, was used to review the relevant studies for this study (Evidence Partners, 2020). This program allows researchers to conduct title

and abstract screenings, full-text reviewing, and duplicate elimination (Evidence Partners, 2020). This tool allows the extraction of study characteristics, as well as the exportation of data and references (Evidence Partners, 2020).

Data collection was in line with the primary aim of scoping the speech perception in noise skills of children with learning difficulties. The relevant data was extracted from the included studies to MS Excel and summarized in Table 1.

The MS Excel data sheet was drawn up by the primary researcher in accordance with item 11 on the PRISMA-ScR checklist, to include the following variables:

- The author of each publication
- The year of each publication
- The study design of each publication
- The study population of each publication
- The assessment measures used in each publication
- The results found in each publication
- The key findings in each publication

This data sheet was used to tabulate, analyze, and categorize the information that was extracted by the primary researcher from the publications included in this study. The data was summarized and tabulated and can be found under the heading *"3. Results"* in Chapter 3. Throughout the reviewing process a second and third researcher were consulted to discuss the findings at each stage and to assist with any uncertainties.

2.5.6. Summary

The scoping review study design was used in this research study to extract, analyze, and present the data. It was important to maintain reliability and validity throughout the research study, through the consistent use of the same reporting tool, namely the PRISMA-ScR checklist. This was to ensure that the data used in this study was extracted and analyzed consistently. Ethical considerations, eligibility criteria, search strategy, study selection, as well as the data extraction and analysis process were discussed.

Chapter 3: Research article

Chapter aim:

This chapter contains the article based on this research study. This article was submitted to the *International Journal of Paediatric Otorhinolaryngology* on the 5 December 2021 (Appendix C). This chapter's format differs to that of the rest of the dissertation in fulfillment with the requirements of the journal specified guidelines for the formatting of this article.

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 [1–3]. 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 [10–13]. 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 2011-2021 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. Figure 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.

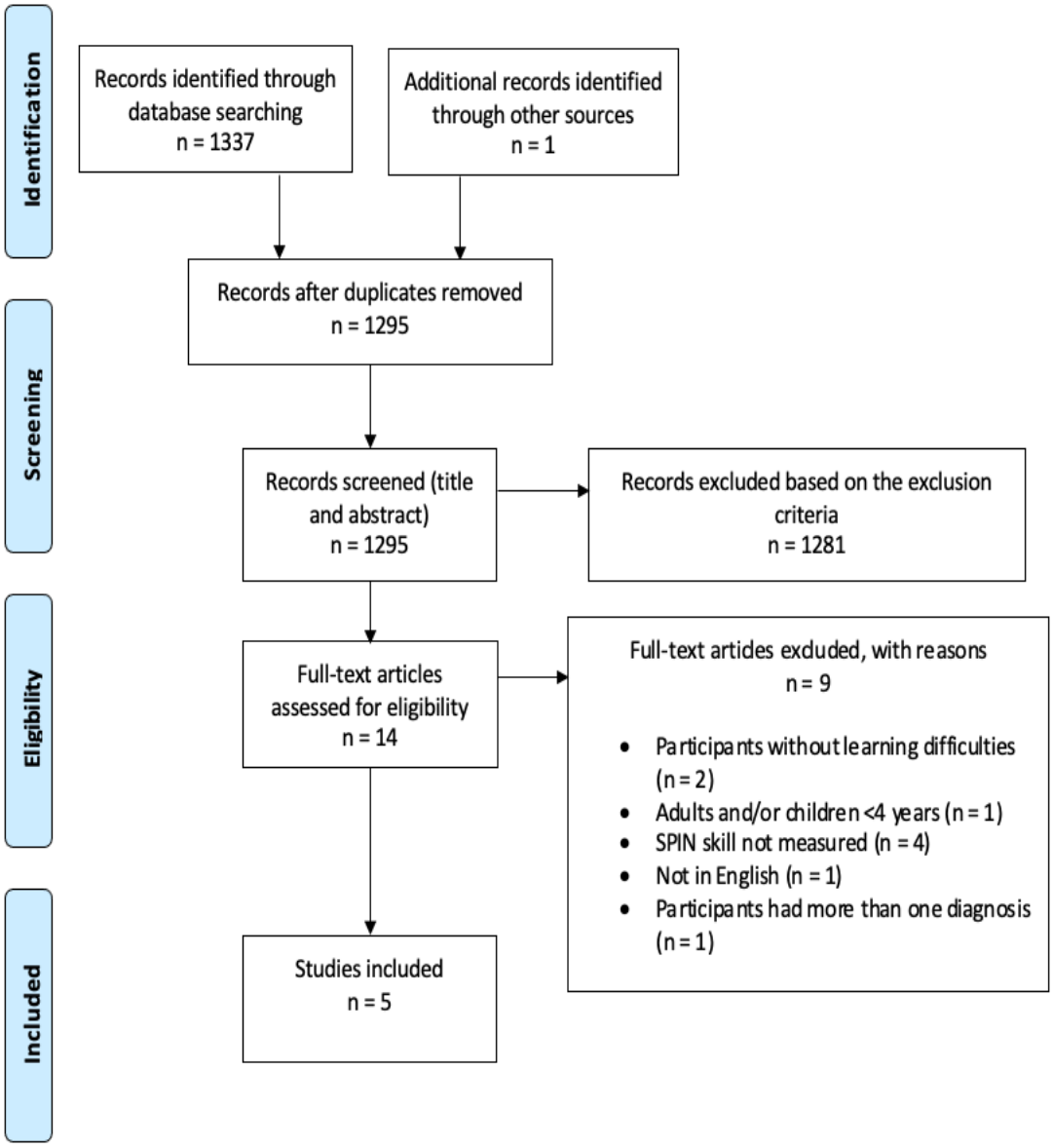

Figure 1: Process and outcome of the search according to the PRISMA-P statement

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 to 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 to 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 to 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 to 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 to 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.

3.2.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.

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 [18–22]. 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 to 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 [18–22].

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 0dB 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 [25–27].

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 [29–31]. 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 [18–22]. 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.

Declarations of interest

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Chapter 4: Discussion and conclusion

Chapter aim:

This aim of this chapter is to discuss the main findings and to consider the strengths and limitations of this scoping review. Lastly this chapter will provide recommendations for future research and will end with a conclusion and summary of the findings of the review.

4.1. Discussion

To the best of the authors' knowledge, this is the first scoping review 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 reviewed. These five articles contained research on the speech perception in noise in children with LDs. The review highlights the scarcity of research in this field, with only a few articles explicitly exploring this skill in children with LDs. The authors are of the opinion that the comprehensive search strategy that was used and the scoping nature of this review allowed for all available, relevant literature to be included. This, along with the fact that more than one researcher was involved in the reviewing process, ensures the strength of this scoping review. The limited number of studies available consistently report a deficit in the SPIN abilities of children with LDs.

There are various definitions of LD and interchangeable terms are used in the literature, possibly causing a lack of consensus between researchers. This may be the reason for the limited amount 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 Individuals with Disabilities Education Act (IDEA) provides a definition for "specific learning disability" that has not changed since the first version was published in 1975. It refers to the disability as *a disorder in one 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 visual, hearing, or motor disabilities,*

of intellectual disabilities, of emotional disturbance, or of environmental, cultural, or economic disadvantage (United States, 2011). 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 (American Psychiatric Association [APA], 2013). The National Joint Committee on Learning Disabilities (NJCLD) (2016) provides 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 individuals from learning and using various skills, namely, listening, speaking, reading, writing, reasoning, and mathematical abilities. Individuals with learning disabilities may also present with self-regulatory behaviour and social interaction difficulties (NJCLD, 2016).

Although there was consensus among the studies with regard to SPIN abilities of children with LDs compared to TD children, various SPIN measures were used to determine these skills. This variability in the measures used indicates that there is currently minimal research on SPIN skills of children with LDs and no specific protocol to test and/or determine the level of 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 (Jones et al., 2015; Strait & Kraus, 2011). Speech perception has been proven to become more accurate with better auditory attention skills (Strait & Kraus, 2011). Jarollahi et al. (2019) found that SPIN difficulty is accompanied by reduced selective auditory attention in children with LDs. These skills are imperative for academic success, as children are expected to selectively attend to and focus on a target signal in competing background noise (Isbell et al., 2016; Law et al., 2014; Strait & Kraus, 2011).

Two studies reported using stimuli comprised of English monosyllabic, bisyllabic, and trisyllabic words (Apeksha et al., 2019a; Apeksha et al., 2019b). Trisyllabic words were better perceived, not only by children with LDs but also by the TD children. Apeksha et al. (2019b) mention that trisyllabic words may be better perceived due to their longer durational cues. This allows more information to be obtained 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 (Romero et al., 2015).

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 (Germano et al., 2009 and Quintas et al., 2010, as cited in Romero et al., 2015). This could, in turn, cause difficulties in the perception and the production of speech (Germano et al., 2009 and Quintas et al., 2010, as cited in Romero et al., 2015). Speech perception, particularly in noise, and phonological awareness focus on linguistic stimuli and therefore ultimately rely on a child's linguistic abilities (Eccles et al., 2021; Krizman et al., 2017; Wilsenach, 2016). If children with LDs have linguistic impairments, this could have affected their SPIN test results. It is therefore recommended that non-linguistic stimuli be used to assess SPIN abilities in order to eliminate the impact that linguistic impairments may have on the results.

4.2. Clinical implications

This scoping review highlighted the SPIN difficulties that children with LDs experience. The results indicated that children with LDs have poorer SPIN abilities than TD children. These results suggested that children with LDs should be assessed with a multidisciplinary team approach. A multidisciplinary team approach will promote evidence-based practice and intervention within the audiological and educational fields. This scoping review also emphasized the role that an Audiologist has in the management of this unique population, with regard to their SPIN abilities and ensuring that these children have an optimal listening and learning environment. Audiologists play a vital role in educating the teachers of children with LDs about how they can ensure that the classroom acoustics provide an optimal listening and learning environment. A referral to a Speech Language Therapist should also be considered for children with LDs, as these children may also present with phonological difficulties. These phonological difficulties may be the cause or result of poor SPIN abilities. Phonological processing and SPIN skills promote learning, communication, and academic success.

4.3. Strengths of the study

The current scoping review displays various strengths. The reliability and validity of this study was kept consistent, with the use of the PRISMA-ScR reporting tool. Throughout the reviewing process, a second and third researcher was consulted to discuss the findings at each stage and to resolve any discrepancies. This was done to strengthen the reliability of this study and to prevent bias. The eligibility criteria were strictly adhered to, to ensure that all children discussed in the various publications experienced LDs. This eliminated any other diagnoses and ensured that only the SPIN abilities of children with LDs were assessed. Lastly, only literature published between 2011 and 2021 was included in this study, to ensure that the most relevant and recent studies would be identified.

4.4. Limitations of the study

Although the authors were of the opinion that this scoping review was comprehensive, it does have some limitations. Firstly, only literature published in English was included. This could have created language bias and relevant articles that were 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, to the knowledge of the researchers, 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.

4.5. Recommendations for future research

In order to fully understand the effect that LDs have on SPIN skills, further and more in-depth research is required. It is recommended that future researchers determine speech perception in noise skills with less linguistically loaded stimuli, in order to understand the actual effect that LDs have on speech perception in noise regardless of the level of linguistic ability. Future studies can investigate the functional outcomes of children with LDs to promote evidence-based practice and intervention for these children 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.

4.6. Conclusion

This scoping review was conducted to identify and scrutinise the literature on SPIN in children with LDs. This review has identified the relevant literature on this topic and has also shown the scarcity of such literature. The review showed that children with LDs have poorer SPIN abilities than TD children. This in turn can negatively impact selective auditory attention. Both of these skills are vital for academic success. Consequently, children with LDs require greater SNRs and lower RTs if they are to be given the same educational opportunities as TD children.

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Appendices

Appendix A

Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	1
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	7
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	8-12
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	12
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	13
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	15
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	16
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	16
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	16-18
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	18-19
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	20-21
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	N/A
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	32-34

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	27-28
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	30-32
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	N/A
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	28-34
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	32-34
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	40-42
Limitations	20	Discuss the limitations of the scoping review process.	43
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	44
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	37

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.
* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.
† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).
‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.
§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

From: Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMAScR): Checklist and Explanation. Ann Intern Med. 2018;169:467–473. doi: 10.7326/M18-0850.

Appendix B

Faculty of Humanities
Fakulteit Geesteswetenskappe
Lefapha la Bomotho

4 August 2021

Dear Miss ML Ferenczy

Project Title:	Speech perception in noise in children with learning difficulties: a scoping review
Researcher:	Miss ML Ferenczy
Supervisor(s):	Prof ME Soer Prof L Pottas
Department:	Speech Language Path and Aud
Reference number:	16002602 (HUM026/0621)
Degree:	Masters

Thank you for the application that was submitted for ethical consideration.

The Research Ethics Committee notes that this is a literature-based study and no human subjects are involved.

The application has been **approved** on 29 July 2021 with the assumption that the document(s) are in the public domain. Data collection may therefore commence, along these guidelines.

Please note that this approval is based on the assumption that the research will be carried out along the lines laid out in the proposal. However, should the actual research depart significantly from the proposed research, a new research proposal and application for ethical clearance will have to be submitted for approval.

We wish you success with the project.

Sincerely,

Prof Innocent Pikirayi
Deputy Dean: Postgraduate Studies and Research Ethics
Faculty of Humanities
UNIVERSITY OF PRETORIA
e-mail: PGHumanities@up.ac.za

Appendix C

Gmail **Marcelle Ferenczy <marcelleferenczy321@gmail.com>**

Submission Confirmation

International Journal of Pediatric Otorhinolaryngology <em@editorialmanager.com> Sun, Dec 5, 2021 at 9:39 AM
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To: Marcelle Lesley Ferenczy <marcelleferenczy321@gmail.com>

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Gmail **Marcelle Ferenczy <marcelleferenczy321@gmail.com>**

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Ms. Ref. No.: IJPORL-D-21-01350
Title: Speech perception in noise in children with learning difficulties: A scoping review
International Journal of Pediatric Otorhinolaryngology

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