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Systematic Review

Revisão Sistemática

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Speech-language pathology findings in Attention Deficit Hyperactivity Disorder: a systematic literature review

Alterações Fonoaudiológicas no Transtorno de Déficit de Atenção e Hiperatividade: revisão sistemática de literatura

Keywords

Speech, Language and Hearing Sciences
Attention Deficit Disorder with Hyperactivity
Language
Auditory Perception
Child

ABSTRACT

Purpose: To systematically review the scientific production on the relationship between Attention Deficit Hyperactivity Disorder (ADHD) and Speech-language Pathology and to methodologically analyze the observational studies on the theme. **Research strategies:** Systematic review of the literature conducted at the databases Medical Literature Analysis and Retrieval System online (MEDLINE, USA), Literature of Latin America and the Caribbean Health Sciences (LILACS, Brazil) and Spanish Bibliographic Index of Health Sciences (IBECS, Spain) using the descriptors: "Language", "Language Development", "Attention Deficit Hyperactivity Disorder", "ADHD" and "Auditory Perception". **Selection criteria:** Articles published between 2008 and 2013. Inclusion criteria: full articles published in national and international journals from 2008 to 2013. Exclusion criteria: articles not focused on the speech-language pathology alterations present in the attention deficit hyperactivity disorder. **Data analysis:** The articles were read in full and the data were extracted for characterization of methodology and content. **Results:** The 23 articles found were separated according to two themes: Speech-language Pathology and Attention Deficit Hyperactivity Disorder. **Conclusion:** The study of the scientific production revealed that the alterations most commonly discussed were reading disorders and that there are few reports on the relationship between auditory processing and these disorders, as well as on the role of the speech-language pathologist in the evaluation and treatment of children with Attention Deficit Hyperactivity Disorder.

Descritores

Fonoaudiologia
Transtorno do Déficit de Atenção com Hiperatividade
Linguagem
Percepção Auditiva
Criança

RESUMO

Objetivo: revisar sistematicamente as produções científicas acerca das relações entre o Transtorno de Déficit de Atenção e Hiperatividade e a Fonoaudiologia e analisar, metodologicamente, os estudos observacionais sobre a temática. **Estratégia de pesquisa:** trata-se de revisão sistemática de literatura, realizada nas bases de dados *Medical Literature Analysis and Retrieval System on-line* (MEDLINE, EUA), *Literatura Latino-Americana e do Caribe em Ciências da Saúde* (LILACS, Brasil) e *Indice Bibliográfico Español de Ciencias de la Salud* (IBECS), na qual foram utilizados os descritores "Linguagem", "Desenvolvimento da Linguagem", "Transtorno do Déficit de Atenção com Hiperatividade", "TDAH" e "Percepção Auditiva". **Critérios de seleção:** foram selecionados artigos publicados entre 2008 e 2013. Os critérios de inclusão foram: artigos completos, publicados em periódicos nacionais e internacionais, no período de 2008 a 2013. Como critério de exclusão, foram considerados os artigos que não apresentavam, como foco principal, as alterações fonoaudiológicas presentes no Transtorno de Déficit de Atenção e Hiperatividade. **Análise dos dados:** foi realizada a leitura dos artigos na íntegra e a extração de dados para caracterização da metodologia e do conteúdo das pesquisas. **Resultados:** foram encontrados 23 artigos, os quais foram separados de acordo com dois eixos temáticos, relacionados à Fonoaudiologia e ao Transtorno de Déficit de Atenção e Hiperatividade. **Conclusão:** o estudo das produções científicas revelou que as alterações fonoaudiológicas mais abordadas foram os distúrbios de leitura e que há poucas publicações acerca da relação entre o processamento auditivo e o transtorno, bem como a respeito da atuação do fonoaudiólogo na avaliação e no tratamento de crianças com Transtorno de Déficit de Atenção e Hiperatividade.

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INTRODUCTION

Attention Deficit Hyperactivity Disorder (ADHD) is one of the most common mental conditions in children. It is often identified at school age, when the demand for attention and inhibition of behavior is greater. The main characteristics of ADHD are inattention, hyperactivity, and impulsivity, whose manifestations may be related to predominantly inattentive, predominantly hyperactive, or combined subtypes[1].

Among the difficulties observed in children with ADHD are those related to the phonological aspects of language and the learning of metalinguistic skills. Deficits in the relation between working memory and performance in activities affect the development of phonological awareness and may lead to difficulties in learning to read[2].

It is also worth mentioning the relation between ADHD and auditory processing disorder, which has been discussed in some studies[3,4]. One of the studies that reported the impression of Brazilian professionals on this relationship[4] shows that some behavioral signs are characteristic of ADHD, whereas others are characteristic of auditory processing disorders. This fact suggests that ADHD and auditory processing disorder possibly occur independently.

Note that the aforementioned characteristics can determine impairments in the learning process and cognitive-linguistic skills. Therefore, it is necessary to investigate the relationship between Speech-Language Pathology disorders and ADHD, as well as to analyze the instruments used to assess these changes.

PURPOSE

The aim of this study is to systematically review the scientific productions addressing the relationship between Attention Deficit Hyperactivity Disorder (ADHD) and Speech-language Pathology, as well as to methodologically analyze the observational studies on the theme.

SEARCH STRATEGY

This is a systematic review of the literature, based on national and international recommendations[5,6], with the following guiding question: "What are the possible Speech-Language Pathology disorders observed in children with Attention Deficit Hyperactivity Disorder (ADHD)?"

After defining the guiding question, the review was prepared in two phases: the first phase comprised the identification of the theme, search for the topic in the literature, categorization and evaluation of the included studies, interpretation of the results, and synthesis of the knowledge evidenced in the articles analyzed, as proposed in the literature[7]; in the second phase, the articles that fit the evidence matrix were included in the study.

The literature search on the theme of interest was conducted at the electronic databases Medical Literature Analysis and Retrieval System on-line (MEDLINE, USA), Literature of Latin America and the Caribbean Health Sciences (LILACS, Brazil), and Spanish Bibliographic Index of Health Sciences (IBECS, Spain) from July 2013 to January 2014. Original and review articles in English, Portuguese, and Spanish published between 2008 and 2013 were surveyed. At completion of the searches in all databases, references in duplicate were deleted.

The following English, Spanish and Portuguese keywords, found in the trilingual and structured vocabulary Health Sciences Descriptors (DeCS), were used in the search: "Language", "Language Development", "Attention Deficit Hyperactivity Disorder", "ADHD", and "Auditory Perception".

SELECTION CRITERIA

Original research articles, published in Portuguese, Spanish or English, indexed between January 2008 and December 2013 were included in this study.

According to the proposed criteria, the following types of publications were excluded from the study: articles that did not respond to the guiding question, articles addressing Attention Deficit Hyperactivity Disorder in adults, review articles, abstracts in congress proceedings, theses, and dissertations. Based on the classification of levels of scientific evidence, case study articles and expert opinions were excluded. Twenty-seven articles that fit the second evidence matrix were selected for this systematic review; of these, 22 analytical observational studies and one descriptive exploratory study were included and two case reports and two literature reviews were excluded.

DATA ANALYSIS

The articles selected in the first phase were critically analyzed and distributed according to two main themes, namely: 1) studies that used only the Speech-language Pathology assessment of ADHD; and 2) studies that used both Speech-language Pathology and Neuropsychology assessments of ADHD. After that, the observational studies were analyzed according to the propositions of the STROBE (**ST**rengthening the **R**eporting of **OB**servational studies in **E**pidemiology) Statement[7], which was developed by researchers from the fields of epidemiology, statistics, and scientific methodology and by editors of scientific journals in order to disseminate the guiding principles for the description of observational studies. The STROBE Statement is composed of 22 items related to information that should be present in the sections Title, Abstract, Introduction, Methodology, Results, and Discussion of articles. After analysis based on this information, the studies were classified as follows: compliant (C), partly compliant (PC), and non-compliant (NC). The studies classified as C and PC were grouped according to a final classification described in Chart 1.

RESULTS

The initial search found 4121 references. According to established inclusion criteria - complete articles addressing the study theme within the area of interest of Speech-Language Pathology published in the last five years in national and international journals - 3727 papers were selected for analysis. After the reading of titles and abstracts, 144 articles were selected

Chart 1. Analysis of the observational studies according to compliance with the STROBE Statement

Authors	Title / Abstract	Introduction	Method	Result	Discussion
Abdo AGR, Murphy CFB, Schochat E[8].	C	PC	PC	PC	PC
Wiemes GRM, Kozlowski L, Mocellin M, Hamerschmid, R, Schuch LH[9].	C	C	PC	PC	PC
Lobo PAS, Lima LAM[10].	C	C	C	C	C
Silva C, Cunha VLO, Capellini AS[11].	C	C	C	PC	PC
Gallo LA, Muñoz MCL, Contreras DCM, Albores DA[12].	C	PC	C	PC	C
Gallardo-Paúls B, Moreno-Campos P, Roca P, Pérez-Mantero JL[13].	C	PC	PC	C	C
Raghubar K, Cirino P, Barnes M, Ewing-Cobbs L, Fletcher J, Fuchs L[14].	PC	C	C	PC	C
Cutting LE, Materek A, Cole CAS, Levine TM, Mahone EM[15].	C	C	PC	PC	C
Kibby MY, Kroese JM, Krebbs H, Hil CE, Hynd GW[16].	C	PC	C	C	C
Silveira DC, Passos LMA, Santos PC, Chiappetta ALML[17].	PC	C	PC	C	PC
Li JJ, Cutting LE, Ryan M, Zilioli M, Denckla MB, Mahone EM[18]	C	PC	C	C	C
Kibby MY, Pavawalla SP, Fancher JB, Naillon AJ, Hynd GW[19].	PC	C	PC	PC	PC
Willcutt EG, Betjemann RS, McGrath LM, Chhabildas NA, Olson RK, DeFries JC et al.[20].	C	C	PC	PC	C
Hart SA, Petrill SA, Willcutt E, Thompson LA, Schatschneider C, Deater-Deckard K et al.[21].	C	C	C	PC	PC
Booth R, Happé F[22].	C	PC	PC	PC	C
Okuda PMM, Pinheiro FH, Germano GD, Padula NAMR, Lourencetti MD, dos Santos LCA et al.[23].	C	C	C	C	PC
Londoño DMM, Cifuentes VV, Lubert CD[24].	PC	C	PC	PC	PC
Jacobson LA, Ryan M, Martin RB, Ewen J, Mostofsky SH, Denckla MB et al.[25].	C	C	C	C	C
Gooch D, Snowling M, Hulme C[26].	PC	C	C	C	C
Simos PG, Rezaie R, Fletcher JM, Juranek J, Passaro AD, Li Z et al.[27].	C	PC	PC	PC	PC
Greven CU, Rijsdijk FV, Asherson P, Plomin R[28].	C	PC	PC	PC	C
Rosenberg J, Pennington BF, Willcut EG, Olson RK[29].	C	PC	PC	PC	C
Birkett EE, Talcott JB[30].	C	PC	PC	C	C

Caption: C = compliant; PC = partly compliant

and read in full. Twenty-seven articles were found at the end of the present review: 21 cross-sectional, analytical, observational studies; one longitudinal, analytical, observational study; one descriptive, exploratory study; two case reports; two literature reviews. No experimental, analytical studies were found.

As previously mentioned, case reports and literature reviews were excluded from this review. Thus the final corpus consists of 23 articles, of which six are national publications and 17 are international publications (Figure 1). The articles were grouped according to theme axes and distributed in tables for presentation of results.

Tables 1 and 2 show the main characteristics of the articles that have focused respectively on 1) studies that used only the Speech-language Pathology assessment of ADHD and 2) studies

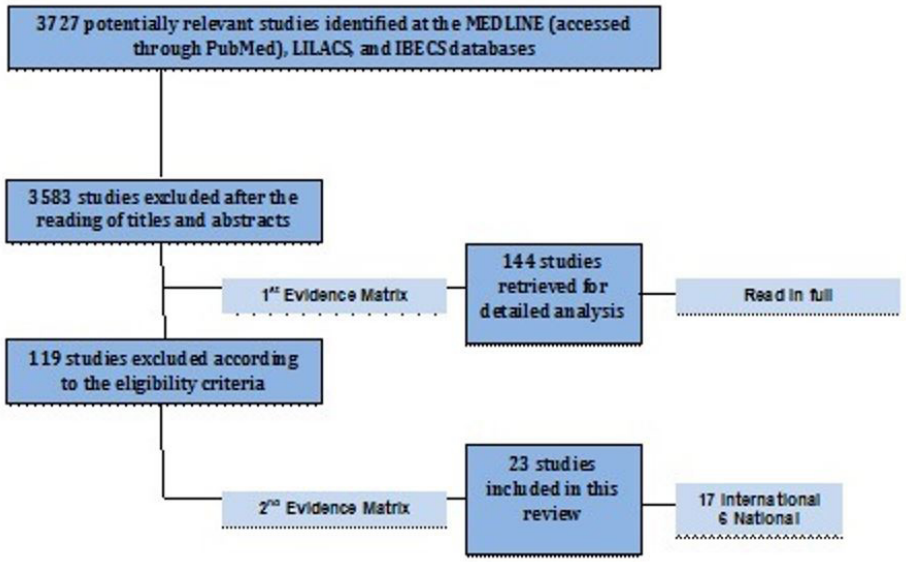

Figure 1. Diagram of the selection process of the studies

Table 1. Description of the studies that used only the Speech-language pathology assessment of Attention Deficit Hyperactivity Disorder

Author	Year	Country	Study design	Participants (general characteristics)	Age (year)	Assessment
Abdo AGR, Murphy CFB, Schochat E[8].	2010	Brazil	Case Control	10 children with Dyslexia, 10 children with ADHD and 10 children in the control group.	7 to 12	Auditory Processing Assessment: Speech in Noise, Dichotic Digits, and Frequency Pattern tests.
Wiemes GRM, Kozlowski L, Mocellin M, Hamerschmidt R, Schuch LH[9].	2012	Brazil	Cohort	21 individuals with a diagnostic hypothesis of Specific Learning Disability (Reading and Writing Disorders) and symptoms of ADHD.	7 to 14	Auditory Processing Assessment: Dichotic Speech (Staggered Spondaic Words - SSW) and Speech in Noise tests; Electrophysiological Assessment: Cognitive Evoked Potential (P300).
Lobo PAS, Lima LAM[10].	2008	Brazil	Exploratory-descriptive	295 students.	7 to 14	Silent Reading Comprehension Test - Adapted (TeCoLeSi/Ad).
Silva C, Cunha VLO, Capellini AS[11].	2011	Brazil	Case Control	10 schoolchildren with ADHD and 10 schoolchildren without ADHD.	9 to 13	Metalinguistics and Reading Skills Testing (PROHMELE).
Gallo LA, Muñoz MCL, Contreras DCM, Albores DA[12].	2011	Mexico	Case Control	302 children with Typical Speech-language Development; 11 children with Autism Spectrum. Disorder (ASD); 11 children with Asperger syndrome (AS); 23 children with ADHD; and 10 children with other psychiatric disorders.	2 to 5	Vocabulary assessment: (Sondeo del desarrollo de linguaje - SDL).
Gallardo-Paúls B, Moreno-Campos P, Roca P, Pérez-Mantero JL[13].	2012	Spain	Case Control	41 argumentative texts and 46 narrative texts by children with and without ADHD aged 8 to 13 years.	8 to 13	Writing of narrative and argumentative texts.

Table 2. Description of the studies that used both Speech-language pathology and Neuropsychology assessments of Attention Deficit Hyperactivity Disorder

Author	Year	Country	Study design	Participants (general characteristics)	Age (year)	Instruments
Raghubar K, Cirino P, Barnes M, Ewing-Cobbs L, Fletcher J, Fuchs L[14].	2009	USA	Cross-sectional	291 third and fourth grade schoolchildren.	9 to 10	Multi-digit task - behavior assessment subscale: Strengths and Weaknesses of ADHD – Symptoms and Normal Behavioral Rating Scale (SWAN).
Cutting LE, Materek A, Cole CAS, Levine TM, Mahone EM[15].	2009	USA	Cross-sectional	56 children with suspected ADHD.	9 to 14	Word recognition: Woodcock Reading Mastery Test, Revised, Normative Update (WRMT-R/NU); Word comprehension: Gray Oral Reading Test, 4th edition (GORT-4); Isolated word fluency: Test of Word Reading Efficiency - Sight Words and Phonemic Decoding (TOWRE); Receptive Vocabulary: Peabody Picture Vocabulary Test (PPVT-III); Test of Language Development - Intermediate - Grammatical Comprehension and Sentence Combining subtests (TOLD-I:3); Test of Language Competence - Expanded (TLC–E); Wechsler Intelligence Scale for Children - Third Edition (WISC-III); Executive function measures: Tower of London (TOL).
Kibby MY, Kroese JM, Krebbs H, Hill CE, Hynd GW[16].	2009	USA	Case Control	10 children with Dyslexia, 15 children with ADHD, 15 children with Dyslexia and ADHD, and 10 children in the control group.	8 to 12	Neuropsychological and language assessment: Clinical Evaluation of Language Fundamentals - Revised (CELF-R); Comprehensive Test of Phonological Processing (CTOPP); Rapid Automatized Naming test (RAN); Wechsler Intelligence Scale for Children - Third Edition (WISC-III). Image Examination: Magnetic resonance imaging (MRI).
Silveira DC, Passos LMA, Santos PC, Chiappetta ALML[17].	2009	Brazil	Case Control	22 students with ADHD and 34 students without ADHD.	7 to 12	Phonologic and semantic verbal fluency: Raven's Progressive Matrices (RPM).
Li,JJ, Cutting LE, Ryan M, Zilioli M, Denckla Mahone M[18].	2009	USA	Case Control	23 children with ADHD and 14 children in the control group.	8 to 14	Rapid Automatized Naming test (RAN); Gray Oral Reading Test, 4th edition (GORT-IV); Wechsler Intelligence Scale for Children - Fourth Edition (WISC–IV).
Kibby MY, Pavawalla SP, Fanche JB, Naillon AJ, Hynd GW[19].	2010	USA	Case Control	10 children with Dyslexia, 13 children with Dyslexia and ADHD, 13 children with ADHD, and 10 children without Dyslexia or ADHD (control group).	8 to 12	Clinical Evaluation of Language Fundamentals - Revised (CELF–R); Vocabulary and Short-term Memory: Wechsler Intelligence Scale for Children - Third Edition (WISC-III); Phonological Awareness: Comprehensive Test of Phonological Processing (CTOPP); Rapid Automatized Naming test (RAN); Academic Achievement: Wide Range Achievement Test (WRAT-3) and Woodcock Reading Mastery Test, Revised (WRMT–R); Image Examination: Magnetic resonance imaging (MRI).
Willcutt EG, Betjemann RS, McGrath LM, Chhabildas NA, Olson RK, DeFries JC et al.[20].	2010	USA	Case Control	457 twin pairs with ADHD and reading disability; only with ADHD; only with reading disability; control group.	8 to 18	Word Reading Test (WRT); Neuropsychological Test Battery (WISC-R-1974).
Hart SA, Petrill SA, Willcutt E, Thompson LA, Schatschneider C, Deater-Deckard K et al.[21].	2010	USA	Cross-sectional	271 twin pairs.	10	Word Reading (WRMT); Mathematics Achievement (subtests of the Woodcock-Johnson III achievement test);

Table 2. Continued...

Author	Year	Country	Study design	Participants (general characteristics)	Age (year)	Instruments
Booth R, Happé F[22].	2010	USA	Case Control	176 individuals (aged 8-10, 11-13, 14-16, and 17-25 years) were divided into 3 groups (children with Autism Spectrum Disorder (ASD), children with ADHD, and the control group).	8 to 25	Sentence Completion Task; Wechsler Intelligence Scale for Children (WISC-III).
Okuda PMM, Pinheiro FH, Germano GD, Padula NAMR, Lourencetti MD, Santos LCA et al.[23].	2011	Brazil	Case Control.	11 schoolchildren with ADHD and 11 schoolchildren in the control group, all males.	8 to 11	Evaluation of Fine Motor, Sensory and Perceptual Function; Dysgraphia Scale.
Londoño DMM, Cifuentes VV, Lubert CD[24].	2011	Colombia	Case Control	30 children com ADHD; 30 children in the control group.	6 to 14	Intelligence Test (WISC-III); Neuropsychological Protocol (CNE Battery)
Jacobson LA, Ryan M, Martin RB, Ewen J, Mostofsky SH, Denckla MB et al[25].	2011	USA	Case Control	41 children with ADHD and 21 children in the control group.	9 to 14	Intellectual ability: General Ability Index (GAI) of the Wechsler Intelligence Scale for Children-IV-Integrated (WISC-IV-I); Fluency in reading (GORT-IV Fluency); Silent reading fluency (WJ-III Reading Fluency); Word Reading (TOWRE); Verbal Working Memory (WISC-IV-I Digit Span Backward and WISC-IV-I Letter-Number Sequencing); Spatial working memory: The Cambridge Neuropsychological Test Automated Battery (CANTAB) - SWM test and WISC-IV-I Spatial Span Backward); Auditory attention (CELF-4 Recalling Sentences and WISC-IV-I Digit Span Forward); Inhibition and Reaction Time (Simple Reaction Time and Go/No-go Tests); Rapid Automatized Naming test (RAN);
Gooch D, Snowling M, Hulme C[26].	2011	England	Case Control	17 children with Dyslexia; 17 children with suspected ADHD; 25 children Dyslexia and suspected ADHD; 42 children in the control group.	5 to 14	Phonological skills: Children's Nonword Repetition task (CNRep) and Working Memory Test Battery for Children (WMTB-C); Phonemic awareness; phonological decoding: Test of Word Reading Efficiency (TOWRE); Stop Signal Reaction Time (SSRT).
Simos PG, Rezaie R, Fletcher JM, Juranek J, Passaro AD, Li Z et al.[27].	2011	USA	Case Control	50 children with reading difficulties; 20 children with ADHD and a negative history of reading difficulties; 50 children in the control group.	7 to 13	Naming tasks (letter-sound and pseudowords); Neuroimaging examinations.
Greven CU, Rijsdijk FV, Asherson P, Plomin R[28].	2012	UK	Longitudinal	7000 twin pairs were analyzed between 7 and 8 and 11 and 12 years of age.		ADHD symptoms and reading difficulties: Questionnaires to the parents. .
Rosenberg J, Pennington BF, Willcutt EG, Olson RK[29].	2012	USA	Case Control	Twins. At least one of them should meet the criteria for ADHD and reading difficulties.	8 to 18	Reading skills: Peabody Individual Achievement Test (PIAT) - Word Recognition (PWR) and Timed Word Recognition (TWR) subtests; Assessment of symptoms of ADHD Rating Scale - IV (ADHDRS-IV); Reading difficulties in adults: Reading History Questionnaire (RHQ).
Birkett EE, Talcott JB[30].	2012	England	Cross-sectional	21 children.	8 to 10	Verbal and nonverbal reasoning: Wechsler Adult Intelligence Scale (WASI); Reading and spelling: Wechsler Individual Achievement Test (WIAT); Test of Everyday Attention for Children (TEA-Ch); Measures of motor reaction time to auditory and visual stimuli.

that used both Speech-language Pathology and Neuropsychology assessments of ADHD.

Analysis of the selected studies according to the proposed theme axes

Six articles were found within the first thematic axis - studies that used only the Speech-language Pathology assessment of ADHD[8-13]. One of these surveys[8] used the tests of Frequency Pattern and Dichotic Digits. Another study[9] used the Dichotic Speech test (Staggered Spondaic Words - SSW) and conducted the electrophysiological assessment by means of the Cognitive Evoked Potential (P300). The objective of the first study was to investigate the performance of children with dyslexia and Attention Deficit Hyperactivity Disorder through auditory processing behavioral tests. In the latter study, the aim was to identify if above the average of P300 latency values, in a group of individuals with Reading and Writing Disability, changes suggestive of Auditory Processing Disorder would also be found in the Staggered Spondaic Word (SSW) and Speech in Noise tests.

Although the study that used electrophysiological assessment, by means of the P300, did not include children with Attention Deficit Hyperactivity Disorder, the results found in the group with Reading and Writing Disability were similar to those presented by children with ADHD in a previous study[3]. These results refer to the finding of higher latencies and lower amplitudes of the P300, which may be related to a slow maturation of the central auditory pathways.

It is worth mentioning that in the studies that evaluated the performance of children with ADHD or with Reading and Writing Disability by auditory processing assessment tests[8,9], both groups presented unsatisfactory performance in the applied tests. In the case of the first study, which evaluated a group of children with ADHD, the low performance in the auditory processing tests may be related to attention and auditory processing abilities. The second study highlights that learning, reading and writing, and ADHD disorders, among others, should be considered as differential diagnoses, so that they are not confused with auditory processing disorders, although they may coexist. In this sense, there is a need for further studies that investigate the relationship between ADHD and auditory processing disorder.

With respect to reading, one of the studies[10], whose objective was to determine whether children with and without ADHD presented differences in silent reading at the level of decoding of isolated words, reported that attention interfered both in the perception of the read item and in the adequacy of reading. The performance of the group of children with ADHD suggests total errors in the reading of pseudowords and a trend to more pronounced lexicalizations in activities that involve orthographic processing. These errors may be related to better performance in phonological processing tasks compared with visual processing tasks and to exclusively phonological reading, without lexical addressing.

In a study conducted in Brazil[11], the authors compared the cognitive-linguistic and reading performance of schoolchildren with ADHD with that of schoolchildren without complaints of behavioral and/or learning disorders; they observed that the difficulties presented by the students with ADHD can be attributed to the characteristics of hyperactivity, inattention, and disorganization, but not to a phonologically-based language disorder.

The relationship between expressive vocabulary and psychiatric disorders was investigated in an international study[12] that compared the lexicon of children with ADHD, Autism Spectrum Disorder (ASD), Asperger Syndrome (AS), and other psychiatric disorders. According to the authors, the children with a diagnosis of ASD presented smaller vocabulary than those of the other studied groups, followed by the group that presented other psychiatric disorders. The performance of the latter group was similar to that of children with typical language development. Performance in the vocabulary test was similar between the groups with ADHD and with AS. The authors also emphasized that there was statistical significance only between the ASD and ADHD groups, and they support that language delay in preschool children with ADHD indicates a need for better investigation of the diagnosis of ASD.

Another study conducted in Spain[13], analyzed the syntax complexity of phrases and the use of verbal tenses by children and adolescents with and without ADHD. The results of this study showed that children with ADHD presented lower values for the levels of syntactic complexity, as well as in the use of subordination, compared with those of the control group. The authors highlight that differences in the verbal management of temporality, associated with grammar verb tenses, can be considered important features in the language of children and adolescents with ADHD.

Analysis of the second thematic axis, concerning studies that used both Speech-language Pathology and Neuropsychology assessments of ADHD, revealed 17 articles[14-30], which assessed not only the Speech-language Pathology disorders observed in ADHD, but also the aspects related to neuropsychological performance, through specific tests and scales of evaluation of the disorder. Among the studies included in this theme axis, eight addressed reading difficulties[15,17,18,20,25,28-30]; two dealt with difficulties of math and reading[14,21]; three had the relation between cerebral structures and the alterations of language as their main focus[16,19,27]; one addressed neuropsychological performance in the inattentive and combined subtypes[24]; one evaluated performance in executive and central coherence tasks[22]; one focused on the perception of time, phonological skills, and executive function in ADHD[26]; and one investigated fine motor, sensory and perceptual functions[23].

Regarding reading difficulties in ADHD, the importance of word recognition and decoding and reading speed for text comprehension was discussed in a study conducted in the United States[15]. According to the authors, slow reading might be associated with the increased demands of the processes involved in working memory, which would lead to difficulties in text processing and, consequently, in comprehension. In addition, failure in understanding would not be explained only by difficulty

in word recognition and decoding, but by deficits related to oral language skills and executive function. Specifically, vocabulary, syntax, semantics, and phonological processing would be involved in the process of reading comprehension. As for the executive function, the authors point to the fact that deficits in the planning, working memory, organization, and inhibition skills may not be associated only with ADHD, but can be observed independently of the symptoms of this disorder. Therefore, the deficits related to the inference ability would be related not only to the semantic and syntactic aspects of oral language, but also to the processes of executive functioning.

In another study conducted in Brazil[17], the authors investigated the performance of children with and without ADHD through phonological verbal fluency and semantic verbal fluency tests. They verified that the performance of the ADHD group was similar to that of the control group, both in terms of phonological verbal fluency and semantic verbal fluency. Nevertheless, the ADHD group required additional time to initiate responses. In the same study, the authors investigated whether there would be a difference in performance between the ADHD subtypes - inattentive, hyperactive, and combined - and observed that the outcomes were not very relevant.

The correlation between Rapid Automatized Naming (RAN) and reading in children with and without ADHD was also analyzed[18]. The authors discuss, mainly, the existence of naming speed deficits in the disorder and suggest that the pause time in rapid naming tasks could predict reading fluency.

Processing speed and reading fluency, related to working memory in ADHD, were also discussed in another study[25]. The researchers describe that children with ADHD who accurately decode words may still present poor reading fluency, compromising other cognitive processes. The outcomes of this study demonstrated that reading fluency and speed in children with ADHD were reduced in both silent reading and reading aloud.

The genetic risk related to ADHD and reading difficulties was discussed in international studies conducted with twins[28,29]. In one of these studies[28], the authors referred to research that demonstrated the co-occurrence of both pathologies due to genetic risk factors. They also examined the longitudinal relationships between ADHD symptoms and reading difficulties, from childhood to adolescence, and verified an association between the symptoms and the difficulties attributable to shared genetic influences.

In another study conducted in the United States[20], the researchers discuss the unique deficit models for the explanation of complex pathologies such as ADHD and reading difficulties. In these models, the various risk factors - genetic, neuropsychological, and environmental - are disregarded for each disease and the comorbidities between the disorders cannot be explained. The authors indicate the existence of more than 20 proposed theoretical models to explain the occurrence of comorbidities between complex diseases, with ADHD and reading difficulties among them. ADHD is assessed through behavioral classifications, whereas reading difficulties are assessed by cognitive tests.

Furthermore, the symptoms that define these two pathologies do not overlap. The results confirmed the hypothesis that ADHD and reading disorder are related to multiple cognitive deficits and not to a single primary cognitive deficit. Reading difficulties would be associated with phonemic awareness, verbal reasoning, and working memory, whereas ADHD would be associated with inhibitory control. Both would share cognitive deficits related to processing speed because of genetic influences that would increase the risks of reading disability and ADHD.

Differences in the perception, detection, and discrimination of auditory and visual stimuli in children with ADHD were investigated in an international study[30] that evaluated the production of motor responses in synchrony with external stimuli. According to this survey, the temporal processing related to the input of stimuli would be compromised in both ADHD and dyslexia. The authors emphasize that the tasks of motor synchronism allow the behavioral evaluation of the processing dimension, in which the precision and accuracy of the responses require cognitive abilities, and not the use of subjective judgments about the nature of the presented stimuli. Thus it would be possible to understand the cognitive mechanisms involved in developmental disorders, such as ADHD and dyslexia, which present deficits in temporal functions.

The results presented in the aforementioned study showed that the differences in performance in temporal processing tasks correlate with phenotypes of highly prevalent disorders, and that the use of visual tasks that require timing may be useful to demonstrate the quality of processing difficulties of children with ADHD and reading difficulties.

Regarding difficulties in mathematics and reading, two studies[14,21] addressed the coexistence of these difficulties in ADHD. In one of them[14], the researchers discuss performance in multi-digit arithmetic in children with difficulties in mathematics. The performance mentioned by the authors includes comprehension of the types of errors committed and the understanding that these errors may vary as a function of reading, severity of problems in mathematics, or presence of attention problems. The performance of children with typical development in arithmetic suggests that the errors made by them can provide clues about the procedural and conceptual knowledge used, aspects that would be impaired in ADHD.

With respect to the relationship between brain structures and language changes in ADHD[16,19,27], one of the studies showed that there is no reduction of brain volume in children with ADHD and dyslexia, as well as in children with only ADHD, or with only dyslexia[19]. However, in the group of children with difficulties in receptive language, associated with dyslexia and ADHD, asymmetry between the right and left hemispheres was found in the comparison with children without comprehension deficits. Another study[16], which discussed the possibility of participation of the region called *pars triangularis* in phonological processing, showed that children with dyslexia did not present changes in the shape and length of this structure. In contrast, children with ADHD presented alterations in the length of the studied region. According to the authors, the size of the *pars*

triangularis structure would be predictive of good performance in phonological awareness skills and in RAN tasks.

Another international study[27] reported that children with reading disability presented decreased amplitude of neurophysiological activity in the upper temporal gyrus, bilaterally, and in the left supramarginal region of the angular gyrus. These findings were mainly revealed by the pseudoword reading tasks. The authors note that no changes were observed in the group of children with only ADHD.

With regard to the neuropsychological performance of children with ADHD, another study[24], conducted in Colombia, investigated the neuropsychological performance characteristics of children with ADHD, inattentive and combined subtypes, and without ADHD. The main results showed differences in the performance of children with ADHD, compared with those of the control group, in metalinguistic abilities and in tasks that evaluated selective attention. The mean of the results presented by the group of children with ADHD, combined subtype, was lower than that presented by the group of children with ADHD, inattentive subtype, in these tasks. As for the results in tasks of executive functions and memory, as well as in the intellectual capacity assessment, no significant differences were found between the ADHD group and the control group.

The performance of children with ADHD in the task of completing sentences and in executive task was evaluated in an international study[22]. The task of completing sentences verifies whether there will be consistency in the words chosen by the child to complete the proposed sentences. The results of the study showed that the group with ADHD presented good performance in this task compared with the control group, composed of children diagnosed with ASD, and with the group of children with typical development. Regarding the executive task, the group with ADHD presented worse performance than the other groups, evidencing that the problems related to inhibition would not be related to the performance in tasks of central coherence.

Another international study[26] investigated the perception of time, phonological abilities, and the executive function in four groups of children: those with only dyslexia, those with only ADHD symptoms, those with dyslexia and ADHD symptoms, and those who were part of the control group, with typical development. The results found in the study suggest that dyslexia and ADHD symptoms are associated with distinct cognitive profiles. In this sense, children with dyslexia or symptoms of ADHD, such as comorbidities, present an additive combination of cognitive deficits, associated only with dyslexia or only with the symptoms of ADHD. The deficits in duration discrimination associated with dyslexia are mediated by symptoms of inattention resulting from the comorbidity between these disorders. The authors emphasize the importance of considering the impact of ADHD symptoms when investigating the neuropsychological profile of children with dyslexia.

The fine motor, sensory and perceptual functions of schoolchildren with ADHD and of students with good school performance and without behavioral changes were evaluated in a survey conducted in Brazil[23]. The results of this study showed that students with ADHD presented dysgraphia and delay in the development of fine motor, sensory and perceptual coordination. The authors attribute these changes to neurological dysfunctions in the frontal-striatal-cerebellar region, which is also related to the planning, organization, and execution of the motor act. Fine motor, sensory and perceptual alterations would hinder bimanual coordination, manual dexterity, dissociation, and motor precision, which would justify the occurrence of dysgraphia in children with ADHD and would compromise the process of acquisition and learning of writing.

Analysis of the observational studies

Regarding the analysis of the observational studies, according to the STROBE Statement, it was possible to verify that most of the studies were partly compliant with the proposed criteria, mainly with respect to the sections Methodology and Results.

This result may be suggestive of difficulties related to the existence of a consensus about the Speech-language Pathology disorders found in ADHD, as well as about the instruments necessary for the evaluation of these alterations. The fact that some studies do not comply with the criteria for Methodology may generate impairment in the reproducibility of Method in other studies. Concerning the criteria not met regarding Results, there may be impairment in the general understanding of the study.

CONCLUSION

The study of the scientific productions revealed that the Speech-language Pathology disorders most frequently addressed in Attention Deficit Hyperactivity Disorder (ADHD) were reading disorders, followed by changes in auditory processing. However, it was not possible to establish a profile of changes in patients with ADHD. There is a need for the participation of speech-language pathologists in the teams that evaluate children and adolescents with symptoms of ADHD considering that Speech-language Pathology disorders are present in most cases.

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Author contributions

NMN participated in the study design, the search, selection and analysis of the included articles, and in the writing and final approval of the manuscript; AMK participated in the study design and the writing and final approval of the manuscript; SMAL participated in the study design and the revision and final approval of the manuscript.