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Influence of phonological processing on poor school performance: systematic literature review

Influência do processamento fonológico no mau desempenho escolar: revisão sistemática de literatura

Keywords

Language
 Learning Disorders
 Developmental Reading
 Underachievement
 School Performance

Descritores

Linguagem
 Transtornos de Aprendizagem
 Leitura
 Transtorno do Desenvolvimento da
 Leitura
 Baixo Rendimento Escolar
 Desempenho Escolar

ABSTRACT

Purpose: To carry out a systematic review of scientific productions that dealt with the topic of phonological processing in relation to the influence of poor academic performance, as well as its interference in the development of reading and writing. **Research strategy:** Articles published until August 2017 were searched in electronic databases. After elaborating the guiding question of the study: “What is the influence of phonological processing on poor school performance and its relation in the development of reading and writing?”, we collected and selected the reports using descriptors, gathered in a single search equation, according to three thematic axes: phonological processing, learning and poor school performance. **Selection criteria:** Original researches with an evaluation of at least two phonological processing skills were included. Articles that had no relationship between phonological processing skills and school performance were excluded. **Data analysis:** The titles and abstracts were read by two speech-language pathologists, separately. The results were compared and the divergences found decided by a third researcher speech therapist, also responsible for the study. The articles included were read in full and data extraction was performed to analyze the methodology and the main results. **Results:** 982 potentially relevant studies were selected. After using the evidence matrices, 38 scientific productions were included for detailed analysis. **Conclusion:** The study of scientific productions revealed that the alteration in phonological processing skills presented a relation with poor academic performance and, together with the schooling phase, directly influenced reading and writing skills

RESUMO

Objetivo: Realizar revisão sistemática de produções científicas que abordaram o tema processamento fonológico quanto à influência no mau desempenho escolar, bem como sua interferência no desenvolvimento de leitura e escrita. Estratégia de pesquisa: Foram pesquisados, em bases de dados eletrônicos, artigos publicados até agosto de 2017. Após elaboração da pergunta norteadora do estudo: “Qual a influência do processamento fonológico no mau desempenho escolar e sua relação no desenvolvimento de leitura e escrita?”, foram realizados levantamento e seleção dos relatos utilizando descritores, reunidos em uma única equação de busca, de acordo com três eixos temáticos: processamento fonológico, aprendizagem e mau desempenho escolar. **Critérios de seleção:** Foram incluídas pesquisas originais com avaliação de no mínimo duas habilidades do processamento fonológico. Foram excluídos os artigos que não apresentavam relação entre as habilidades do processamento fonológico e desempenho escolar. **Análise dos dados:** Foi realizada a leitura dos títulos e resumos por duas profissionais fonoaudiólogas, separadamente. Os resultados foram comparados e as divergências encontradas, decididas por uma terceira pesquisadora fonoaudióloga, também responsável pelo estudo. Os artigos incluídos foram lidos na íntegra e realizada a extração de dados para análise da metodologia e dos principais resultados. **Resultados:** Foram selecionados 982 estudos potencialmente relevantes. Após a utilização das matrizes de evidência, 38 produções científicas foram incluídas para análise detalhada. **Conclusão:** O estudo das produções científicas revelou que a alteração em habilidades do processamento fonológico apresentou relação com o mau desempenho escolar e, associada à fase de escolarização, houve influência direta nas competências de leitura e escrita.

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INTRODUCTION

The high number of children with poor school performance has intrigued professionals who deal directly with this audience and motivated the investigation of factors that would be related to the underperforming efficiency for age and education⁽¹⁾.

Poor school performance may be due to factors intrinsic to the individual, such as cognitive disorders of neurobiological origin, characterizing the learning disorder, or may be related to extrinsic factors, without any organic involvement, such as pedagogical, socio-cultural and socio-affective disadvantages, known as school difficulties⁽¹⁻²⁾.

In this context, phonological processing appears as a topic of interest in previous studies⁽³⁻⁵⁾, since it concerns the use of phonological information in the processing of oral and written language. It can be divided into three skills: phonological awareness, phonological memory and lexical access^(2,3). Such skills are associated with learning success, as they are responsible, respectively, for the ability to analyze the sound structure of speech, information retention and quick access to representations of the phonological information of the language⁽²⁻⁵⁾.

At the beginning of the school process, children may present discrepant performances in the acquisition of reading and writing due to the peculiarities of the phonological processing skills⁽⁴⁾. Thus, variations in individual skills in the treatment of information can be more easily observed and analyzed in the initial years of literacy, since this is considered the critical period in the consolidation of cognitive processes⁽⁴⁻⁵⁾. Thus, the assessment of phonological processing skills allows the identification of the difficulties presented and contributes to the design of prevention actions, as well as the intervention process^(4,6-7).

Faced with this scenario, the speech-language therapist has relevance for being the apt communication professional, with the interdisciplinary team, working in the analysis of the correlation of phonological processing skills and school performance in the initial years of academic training. This analysis is carried out through procedures relevant to the process of identifying and promoting necessary activities to subsidize the intervention process of the factors considered predictive for adequate school performance⁽³⁾.

It is important to emphasize that the mentioned characteristics can determine impairments in the cognitive-linguistic abilities and the learning process. Thus, it is necessary to investigate the relationships between phonological processing skills in the acquisition of reading and writing, as well as to analyze their influence on school performance.

PURPOSE

To carry out a systematic review of scientific productions that deals with the topic of phonological processing concerning the influence of poor academic performance, as well as its interference in the development of reading and writing.

RESEARCH STRATEGY

The work design was defined based on national⁽⁸⁾ and international^(9,10) recommendations. Initially, the guiding question of the study was elaborated: *What is the influence of phonological processing on poor school performance and its relationship in the development of reading and writing?*

After this stage, the descriptors were defined, having as reference the following thematic axes: phonological processing, learning and poor school performance. For the thematic axis 'phonological processing', we chose not to include a specific descriptor in the search and, thus, leave it as a free term, using precisely this terminology, since this theme encompasses broad concepts and does not present itself as a descriptor in health science. The group of descriptors "Learning Disorders, Dyscalculia, Dyslexia, Developmental Dyslexia, Dysgraphia, Reading and Handwriting" was selected to organize the thematic axis of learning. And, finally, the set "Reading Development Difficulties, Reading Disorder, Reading Development Disorder, School Problems, Low School Performance and School Performance", for the constitution of the thematic axis 'poor school performance'. It is important to note that all of the aforementioned descriptors were used together in the search equations, plus the free term "phonological processing", combined with the use of the Boolean operators AND and OR, forming the three search strategies used in the different databases searched.

The bibliographic survey was carried out in the electronic databases Medical Literature Analysis and Retrieval System Online (MEDLINE, USA), Virtual Health Library (VHL) Research Portal, including the *Índice Bibliográfico Español de Ciencias de la Salud* (IBECS), *Literatura Latino-Americana e do Caribe em Ciências da Saúde* (LILACS, Brazil) and *Index Psicologia - Periódicos técnico-científicos*, in addition to the Educational Resources Information Center (ERIC) portal, in August 2017. We chose to perform a search without delimiting the period. Thus, all answers to the questioning of the guiding question were included for analysis.

It is worth mentioning that all the descriptors used are based on *Descritores em Ciência da Saúde* (DECS) and Medical Subject Headings (MESH). Descriptors were searched in Portuguese and their correlates in English and Spanish. Besides, the entire elaboration process involving the thematic axes and the descriptors that best represented them and the search strategies in electronic databases was duly accompanied by a librarian from the institution.

SELECTION CRITERIA

The selection of studies was based on original articles indexed in the aforementioned databases and which met the following inclusion criteria: being an original research article and including the assessment of at least two phonological processing skills. Duplicate references in each database were excluded. Given the classification of levels of scientific evidence^(11,12), the exclusion criteria was case report articles,

expert opinions, letters to the editor, abstracts in conference proceedings, review articles, theses and dissertations, and those who did not answer the guiding question of this study. Thus, in the end, 44 articles were selected that passed through the second evidence matrix. Of these, 34 analytical observational studies, three pre-experimental studies⁽¹³⁾ and one experimental study were included.

DATA ANALYSIS

The analysis of the articles was carried out in three stages. In the first stage, characterizing the initial evidence matrix, the titles and abstracts were read as follows: two independent evaluators read titles and abstracts regarding the established inclusion criteria and deliberated according to three answers: yes, no and maybe. When the article received only “yes” answers, or a “yes” or “maybe” answer from the two reviewers, the publication was included. When there were “no” answers by both evaluators, the article was excluded. All results of the two evaluators were compared and, in cases where there was disagreement regarding the inclusion or exclusion of the article, a consensus meeting was held with a third researcher who read and evaluated the title and the abstract. It is worth mentioning that all the reviewers of the article were speech-language therapists to ensure conceptual alignment regarding the subject studied.

In the second stage, after the consensus meeting, the articles were read in full in search of the answer to the guiding question for final selection, consisting of the second evidence matrix. In the third stage, a detailed analysis of the selected articles was carried out. The analysis protocol was carried out regarding the recommendations of the STROBE initiative⁽¹⁴⁾ and structured in a database in the Microsoft Office – Excel® software, which included the details of the study identification data, introduction, methodology, main results, discussion and conclusions.

RESULTS

Results in electronic databases

As an initial result of the search, 982 references were identified in the three databases searched, with 486 articles published on the PubMed portal, 90 articles on the VHL portal and 406 on the ERIC database. Of these studies, 409 were excluded because they were replicated, indexed simultaneously in different databases, or because they had a lower level of scientific evidence.

In the initial evidence matrix, carried out individually by two researchers and defined by a third after the consensus meeting, 25 articles from the PubMed portal, 15 articles from the VHL portal and four articles from the ERIC database were included. In the second evidence matrix, after reading the full text, six articles were excluded, including a case report, an integrative literature review, a thesis, two studies that evaluated only one phonological processing skill and a reference that did not answer the guiding question, remaining 38 scientific productions for detailed analysis, considered essential for this study.

Of the articles that make up this study, nine are national publications, 28 are international and one publication carried out jointly by five countries, including Brazil. The flowchart shown in figure 1 demonstrates the process of selecting studies for this review.

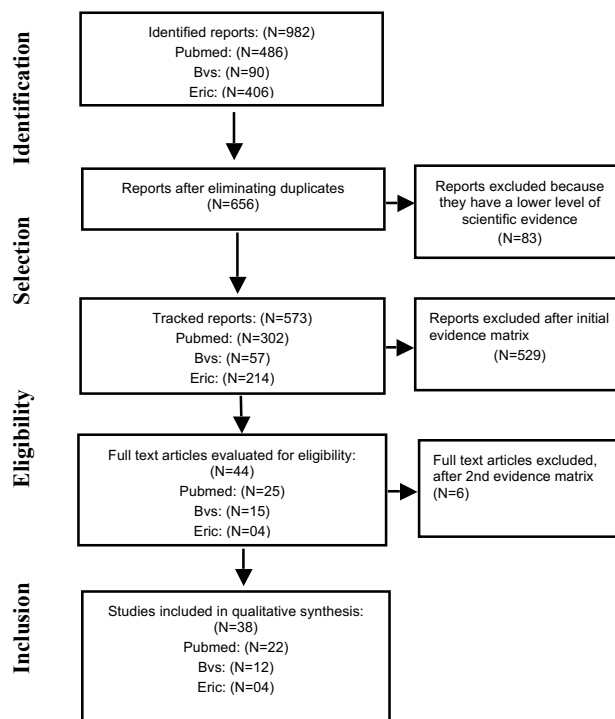


Figure 1: Flowchart of the study selection process

Analysis of selected studies

Among the 38 articles selected for detailed analysis, it was observed that the objectives were similar to the guiding question of this study, that is, to verify the influence of phonological processing skills, considered to be predictors of the success of reading and writing acquisition and its relationship with the poor school performance. However, the subject in question was approached considering different parameters in a wide range of countries, with very peculiar linguistic configurations.

Reinforcing the validity of the selected studies, the use of at least one standardized instrument in all analyzed articles is emphasized. To evaluate the phonological processing skills, the testing procedures applied were diverse, highlighting the greater use of the instruments: Elision and Blending subtests of the Preschool Comprehensive Test the Phonological and Print Processing (PCTOPPP) and Rapid Automatized Naming - RAN. The same occurred for the analysis of school performance and cognitive intelligence level of the samples studied using the School Achievement Test (*Teste do Desempenho Escolar* - TDE; Stein, 1994) and Wechsler Intelligence Scale for children-WISC III, respectively.

As for the design of the articles, it was found that a large part (13 studies) had a cross-sectional observational design^(4,15-26) and that the majority (21 studies) consisted of

prospective and retrospective studies⁽²⁷⁻⁴⁷⁾. In addition to these, three were considered pre-experimental⁽⁴⁸⁻⁵⁰⁾, addressing intervention programs. The highest level of scientific evidence was found in an article in a randomized clinical trial⁽⁵¹⁾ conducted in Canada.

The description of the results of the selected studies is presented in Table 1, in decreasing chronological order of publication, including the main characteristics of the articles analyzed in the present review, such as authors, design, the axis of phonological processing and observed results.

Table 1. Results description of the selected studies

Author	Year	Location	Design	Age (years)	Phonological processing axis	Results
Gutiérrez et al.	2017	Spain	Longitudinal Pre-experimental	5 to 6	Phonological awareness/ Phonological working memory	Concerning the writing learning processes, the data indicated that, although there is no difference in the acquisition of alphabetical knowledge, the intervention program contributed significantly to the improvement of phonological processing skills.
Choi et al.	2017	USA	Transversal	4 to 19	Phonological awareness/ Phonological working memory/ Lexical access	The sample with changes in all phonological processing skills had a greater impact on reading, writing and oral language skills when compared to the sample with changes in phonological awareness only.
lot et al.	2016	Netherlands	Case-control	7 to 10	Phonological awareness/ Phonological working memory/ Lexical access	Changes in phonological processing skills were associated with learning disorders in mathematics and reading and spelling.
Loucas et al.	2016	United Kingdom	Case-control	5 to 17	Phonological awareness/ Phonological working memory	The specific language impairment associated with the alteration of reading decoding would be related to the deficiency in the active maintenance of phonological representations for phonological processing.
Hakvoort et al.	2016	Netherlands	Case-control	12	Phonological Awareness / Lexical Access	There was an association between the ability of phonological awareness and family risk for dyslexia but without robust evidence of direct interference from phonology to reading. Changes in categorical speech perception at the behavioral level would not be directly associated with dyslexia.
Barbosa et al.	2015	Brazil	Case-control	8 to 14	Phonological awareness / Phonological working memory	There was a predominance of changes in phonological processing skills in the group with dyslexia, not compatible with delayed development, but with atypical development, consequently affecting the development of reading and writing, even in older children.
Groot et al.	2015	Netherlands	Case-control	8 to 13	Phonological awareness / lexical access	The ADHD-only and comorbid groups showed a negative performance in phonological processing skills even greater when compared to the group composed of participants with only reading difficulties.
Moyeda et al.	2015	Mexico	Longitudinal Pre-experimental	6 to 7	Phonological awareness / Phonological working memory / Lexical access	The study pointed out significant differences in phonological processing skills before and after the intervention program.
Kibby et al.	2014	United States	Transversal	8 to 12	Phonological awareness / Phonological working memory / Lexical access	Phonological processing was a major contributor to reading ability, regardless of the aspect of reading assessed. There was a strong association of phonological awareness as the best single predictor of each reading skill assessed.
Batnini et al.	2014	Tunisia	Transversal	7 to 9	Phonological working memory / Lexical access	Phonological memory and lexical access were good predictors of reading ability in Arabic, whereas these skills, in themselves, were exclusive predictors of the orthographic ability in Arabic in children of the third grade of Tunisia.

Table 1: Continuation...

Author	Year	Location	Design	Age (years)	Phonological processing axis	Results
Moura et al.	2014	Portugal	Case-control	7 to 12	Phonological awareness / Phonological working memory / Lexical access	They revealed that phonological awareness was the most important predictor of all measures of reading accuracy while naming speed was particularly related to fluency in text reading.
McArthur et al.	2013	Australia	Case-control	7 to 12	Phonological awareness / Phonological working memory / Lexical access	The group with specific reading impairment associated with specific language impairment showed changes in all phonological processing skills. The group with specific reading disabilities had adequate phonological working memory. The group with specific language disorders did not show changes in phonological processing skills.
Zamo et al.	2013	Brazil	Case-control	7 to 12	Phonological awareness / Phonological working memory	The performance in the neuropsychological assessment of children with reading difficulties was statistically inferior in tasks that assessed orientation, working memory (phonological and central executive components), phonological awareness, reading and writing, visuoconstructive skills, arithmetic skills and executive functions regardless of age factors, the result of nonverbal intelligence quotient (IQ) and symptoms of inattention and hyperactivity.
Park et al.	2013	USA	Transversal	6 to 15	Phonological awareness / Lexical access	The groups differed only in the task of visual matching of processing speed. The group of older children showed significantly slower performance of phonological processing skills compared to the younger group.
Pinheiro et al.	2012	Brazil	Longitudinal Pre-experimental	7	Phonological awareness / Phonological working memory / Lexical access	After the intervention process, significant progress was observed in the development of phonological working memory and in phonological awareness tasks. On the other hand, there was no evolution of children in lexical access tasks.
Vandewalle et al.	2012	Belgium	Case-control	6 to 8	Phonological awareness / Phonological working memory / Lexical access	Children with specific language impairment and typical literacy, even over time, continued to have difficulties in complex tasks of phonological awareness and phonological working memory. Children with specific language impairment, changes in phonological awareness and rapid naming in kindergarten were at high risk of developing literacy problems in transparent spelling.
Tenório et al.	2012	Brazil	Transversal	5 to 8	Phonological awareness / Phonological working memory / Lexical access	The more advanced students showed better performance in writing, reading, arithmetic and phonological awareness. Conversely, lexical access and phonological memory performances did not differentiate school years. There were positive correlations between school performance and phonological processing in both school years.
Anthony et al.	2011	USA	Case-control	3.6 to 5.6	Phonological awareness / Lexical access	Children with phonological processing disorders related to the representation presented difficulties in phonological awareness and reading that were also demonstrated by children with speech disorder.
Zeguers et a.	2011	Netherlands	Case-control	7 to 11	Phonological working memory / Lexical access	There was a positive correlation between the difficulty in visual and auditory recognition of words and changes in phonological processing skills.

Table 1: Continuation...

Author	Year	Location	Design	Age (years)	Phonological processing axis	Results
Tanaka et al.	2011	USA	Case-control	7 to 16	Phonological awareness / Lexical access	The dyslexic group with high intelligence quotient (IQ) exhibited similar patterns of reduced activation in brain areas, such as left and occipitotemporal parietotemporal regions. These results converged with behavioral evidence that indicated that, regardless of the intelligence quotient (IQ), reading difficulties would be related to phonological processing skills.
Perez et al.	2011	Belgium	Cohort	6 to 7	Phonological awareness / Phonological working memory / Lexical access	It was found that phonological awareness and phonological working memory functioned as independent predictors of reading skills, even after controlling the initial knowledge of letters. On the other hand, there was no association between the RAN task, the speed of access to the phonological form of words and the ability to read later.
Frijters et al.	2011	Canada	Randomized Clinical Trial	6.6 to 8.6	Phonological awareness / Phonological working memory / Lexical access	Phonological, cognitive and visual memory had predictive value in explaining the response to the intervention among children with reading difficulties. These effects were demonstrated regardless of the contributions of multiple intervention components, phonological awareness and rapid naming skills.
Justi et al.	2011	Brazil	Transversal	8 to 10	Phonological awareness / lexical access	There was a robust and independent contribution of phonological awareness and rapid serial naming for reading and writing accuracy and fluency.
Araújo et al.	2010	Portugal	Case-control	9	Phonological awareness / lexical access	There were significant differences between groups in all tasks. Students with dyslexia performed below the control group in all assessed phonological tasks.
Wayland et al.	2010	USA	Case-control	8 to 11	Phonological awareness / Phonological working memory / Lexical access	There was a strong association between naming and word reading skills among experienced readers, but this association was not found in less qualified readers.
Mousinho et al.	2010	Brazil	Cohort	7 to 9	Phonological awareness / Phonological working memory / Lexical access	There was an association between phonological processing skills and reading comprehension, and these skills were fundamental for the success of understanding texts read at the beginning of the literacy process.
Diuk et al.	2009	Argentina	Cohort	6 to 7	Phonological awareness / Phonological working memory / Lexical access	The students with good phonological awareness development showed learning as expected, regardless of social class. However, the development of these skills was lower in students in situations of greater social vulnerability.
Gallego et al.	2009	Spain	Case-control	7 to 12	Phonological awareness / Phonological working memory / Lexical access	The reading impaired group had worse performance in all examined phonological tasks.
Barbosa et al.	2009	Brazil	Case-control	7 to 8	Phonological awareness / Phonological working memory	The group with impaired literacy showed worse performance in all phonological processing skills and aspects of language when compared to the group with typical literacy.
Smedt et al.	2009	Canada	Transversal	9 to 11	Phonological awareness / Phonological working memory	The quality of children's long-term phonological representations measured individual differences in single-digit arithmetic, suggesting that more distinct long-term phonological representations are related to more efficient arithmetic recovery.

Table 1: Continuation...

Author	Year	Location	Design	Age (years)	Phonological processing axis	Results
Smythe et al.	2009	United States	Transversal	7 to 8	Phonological awareness / Phonological working memory / Lexical access	The relationship between phonological processes and acquisition of literacy was inconsistent in all languages analyzed in the study with different spellings.
Mota et al.	2008	Brazil	Transversal	7 to 8	Phonological awareness / Phonological working memory	The better the children's processing of the morphological aspects of the language, the better their performance in writing. The contribution of morphological processing could be independent of the influence of phonological processing in the acquisition of reading and writing.
Billard et al.	2008	France	Case-control	7 to 8	Phonological awareness / Phonological working memory / Lexical access	Reading difficulties were particularly common in disadvantaged socio-cultural environments. The most relevant factors in reading scores were the best-developed skills of phonological awareness and rapid naming.
Christo et al.	2008	USA	Transversal	2 to 5	Phonological working memory / Lexical access	The rapid naming was configured as the strongest predictor of word reading, reading comprehension and spelling when compared to phonological memory.
Anthony et al.	2007	USA	Prospective	3.6 to 5.6	Phonological awareness / Phonological working memory / Lexical access	When all phonological processing skills and general cognitive ability were compared, phonological awareness was the best predictor of decoding skills in older preschool children. The phonological awareness of young children would be involved in the acquisition of English literacy.
Savage et al.	2005	United Kingdom	Transversal	10	Phonological awareness / Lexical access	The fluency of reading text would be specifically related to the rapid automatized naming of digits, while phonological measures would be more related to reading accuracy and comprehension, even in a reading task that required the simultaneous integration of accuracy, rate and comprehension components.
Capovilla et al.	2004	Brazil	Transversal	5 to 9	Phonological awareness / Lexical access	There was a significant association between the development of reading/writing and phonological processing.
Compton et al.	2001	United States	Transversal	8 to 18	Phonological awareness / Lexical access	Rapid automatized naming and phonological awareness had an additive effect on the written language skills of children with reading difficulties, the first of which affected performance on reading tasks that required an accelerated/fluent response as changes in phonological awareness affected performance in reading tasks that emphasized the phonological processing ability.

Based on the assumption on the scientific evidence scale^(11,12) mentioned above, a randomized clinical trial⁽⁶¹⁾ investigated the contribution of eight predictors of specific neurocognitive processes to assess the degree of response to intervention among children in early school years with reading difficulties. For that, two models were used, one of intervention and phonological processing that included the intervention group, phonological awareness and rapid naming, considered the basis; and the other cognitive-additive neuropsychological that included measures of memory, visual processes and cognitive or intellectual functioning. It was observed that, in addition to the substantial explanatory power of the base model, the additive model improved the classification of poor and good respondents in reading tasks. Thus, it was found

that cognitive skills and neuropsychological variables can predict the degree of reading development considering interventions, phonological awareness and rapid naming.

A national study⁽⁵⁰⁾ and two international studies⁽⁴⁸⁻⁴⁹⁾ that analyzed the effect of intervention programs focusing on phonological processing and stimulation of oral language in reading and writing learning indicated an impact on the different variables involved in word writing. It is important to highlight that there was a similarity in the age range of the participants, between 5 and 7 years old, demonstrating the relevance of the common findings between the three studies. After the intervention process, significant progress was observed in the development of phonological processing tasks.

In three international productions^(28,33,35) analyzed, the associations between phonological processing in children with specific language impairment were investigated, by comparing groups of children with and without difficulties in decoding or delaying the literacy process. One of them was performed in the United Kingdom⁽²⁸⁾ and another in Australia⁽³³⁾, both with a case-control observational design, the results suggested that the specific language impairment associated with the reading decoding alteration could be related to the deficiency in the active maintenance of phonological representations for phonological processing, which is not present in those without reading decoding changes and which leads to a reading of decoding difficulties. The other study, carried out in Belgium⁽³⁵⁾, had a longitudinal design and observed that children with specific language impairment and normal literacy continued to present difficulties, even over time, in tasks that required phonological awareness and short-term verbal memory. The results also pointed out that children with specific language disorders and changes in phonological awareness and rapid naming, in early childhood education, were at high risk of developing literacy problems in a transparent spelling. Comparatively, a Brazilian study⁽⁴⁵⁾ aimed to identify changes in the phonological working memory, phonological awareness and language skills of children with impaired reading. As in the other studies cited, it was observed that the group with impaired literacy showed lower performance concerning normal literacy in the tested phonological processing skills and language aspects, suggesting that these inadequacies are the result of changes in phonological representations and precarious language skills before the literacy period. This same association was found in two other studies, both with a case-control design, one carried out in the United States⁽⁴¹⁾ and the other in Spain⁽⁴⁴⁾, in which groups with altered reading showed lower performance in all phonological tasks examined.

It is relevant to highlight the expressive number of studies selected for this review with dyslexic children. In one of them, carried out in the Netherlands⁽²⁹⁾, it was assessed whether a change in categorical speech perception would be associated with dyslexia or family risk of dyslexia, exploring a possible cascade relationship from speech perception to phonology for reading and identifying whether speech perception distinguished children at family risk with dyslexia from those without dyslexia. It was observed that, although the categorical speech perception as a phonological skill is related to dyslexia, there was no strong evidence of direct interference of phonology in reading. Thus, changes in categorical speech perception at the behavioral level would not be directly associated with dyslexia. Other three studies, one national⁽³⁰⁾ and two with Portuguese children^(32,40), all in the age group between 7 and 14 years old, verified the presence of specific changes in the phonological processing of children and adolescents with dyslexia and its association with the fluency of reading and reading accuracy, further investigating the diagnostic accuracy of phonological processing measures to correctly discriminate between typical readers and dyslexic children. There were significant differences between groups, in which all tasks with dyslexic subjects performed less than that of the control group. Also, there was a predominance of changes in phonological processing skills in the group with

dyslexia, not compatible with delayed development, but with atypical development, consequently affecting the development of reading and writing, even in older children and revealing that phonological awareness was the most important predictor of all reading accuracy measures. The naming speed was particularly related to the fluency of reading text. Reinforcing this hypothesis, another international study⁽¹⁸⁾, carried out in the United States, presented a comparison of the degree of performance in two cognitive skills, phonological awareness and processing speed, in two groups of different age groups of dyslexic children, to evaluate processing speed and phonological awareness with their performance in component reading skills and determine which of these two cognitive constructs served as stronger simultaneous predictors of separate component reading skills. As in the Brazilian study⁽³⁰⁾ and the two Europeans^(32,40), it was observed that younger children showed greater losses in processing speed tasks when compared to phonological awareness tasks.

Since the nature of the word recognition difficulties in developmental dyslexia is still a controversial topic, an international article⁽³⁷⁾ carried out in the Netherlands investigated the contribution of phonological processing changes and the uncertainty to the speech recognition difficulties of dyslexic children and which parameters of the diffusion model would be affected in this sample, analyzing the data at two different times, within the same research: a study involving only the visual lexical decision and another relating it to the auditory lexical decision. The first study showed that the poor visual lexical decision performance of children with impaired reading was mainly due to a delay in the evaluation of word characteristics, suggesting problems of phonological processing. The second study replicated the results for the visual lexical decision with formally diagnosed dyslexic children and observed that, during the auditory lexical decision, the dyslexics presented reduced precision, which also resulted from the late evaluation of the word characteristics. As the orthographic influences were reduced during the auditory lexical decision, this strengthened the hypothesis of alteration in phonological processing. Thus, the results indicated that the difficulties in visual and auditory recognition of words can be found in alterations in the processes in which the characteristics of the words are evaluated, supporting the assumption that a phonological alteration is the main cause of dyslexic reading disabilities, as well as speech perception.

Two other studies, one Brazilian⁽³⁴⁾ and another Dutch⁽³¹⁾ evaluated the contributing and discriminatory values of reading difficulties and attention-deficit/hyperactivity disorder (ADHD) for phonological processing skills, using the instrument Child Brief Neuropsychological Assessment NEUPSILIN-INF and standardized tests, respectively. Besides, the second study⁽³¹⁾ investigated whether the presence of comorbidity should be considered an addictive phenomenon regarding performance in tasks related to phonological processing. In the comparison with control groups, it was verified, in the national study⁽³⁴⁾, that the performance in the neuropsychological evaluation of children with reading difficulties was statistically inferior in tasks that evaluated orientation, working memory (phonological and central executive components), phonological awareness, reading and writing, visuoconstructive skills, arithmetic skills and executive

functions independent of age factors, the result of nonverbal intelligence quotient (IQ) and symptoms of inattention and hyperactivity, partially suggesting the hypothesis of alteration in phonological processing. In the Dutch study⁽³¹⁾, although the results indicated inferior performances for all groups compared in the phonological processing measures, the performance in these tasks was considerably higher for the groups with reading difficulties, in comparison with the ADHD-only group and the comorbid group, suggesting that processes not directly related to reading represent a negative influence, regardless of the performance of phonological processing tasks.

Another highlight was a case and control study carried out in the United States (38), focused on the activation and effective connectivity of brain regions during the execution of phonological processing tasks, through the use of functional magnetic resonance. For this purpose, a group of children with typical reading was compared with two groups of children with low reading skills, with high or decreased intelligence quotient (IQ) scores. In this study, it was observed that the two groups of children with reading disabilities exhibited similar patterns of reduced activation in brain areas, such as left and occipitotemporal parietotemporal regions. These results converge with behavioral evidence that indicates that, regardless of IQ, poor readers have similar reading difficulties concerning phonological processing.

Two international studies^(20,27) specifically addressed the relationship between phonological processing and difficulties in learning mathematics to verify the contribution of different cognitive skills to mathematics and good literacy results. The cross-sectional and observational case-control designs, respectively, indicated that, due to changes in mathematics learning and reading and spelling, they can be considered two separate but correlated skills, justifying the high rate of comorbidities.

Assessment tools and early identification based on phonological predictors at the word level were the subjects of an international study⁽²¹⁾ that aimed to develop a universal instrument to be used with speakers of different languages at the same stage of formal education. To this end, the research aimed to identify the predictors of literacy in five languages, using similar procedures adapted in the testing of children. The data pointed out that the decoding measures and phonological processing skills were good predictors of reading and spelling of words among Arab and English-speaking children, but were less able to predict variability in these same initial literacy skills between Chinese and Hungarian children. Also, they were better at predicting variability in reading in Portuguese when compared to spelling, demonstrating that the relationship between phonological processes and acquisition of literacy would be inconsistent in all languages with different spellings. Phonological awareness may be a common factor in all languages, but its ability to predict literacy levels seemed to vary with spelling. Therefore, the level of transparency of the spelling of the language can determine, to some extent, the relationships between basic literacy skills and measured phonological processing, establishing a better grapheme-phoneme association in less opaque languages.

Regarding the scenario, most of the studies included in the review were carried out in a school setting^(4,15,17,19-21,25,27,32,38-50) and, to a lesser extent, in clinics^(16,18,23-24,28-30,33,35-37,51) and one of them, in an outpatient clinic of a higher education institution⁽³¹⁾. Besides, there is a greater number with large samples studied and a substantial increase in the number of publications since 2009, reaching 80% of the scientific productions analyzed in this review. Of these, more than a third corresponds to the final five years, showing an increasing concern with the development of research related to the subject under study. Such findings allow us to reflect that the strategies used for the selection of articles were adequate and consistent with the search results found.

CONCLUSION

This systematic review exposed that, in children and adolescents, phonological processing was associated with fluency in reading, spelling, reading comprehension and mathematical skills, acting as an essential factor for learning regardless of social level, although the development of these skills is minor in children less favored socially. Regarding school performance, the review indicated that children with impaired literacy have lower performance in most of the phonological processing skills when compared to children with adequate literacy, with this picture being aggravated in schoolchildren with comorbidities. Therefore, the selected scientific studies point to the relevance of lexical development, phonological working memory and phonological awareness that, with the schooling phase, directly influence reading and writing skills.

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REFERENCES

1. Andrade OVC, Andrade A, Estêvão P, Capellini SA. Caracterização do Perfil Cognitivo-Linguístico de Escolares com Dificuldades de Leitura e Escrita. *Psicol Reflex Crit.* 2014;27 (2):358-367. <https://doi.org/10.1590/1678-7153.201427217>.
2. Siqueira CM, Gurgel-Giannetti J. Mau desempenho escolar: uma visão atual. *Rev Assoc Med Bras.* 2011jan-fev;57(1):78-87. <https://doi.org/10.1590/S0104-42302011000100021>.
3. Capellini SA, Conrado TLBC. Desempenho de escolares com e sem dificuldades de aprendizagem de ensino particular em habilidade fonológica, nomeação rápida, leitura e escrita. *Rev CEFAC.* 2009 mar;11(2):183-193. <https://doi.org/10.1590/S1516-18462009005000002>.
4. Tenório SMP, Ávila CRB. Processamento fonológico e desempenho escolar nas séries iniciais do ensino fundamental. *Rev CEFAC* 2012 jan-fev;14(1):30-38. <https://doi.org/10.1590/S1516-18462011005000099>.
5. Pedrosa BAC, Dourado JS, Lemos SMA. Desenvolvimento lexical, alterações fonoaudiológicas e desempenho escolar: revisão de literatura. *Rev CEFAC set-out;17(5):1633-1642.* <https://doi.org/10.1590/1982-0216201517519913>.

6. Silva B, Luz T, Mousinho R. A eficácia das oficinas de estimulação em um modelo de resposta à intervenção. *Rev Psicopedagog.* 2012;29(88):15-24.
7. Calero MD, Carles R, Mata S, Navarro E. Diferencias en habilidades y conducta entre grupos de preescolares de alto y bajo rendimiento escolar. *RELIEV.* 2010, 16 (2): 1-17.
8. Berwanger O, Suzumura EA, Buehler AM, Oliveira JB. Como avaliar criticamente revisões sistemáticas e metanálises. *Rev Bras Ter Intensiva.* 2007;19(4):475-80. <https://doi.org/10.1590/S0103-507X2007000400012>.
9. Braga M, Melo M. Como fazer uma revisão baseada na evidência. *Rev Port Clin Geral.* 2009; 25 (6): 660-6. DOI: 10.32385/rpmgf.v25i6.10691
10. Moher D, Shamseer L, Clarke M, Ghersi D, Liberati A, Petticrew M et al. Reprint-preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Physical Therapy.* 2009; 89(9): 873-880. PMID: 19723669. DOI: 10.1016/j.jclinepi.2009.06.005.
11. Pereira AL, Bachion MM. Atualidades em revisão sistemática de literatura, critérios de força e grau de recomendação de evidência. *Rev Gaucha Enferm.* 2006; 27(4): 491-8.
12. Zina LG, Moimaz SAS. Odontologia baseada em evidência: etapas e métodos de uma revisão sistemática. *Arq Odontol.* 2012;48(3):188-99.
13. Sampieri HR. Metodologia de pesquisa. 5. ed. Porto Alegre: Penso; 2013.
14. Malta M, Cardoso LO, Bastos FI, Magnanini MMF, Silva CMFP. Iniciativa STROBE: subsídios para a comunicação de estudos observacionais. *Rev. Saud Public.* 2010;44(3):559-65. <https://doi.org/10.1590/S0034-89102010000300021>.
15. Choi D, Hatcher RC, Dulong-Langley S, Liu X, Bray MA, Courville T et al. What Do Phonological Processing Errors Tell about Students' Skills in Reading, Writing, and Oral Language? *J Psycho Asses.* 2016 oct;35 (1-2):24-46. <https://doi.org/10.1177/0734282916669018>.
16. Michelle YK, Sylvia EL, Sarah MD. Reading performance is predicted by more than phonological processing. *Front Psychol.* 2014;5(960):1-7. PMID: 25285081. DOI: 10.3389/fpsyg.2014.00960.
17. Soulef B, Akira U. Investigation of basic cognitive predictors of reading and spelling abilities in Tunisian third-grade primary school children. *Brain Dev.* 2015; 37(6):579-591. <https://doi.org/10.1016/j.braindev.2014.09.010>.
18. Park H, Lombardino LJ. Relationships among cognitive deficits and component skills of reading in younger and older students with developmental dyslexia. *Res Dev Disabil.* 2013 sept; 34(9):2946-2958. PMID: 23816630. DOI: 10.1016/j.ridd.2013.06.002.
19. Justi CNG, Roazzi A. A contribuição de variáveis cognitivas para a leitura e a escrita no português brasileiro. *Psicol Reflex Crit.* 2012; 25(3):605-614. <https://doi.org/10.1590/S0102-79722012000300021>.
20. Smedt BD, Taylor J, Archibald L, Ansari D. How is phonological processing related to individual differences in children's arithmetic skills? *Dev Sci.* 2010 may;13(3):508-520. PMID: 20443971. DOI: 10.1111/j.1467-7687.2009.00897.x.
21. Smythe I, Everatt J, Al-Menaye N, He X, Capellini S, Gyarmathy E, et al. Predictors of word-level literacy amongst Grade 3 children in five diverse languages. *Dyslexia.* 2008 aug; 14(3):170-87. PMID: 18697190. DOI: 10.1002/dys.369.
22. Mota MMPE, Anibal L, Lima S. A morfologia derivacional contribui para a leitura e escrita no português? *Psicol Reflex Crit.* 2008;21(2): 311-318. <https://doi.org/10.1590/S0102-79722008000200017>
23. Catherine C, Jack D. Rapid Naming and Phonological Processing as Predictors of Reading and Spelling. *Contemp School Psychol.* 2008; 13(7):7-18. DOI: 10.1007/BF03340938.
24. Savage R, Frederickson N. Evidence of a highly specific relationship between rapid automatic naming of digits and text-reading speed. *Brain Lang.* 2005 may; 93(2): 152-159. PMID: 15781303. DOI: 10.1016/j.bandl.2004.09.005.
25. Capovilla AGS, Capovilla FC, Suiter I. Processamento cognitivo em crianças com e sem dificuldades de leitura. *Psicol Est.* 2004; 9(3):449-458. <https://doi.org/10.1590/S1413-73722004000300013>.
26. Compton DL, Fries JC, Olson RK. Are RAN and phonological awareness-deficits additive in children with reading disabilities? *Dyslexia.* 2001 jul-sep;7(3):125-149. PMID: 11765981. DOI: 10.1002/dys.198.
27. Slot EM, Viersen SV, Bree EH, Kroesbergen EH. Shared and Unique Risk Factors Underlying Mathematical Disability and Reading and Spelling Disability. *Front Psychol.* 2016 jun; 7(803):1-12. PMID: 27375508. PMID: PMC4901067. DOI: 10.3389/fpsyg.2016.00803.
28. Loucas T, Baird G, Simonoff E, Slonims V. Phonological processing in children with specific language impairment with and without reading difficulties. *Int J Lang Commun Disord.* 2016 sept-oct; 51(5): 588-581. PMID: 26992032. DOI: 10.1111/1460-6984.12225.
29. Hakvoort B, Bree ED, Leij AVD, Maassen B, Setten EV, Maurits N, Zuijlen TL. The Role of Categorical Speech Perception and Phonological Processing in Familial Risk Children With and Without Dyslexia. *J Spe Lang Hear Res.* 2016 dez; (59):1460-1448. PMID: 27942706. DOI: 10.1044/2016_JSLHR-L-15-0306.
30. Barbosa T, Rodrigues CC, Toledo-Piza CM, Navas ALGP, Bueno OFA. Perfil de linguagem e funções cognitivas em crianças com dislexia falantes do Português Brasileiro. *CoDAS [Internet].* 2015; 27(6): 565-574. <https://doi.org/10.1590/2317-1782/20152015043>.
31. De Groot BJ, Van den Bos KP, Minnaert AE. Rapid Naming and Phonemic Awareness in Children With or Without Reading Disabilities and/or ADHD. *J Learn Disabil.* 2017 oct;50(2):168-179. PMID: 26475322. DOI: 10.1177/0022219415609186.
32. Moura O, Moreno J, Pereira M, Simões MR. Developmental Dyslexia and Phonological Processing in European Portuguese Orthography. *Dyslexia.* 2015; 21:60-79.
33. McArthur G, Castles A. Phonological Processing Deficits in Specific Reading Disability and Specific Language Impairment: Same or Different? *J Res Rea.* 2013 aug; 3(36):280-302. <https://doi.org/10.1111/j.1467-9817.2011.01503.x>
34. Zamo RS, Salles JF. Perfil Neuropsicológico no Neupsilin-Inf de Crianças com Dificuldades de Leitura. *Psico,* 2013 jul; 2(44):204-214.
35. Vandewalle E, Boets B, Ghesquière P, Zink I. Development of phonological processing skills in children with specific language impairment with and without literacy delay: a 3-year longitudinal study. *J Spe Lang Hear Res.* 2012 aug; 55(4):1053-67. PMID: 22232409. DOI: 10.1044/1092-4388(2011/10-0308).
36. Jason LA, Rachel GA, Martha JD, Teresa IA, Jeffrey MW, Zhou Z. What factors place children with speech sound disorders at risk for reading problems? *Am J Speech Lang Pathol.* 2011 may; 20(2):146-60. PMID: 21478282. DOI: 10.1044/1058-0360(2011/10-0053).
37. Zeguers MH, Snellings P, Tijms J, Weeda WD, Tamboer P, Bexkens A et al. Specifying theories of developmental dyslexia: a diffusion model analysis of word recognition. *Dev Sci.* 2011 nov;14(6):1340-54. PMID: 22010894. DOI: 10.1111/j.1467-7687.2011.01091.x.
38. Hiroko T, Jessica MB, Charles H, Leanne MS, Shelli RK, Susan WG et al. The brain basis of the phonological deficit in dyslexia is independent of IQ. - *Psychol Sci.* 2011 nov;22(11):1442-51. PMID: 22006060. PMID: PMC4380286. DOI: 10.1177/0956797611419521.
39. Martinez TP, Majerus S, Poncelet M. The contribution of short-term memory for serial order to early reading acquisition: evidence from a longitudinal study. *J Exp Child Psychol.* 2012 Apr;111(4):708-23. DOI: 10.1016/j.jecp.2011.11.007. Epub 2011 Dec 29.
40. Araújo S, Pacheco A, Faisca L, Petersson KM, Reis A. Visual rapid naming and phonological abilities: different subtypes in dyslexic children. *Int J Psychol.* 2010 dec 1;45(6):443-52. PMID: 22044084. DOI: 10.1080/00207594.2010.499949.
41. Wayland RP, Eckhouse E, Lombardino L, Roberts R. Speech perception among school-aged skilled and less skilled readers. *J Psycholinguist Res.* 2010 dec;39(6):465-84. PMID: 20033848. DOI: 10.1007/s10936-009-9141-3.
42. Mousinho R, Correa J. Interrelação entre processamento fonológico e compreensão leitora do 2º ao 4º ano do ensino fundamental: um estudo longitudinal. *Rev. Psicop* 2010;27(82):27-35.

43. Diuk B, Ferroni M. Aquisição leitora em crianças que crescem em contextos de pobreza: perfis cognitivos de crianças com alto e baixo nível de leitura. *Cad. Psicopedag.* 2009;7(13):70-89.
44. Gallego MJMC. Alegria Isoca Exploración de las habilidades fonológicas en escolares disléxicos: teoría y práctica. *Rev Logop Fonia Audio.* 2009; 29(2):115-130. DOI: 10.1016/S0214-4603(09)70149-4.
45. Barbosa T, Miranda MC, Santos RF, Bueno OFA. Phonological Working Memory, Phonological Awareness and Language in Literacy Difficulties in Brazilian Children. *Read Writ.* 2009 fev; 22(2):201-218. DOI: 10.1007/s11145-007-9109-3
46. Billard C, Fluss J, Ducot B, Warszawski J, Ecalle J, Magnan A et al. Study of causal factors of reading impairment in a sample of 1062 7 to 8-year-old children. *Arch Pediatr.* 2008 jun;15(6):1058-67. PMID: 18456475. DOI: 10.1016/j.arcped.2008.02.020.
47. Anthony JL, Williams JM, McDonald R, Francis DJ. Phonological processing and emergent literacy in younger and older preschool children. *Ann Dyslexia.* 2007 dec;57(2):113-37. PMID: 18058023. DOI: 10.1007/s11881-007-0008-8.
48. Gutiérrez R. Facilitators of the learning process of writing in early ages. *Anal. Psicol.* 2017 ene;33(1):32-39. DOI: 10.6018/analesps.33.1.229611
49. Moyeda IXG, Ojeda FJR, Velasco AS. Efectos de actividades fonológicas en el vocabulario, las habilidades psicolingüísticas y los procesos lectores de niños de primer grado. *Acta Colomb Psicol.* 2015. 18(2):29-40.
50. Pinheiro L, Correa J, Mousinho R. A eficácia de estratégias de remediação fonoaudiológica na avaliação das dificuldades de aprendizagem. *Rev Psicopedag.* 2012. 29(89):215-225.
51. Frijters JC, Lovett MW, Steinbach KA, Wolf M, Sevcik RA, Morris RD. Neurocognitive predictors of reading outcomes for children with reading disabilities. *J Learn Disabil.* 2011 mar-apr;44(2):150-66. PMID: 21383107. DOI: 10.1177/0022219410391185.

Authors' contributions

ASPS: design of study, search, selection and analysis of included articles, analysis and interpretation of data, writing of the article and approval of the final version. AGE: conception, design, analysis and interpretation of data, writing of the article, critical review and approval of the version to be published. LLA: survey of literature and selection of articles to be included. SMAL: conception, design, analysis and interpretation of data, writing of the article, critical review and approval of the version to be published.