ARTÍCULOS DE REVISIÓN
Review articles

Predicting developmental dyslexia prior reading instruction: a systematic review[1]

Predecir la dislexia evolutiva antes de la instrucción lectora: una revisión sistemática

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Abstract

Introduction: Developmental dyslexia is a neurobiological disorder with a heterogeneous profile that is diagnosed after verifying that a child has not learned to read as expected. Its detection, before the beginning of the reading instruction, tends to be imprecise. **Objective:** The aim of this study was to identify and assess which psycholinguistic skills, assessed before formal reading instruction, can predict later reading difficulties

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and guide early intervention. **Method:** A systematic review (years 2010-2020) was carried out following the PRISMA statement in the PsycINFO, Medline, Web of Science, Eric and SCOPUS databases. **Results:** 42 studies were selected that confirm that certain psycholinguistic skills are relevant to predict reading success. **Conclusions:** Phonological awareness, naming speed, alphabet knowledge, and phonological memory strongly correlate with early reading progress and predict later reading skills and developmental dyslexia.

Keywords

Dyslexia; Learning disabilities; Reading ability; Learning readiness; Reading instruction; Psycholinguistic skills; Phonological awareness; Systematic review.

Resumen

Introducción: La dislexia evolutiva es una alteración neurobiológica con perfil heterogéneo que se diagnostica tras comprobar que un niño no ha aprendido a leer como se esperaba. Su detección, antes del inicio de la instrucción lectora, tiende a ser imprecisa. **Objetivo:** El objetivo de este estudio fue identificar y valorar habilidades psicolingüísticas que, evaluadas antes de la instrucción formal de la lectura, pueden predecir dificultades de lectura posteriores y guiar una intervención temprana. **Método:** Se llevó a cabo una revisión sistemática (años 2010-2020) siguiendo la declaración PRISMA en las bases de datos PsycINFO, Medline, Web of Science, Eric y SCOPUS. **Resultados:** Se seleccionaron 42 estudios que confirman que determinadas habilidades psicolingüísticas son relevantes para predecir el éxito lector. **Conclusiones:** Conciencia fonológica, velocidad de denominación, conocimiento del alfabeto y memoria fonológica presentan una fuerte correlación con el progreso inicial de la lectura y predicen las habilidades lectoras posteriores y la dislexia evolutiva.

Palabras clave

Dislexia; Dificultad en el aprendizaje; Aptitud para la lectura; Preparación para la lectura; Enseñanza de la lectura; Habilidades psicolingüísticas; Conciencia fonológica; Revisión sistemática.

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Introduction

Developmental dyslexia is a disorder of written language learning identified in children with typical intelligence and sensory skills. It is characterized by difficulties in confident and fluent word recognition, resulting in inaccurate or slow reading (Rivas & López, 2015). Currently, it is estimated that between 5% and 15% of school-aged children present a specific learning disorder (American Psychological Association [APA], 2014). Among them, developmental dyslexia is the most common learning disability and has the most significant personal, academic, and social impact (Ozernov-Palchik et al., 2017). However, this problem is not diagnosed until it is observed that a child has not learned to read as expected (in second grade or later usually), when the optimal time for intervention has passed, which some authors have called the "dyslexia paradox" (Ozernov-Palchik & Gaab, 2016, p. 157).

Analyzing current knowledge to detect risk indicators and implement prevention programs in the classroom as early as possible is a priority (Bravo, 2016) because, as Shaywitz and Shaywitz (2007) point out, the earlier they are initiated, the more effective they are, since the younger the child, the greater the plasticity of the brain and, therefore, the possibility of increasing the neural connections and brain circuits responsible for reading. In addition, future school failure would be avoided by implementing educational interventions tailored to the needs of these children. Thus, the importance of early detection is undeniable, as it allows an optimizing intervention, which increases the effectiveness of any treatment and minimizes the impact of the disorder during the school years of the dyslexic student (Ozernov-Palchik et al., 2017; Xia et al., 2017).

However, the task of detection is complex since it must be taken into account that one of the characteristics of this disorder is the great heterogeneity in its manifestations (Jiménez-Fernández et al., 2012). Explaining the variability and specificity of dyslexia is a real challenge for current scientific research (Ozernov-Palchik et al., 2017) since this population is composed of a very diverse group with different profiles, characteristics, difficulties, and needs (Jiménez-Fernández et al., 2012). Due to this variability, most researchers have adopted a multiple deficit approach (Pennington, 2006), where dyslexia is assumed to be a complex disorder of neurobiological origin, whose genesis is multifactorial (APA, 2014), and is associated with structural and functional alterations in several brain regions involved in reading (Ozernov-Palchik et al., 2016).

Dyslexia is evident in the formal learning of reading and writing. Nevertheless, if we take into account, as Bravo (2016) points out, the fact that, as a neurobiological disorder, it is present before its symptoms are clearly visible during the learning of reading, it opens the door to early identification practices and teaching intervention. Thus, several pre-literacy skills have been

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found to be strong predictors of dyslexia in different languages when measured in the preschool years (Furnes et al., 2011; Landerl et al., 2013; National Early Literacy Panel, 2010; Ozernov-Palchik & Gaab, 2016).

However, although this approach seems promising for predicting which children will develop dyslexia, early detection prior to reading instruction tends, to date, to be inaccurate, as some children fail the screening test but later do well in reading, while others pass the screening test but then experience difficulties (Catts et al., 2015; Poulsen et al., 2017). As a result, various studies have found that educators did not identify many children who needed additional support for their early reading development (Quinn & Wagner, 2015), indicating that difficulties in identifying signs of dyslexia are still common in school settings.

Early identification of students at potential risk for dyslexia continues to be an educational challenge in recent years (Germano et al., 2017; Lundetræ & Thomson, 2018). Therefore, this study aimed to identify and assess psycholinguistic skills that, when assessed prior to formal reading instruction, may predict later reading difficulties and guide early intervention.

Method

A systematic review was conducted following the PRISMA guidelines (Moher et al., 2009), taking into account the protocol and suggestions of the Cochrane Handbook for Systematic Reviews of Intervention (Higgins & Green, 2011) for the extraction of information from each article and the assessment of the risk of bias. The quality assessment of each of the selected studies was carried out using The McMaster Critical Review Form–Quantitative Studies (CRF-QS; Law et al., 1998) composed of 16 dichotomous items that allow for identifying the methodological precision and potential biases of the studies. For each item, a score of 1 point is given if the criterion is met, 0 if it is not met, and N/A if it does not apply. Based on the score obtained, each study was included in one of the following categories: excellent (score 15-16), very good (13-14), good (11-12), fair or acceptable (9-10) and poor (≤8).

The search strategy included consultation of relevant databases in the field of Psychology and Education (PsycINFO, Medline, Web of Science, Eric, and SCOPUS) and a manual search throughout the study to access material not included in the electronic databases. The descriptors used were selected from controlled vocabulary or thesauri, but free-text terms were also included in order to identify the greatest number of potentially relevant records. No filters were applied, "all fields" was used in the search engine, and they were entered in English and Spanish, both independently and combined, using the Boolean operators OR and AND. The equation was as

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follows: (Dyslexia OR ["reading disabilities" OR "reading disability" OR "reading disorders"]) OR ("Reading difficulties") OR ("specific learning dis*") OR ("specific learning difficulties") OR ("neuropsychological delay") AND (psycholinguistic OR Predictor* OR ("Psycholinguistic processes") OR ("Linguistic predictor*") OR ("Psycholinguistic skills") OR ("metalinguistics abilities") OR ("phonological awareness") OR ("naming speed") OR ("letter knowledge") OR ("phonological memory").

The search was conducted in the third quarter of 2020, including articles published from 2010 through August 2020. The selection process was carried out in several stages. First, the search results were integrated, duplicates were eliminated using the Refworks program, and those clearly irrelevant by title were discarded. Subsequently, the abstracts were assessed, and after discarding those considered irrelevant to the objectives of this review, 91 investigations were selected for full-text analysis. Several investigators carried out the analysis, and doubts were always resolved by consensus to avoid selection bias.

The inclusion and exclusion criteria applied in the selection of articles can be found in Table 1.

Table 1

Inclusion and exclusion criteria applied for study selection

Inclusion criteria	Exclusion criteria
Is child-centered. Uses samples of children whose psycholinguistic skills are assessed prior to formal reading instruction. Addresses reading-related difficulties assessed in the early grades of elementary school.	Includes neurological records, a major neurodevelopmental disorder, or any type of sensory or motor disability. Presents identified genetic alterations or syndromes or chronic medical conditions that could affect the subject under study. Non-original, theoretical research or research with irrelevant results. Articles produced in countries with logographic languages (China or Japan).

For the analysis of the studies, information was extracted on the sample and age range, design used, instruments applied, objective, and results. Due to the heterogeneity of the results, a narrative analysis was performed taking into account the outcome variables.

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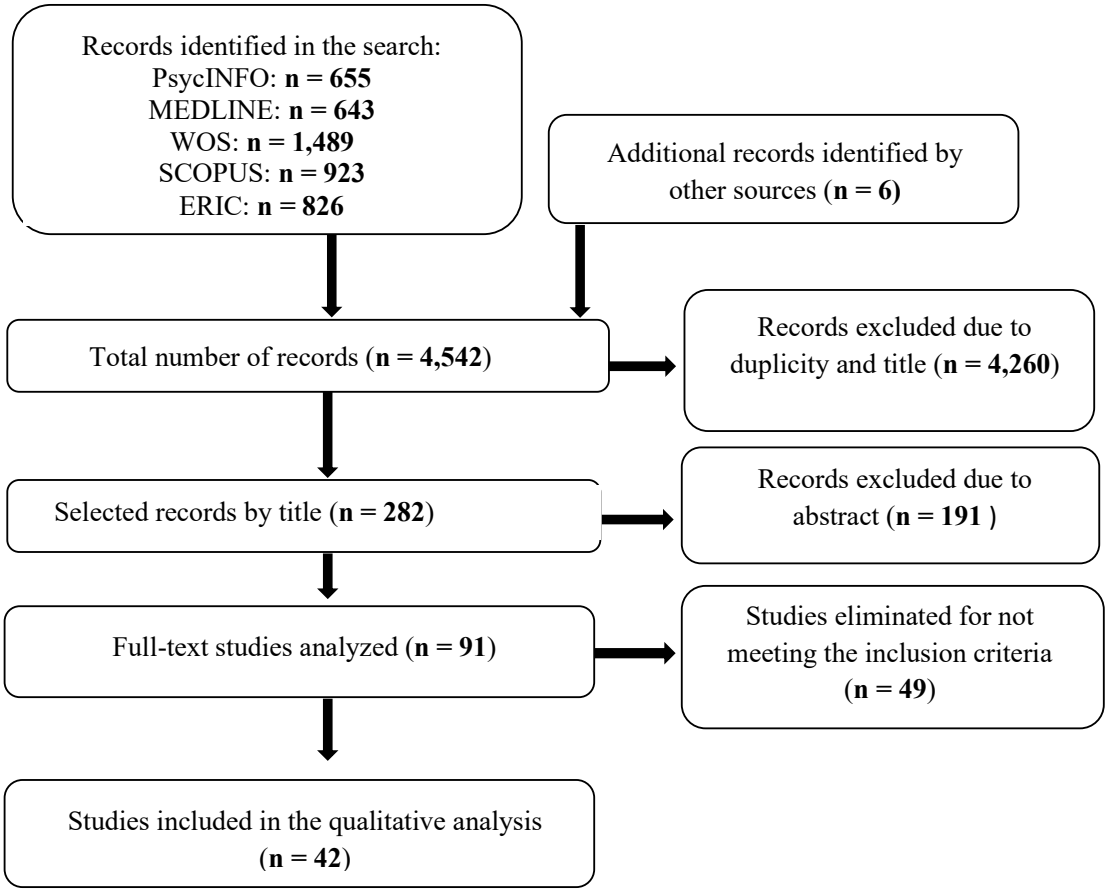
Results

Forty-two articles were included (see Table 2). The selection process can be seen in Figure 1. The database search yielded 4,536 records, to which 6 manually identified studies were added. After eliminating 4,260 due to duplicity or title and 191 for having irrelevant abstracts, 91 articles were selected for full-text review, and 49 were finally discarded for not meeting the inclusion criteria.

Figure 1. *Systematic review process flowchart*



Note. Adapted from "Preferred reporting items for systematic reviews and meta-analysis: The PRISMA statement." by D. Moher, A. Liberati, J. Tetzlaff, D.G., Altman, & The Prisma Group, 2009, PLoS Medicine, 6(6), p. 3.

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The quality assessment of the 42 included studies, excluding four of the 16 items because they were not considered relevant to the research topic, was excellent in 84.4% of the cases and very good in 15.5%. The most common bias was related to the lack of justification of the sample size or the measure records. In the evaluation of methodological quality, a high level was obtained (8 out of a maximum of 11 points).

The psycholinguistic skills identified in the research as particularly relevant in predicting reading success were phonological awareness, naming speed, alphabet knowledge, followed by phonological memory, and early language skills.

Phonological awareness

The contribution of phonological awareness to word decoding is well-established (Suárez-Coalla et al., 2013). It is consistently obtained that, at the infant stage, this skill is a reliable predictor of future reading development and reading difficulties (Brunswick et al., 2012; Carroll et al., 2016; Costa et al., 2013; Eklund et al., 2018; Moll et al., 2016; Nithart et al., 2011; Papadimitriou et al., 2014; Piquard-Kipffer et al., 2013; Suárez-Coalla et al., 2013; Snowling et al., 2019). However, not all studies reviewed were able to replicate this association (Aguilar et al., 2010; Bigozzi et al., 2016; Blomert et al., 2010; Helland et al., 2016; Van Bergen et al., 2011).

Brunswick et al. (2012) observed that rhyme awareness was correlated with future reading ability during the early stages. Costa et al. (2013) reported that the syllable deletion subtest contributed significantly to the fifth-grade word reading prediction. Regarding phonemic awareness, several authors determined that this was an important predictor of reading acquisition (Clayton et al., 2020; Fonseca et al., 2019; Macdonald et al., 2013; Piquard-Kipffer et al., 2013; Suarez-Coalla et al., 2013; Snowling et al., 2019; Zakopoulou et al., 2011). Thus, children with better phonetic skills at the prereading stage had higher reading accuracy (Suárez-Coalla et al., 2013).

Results from numerous studies indicate that phonological awareness is one of the early markers that can distinguish between children who will later become dyslexic or typical readers (Carroll et al., 2016; Dandache et al., 2014; Moll et al., 2016; Piquard-Kipffer et al., 2013; Torppa et al., 2010). Dandache et al. (2014) concluded that children diagnosed with dyslexia scored lower on phonological awareness than familial high-risk normotypical readers. Piquard-Kipffer et al. (2013) observed that the proportion of children with reading disabilities was higher in the group that showed difficulties in the phonetic discrimination task at age 5. Also, Torppa et al. (2010)

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found that phonological awareness discriminated well between groups of typical and dyslexic readers at 3.5 and 5.5 years of age. However, their analysis revealed that the role of phonological awareness was small, predicting only 1.2 % of the variance in reading accuracy and fluency.

Nevertheless, it should be noted that in transparent languages (from the grapheme-phoneme correspondence perspective), both reading accuracy and phonological awareness are easily acquired, even in dyslexic children, so this might not be a relevant factor in predicting reading in this type of languages (Bigozzi, et al., 2016; Furnes et al., 2011, Furnes et al., 2019). Thus, it has been reported that phonological awareness seems to be more influential in the early stages of literacy learning and ceases to be an indicator of individual differences in the early elementary school years due to the early ceiling effect (Brunswick et al., 2012; Furnes et al., 2011; Suarez-Coalla et al., 2013; Torppa et al., 2010).

Naming speed

Evidence suggests that naming speed is a powerful indicator both for predicting future reading acquisition from an early age (Aguilar et al., 2010; Georgiou et al., 2013; Fonseca et al., 2019; Furnes et al., 2011, 2019; Helland et al., 2016; Kim et al., 2012) and for distinguishing between typical readers and others with difficulties, such as dyslexic students (Gellert et al., 2015; Moll et al., 2016; Ozernov-Palchik et al., 2016; Snowling et al., 2019; Suárez-Coalla et al., 2013; Thompson et al., 2015; Torppa et al., 2010).

Although some authors have not been able to confirm an association between performance on naming speed tasks and future reading ability (Martínez Pérez et al., 2012a; Macdonald et al., 2013; Papadimitriou et al. 2014), results from numerous studies show that this skill can be assessed before children learn to read and has a strong predictive association with measures of future reading fluency and accuracy (Ozernov-Palchik et al., 2016; Thompson et al., 2015; Torppa et al., 2010).

This is a particularly strong predictor in transparent orthographies, such as Finnish or Spanish, where simple letter-sound correspondence rules make phonological awareness a more effortless skill to acquire, and reading difficulties are observed more frequently in fluency than in word decoding (Fonseca et al., 2019; Ozernov-Palchik et al., 2016). Thus, for some authors, this skill was a better predictor of future reading development than phonological awareness, which contributed little or nothing to word reading (Aguilar et al., 2010; Fonseca et al., 2019; Furnes et al., 2011, 2019).

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Aguilar et al. (2010) showed that letter naming efficiency accounted for 50% of the variance in word reading in 1st grade, increasing to 64.9% if digit naming efficiency is added. Fonseca et al. (2019) reported similar data observing that color naming was the best predictor for word and pseudoword reading fluency, determining 56.5% and 46.6 % of the variance, respectively. Likewise, Furnes et al. (2011) found that naming speed was the only significant predictor for word recognition and phonological decoding in 1st grade.

There is now consensus that naming speed can be used as an early indicator of risk for dyslexia (Thompson et al., 2015; Torppa et al., 2010). Studies of children at familial risk have confirmed that, in cases of developmental dyslexia, these usually show low performance in tasks of this type, as they are often very slow (Dandache et al., 2014; Torppa et al., 2010; Van Bergen et al., 2011). Along these lines, Torppa et al. (2010) reported that those children identified as dyslexic at the end of 2nd grade were slower on an object naming task at 3.5 years of age. Areces et al. (2018) also found that color-naming tasks and alternating stimuli at early ages were effective in identifying reading difficulties.

Finally, it should be noted that the predictive power of this indicator also varies depending on the stimuli used (drawings, colors, letters, or numbers). Some authors agree that rapid naming of objects and/or colors is the strongest predictor in the earliest stages (Fonseca et al., 2019; Suárez-Coalla et al., 2013), while others found that number and letter naming speed had greater predictive power on future reading (Aguilar et al., 2010; Clayton et al., 2020; Kim et al., 2012).

Alphabet knowledge

Evidence indicates that children with reading difficulties acquire letter-naming proficiency later in life (Clayton et al., 2020; Justi, Cunha & Justi, 2020), a skill that is considered a strong predictor of reading acquisition (Costa et al., 2013; Eklund et al., 2018; Gellert & Elbro, 2015; Macdonald et al., 2013; Ortiz et al., 2012; Piquard-Kipffer et al., 2013; Torppa et al., 2010). Letter name knowledge assessed in preschool explained a high proportion of the variance in reading at age 8 years in the study by Piquard-Kipffer et al. (2013). Comparable results were obtained by Costa et al. (2013) when they observed that a letter knowledge test in preschool predicted word reading in 5th grade.

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Longitudinal studies on the prediction of dyslexia have shown that good early development of this skill dramatically reduces the likelihood of a future diagnosis of dyslexia (Carroll et al., 2016; Furnes & Samuelsson, 2011; Justi et al., 2020; Moll et al., 2016). Thus, alphabet knowledge constitutes one of the best early predictors of developmental dyslexia at stages prior to formal reading instruction (Blomert et al., 2010; Ozernov-Palchik et al., 2017; Petscher & Kim, 2011; Torppa et al., 2010; Van Bergen et al., 2011). Torppa et al. (2010) showed that the best predictor of reading accuracy and fluency in 2nd grade was letter knowledge at age 5. Along the same lines, Thompson et al. (2015) observed that knowing a child's letter knowledge at age 3.5 and the level of family risk could tell us whether that child will develop reading difficulties in school.

However, although letter knowledge may be considered the most robust predictor of reading ability in preschool (Blomert et al., 2010), this may prove to be short-lived, as difficulties experienced in preschool appear to have been resolved in early elementary school (Clayton et al., 2020).

Phonological memory

Phonological memory is part of the phonological linguistic deficit underlying reading difficulties. Though less studied, this implicit phonological skill plays a fundamental role in the early learning stages of reading (Brunswick et al., 2012; Martínez Pérez et al., 2012b).

Most studies suggest a causal relationship between phonological memory and the early acquisition of reading skills (Binamé et al., 2016; Brunswick et al., 2012; Cunningham et al., 2020; Martínez-Pérez et al., 2012b; Nithart et al., 2011; Papadimitriou et al., 2014). Therefore, it has been included in numerous publications as a predictor of initial reading progress, along with phonological awareness and naming speed (Catts et al., 2015; Cunningham et al., 2020; Martínez-Pérez et al., 2012a). However, not all of the studies reviewed were able to replicate these findings, and several studies found that phonological memory tasks were not directly related to the differences found in reading ability (Furnes et al., 2011; Nevo et al., 2015), and played a comparatively minor role in predicting reading performance versus phonological awareness and naming speed (Carroll et al., 2016; Suárez-Coalla et al., 2013).

While the relationships between phonological memory and fluency are not yet fully understood, it is well established that individuals with dyslexia manifest deficits in these types of skills (Moll et al., 2016). Although longitudinal research evaluating prereading children with a dyslexia diagnosis later in life is sparse, studies of children at familial risk have confirmed that pseudoword repetition skills (a way of assessing phonological memory) are particularly inferior in children at

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familial risk for dyslexia who later develop dyslexia (Carroll et al., 2014; Ozernov-Palchik et al., 2016). Thus, one of the most recent causal hypotheses of dyslexia attributes the specific problems of dyslexics to a particular deficit in serial order learning, i.e., the serial order component of phonological memory (Martínez-Pérez et al., 2012a).

Early language skills

It is agreed that early language development provides a foundation for the future development of language and literacy skills (Torppa et al., 2010, Van Viersen et al., 2017). Familial risk studies have shown that speech, language, and phonological skills are closely related to literacy and that children at familial risk for dyslexia who will become dyslexic tend to show deficits in each of these areas in the preschool years (Carroll et al., 2014). Along these lines are the findings of Torppa et al. (2010), which revealed a broad and consistent pattern of oral language decline in children aged 2.5 years and older who went on to have reading difficulties.

Despite this close relationship, longitudinal studies investigating the predictive ability of early language on future reading disorders have yielded inconsistent results, while some authors have reported that early language difficulties may predict a child's potential for future difficulties with literacy (Carroll et al., 2014; Costa et al., 2013; Goldammer et al., 2010; Moll et al., 2016; VanViersen et al., 2017), ample evidence to date suggests that the predictive ability of vocabulary for detecting future reading deficits is low (Duff et al., 2015; Kim et al., 2012; Thompson et al., 2015; Torppa et al., 2010; Zubrick et al., 2015) or null (Furnest et al., 2011).

It, therefore, appears that preschool oral language skills are surprisingly weak predictors of literacy progress and can only be considered as a significant predictor of dyslexia at elementary school entry, between the ages of 5.5 and 7 years, but not before (Duff et al., 2015; Thompson et al., 2015). Thus, more general verbal skills play a minor role in predicting dyslexia, as it appears that vocabulary deficits, despite their stability, appear to have little effect on future reading development and are found in only a small portion of the dyslexic group (Duff et al., 2015; Van Viersen et al., 2017).

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Table 2

Studies included in the systematic review

Author and year	Country	Sample	Design and instruments	Results
Aguilar et al., 2010	Spain	n = 85 5.5-6.5 years.	Longitudinal study. Rapid Automatized Naming test; phonological knowledge assessment test; PROLEC-R reading test.	For word reading efficiency, letter naming efficiency accounted for 50% of the variance, and adding digit naming efficiency increased the variance to 64.9%. Phonological awareness did not contribute to the variance.
Blomert et al., 2010	Netherlands	n = 100 (53 with a dyslexic relative and 47 without risk). 5-11 years.	Longitudinal study. 3DM Dyslexie test.	Only problems with letter-sound association in preschool were directly related to a reading deficit in 1st grade.
Torppa et al., 2010	Finland	n = 198 1.5-2 years.	Longitudinal study. MacArthur Communicative Development Inventories (CDI) (Finnish version), Reynell Developmental Language Scales (RDLS), Boston Naming Test (BNT), Berko-type test, NEPSY, rapid serial naming of objects, Peabody Picture Vocabulary Test-Revised (PPVT-R), standardized reading test Lukilasse.	Only letter knowledge, rapid naming, inflectional morphology, and phonological processing were direct predictors of a combination of reading fluency and accuracy.
Furnes et al., 2011	Norway, Sweden, USA Australia	n = 750 Americans/ Australians; 230 Scandinavians. Preschool-2nd grade.	Longitudinal study. WPPSI-Revised battery, Comprehensive Test of Phonological Processing, Test of Word Reading Efficiency (TOWRE), Wide Range Achievement Test (WRAT).	In Scandinavia, NS was the only significant predictor for word recognition and phonological decoding in 1st grade. In the American sample, NS was the strongest predictor for word recognition and phonological decoding, accounting for two to three times more variance than PA.
Nithart et all., 2011	France	n=34 Preschool-end of 1st grade.	Longitudinal study. Tasks on phonological discrimination, common units (rhyme, syllable, and phoneme); and memory for items, serial order, and influence of long-term phonological knowledge; Peabody test (French version); L'Alouette standardized reading test in French.	Reading skills are predicted primarily by PA measured in preschool and then by phonological memory measured at the end of 1st grade. Specifically, short-term memory for serial order information appears to contribute to the development of decoding skills.
Petscher et al., 2011	USA	n= 613 Preschool.	Longitudinal study. Florida Assessments for Instruction in Reading (FAIR), the word reading section of the Stanford Early School Achievement Test (SESAT).	Students' scores on the 15 easiest letters were statistically indistinguishable from the 26 letters in predicting failure on SESAT.

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Author and year	Country	Sample	Design and instruments	Results
Von Goldammer et al., 2010.	Norway	n = 53 5-8 years.	Longitudinal study. Language, phonological processing, reading, and spelling tasks.	Sentence recall in preschool, as determined by vocabulary capacity and phonological working memory, was found to be the strongest predictor of future reading and spelling skills.
Van Bergen et al., 2011	Netherlands	n = 79 (22 at-risk dyslexics, 45 non-at-risk dyslexics and 12 controls). Preschool-5th grade.	Longitudinal study. Alliteration, phoneme-blending, and segmentation; Rapid Automatized Naming (RAN) of colors and objects, receptive letter knowledge test, Word-Reading Fluency (WRF), pseudoword test.	In preschool, letter knowledge and NS differed between the groups of dyslexic, non-dyslexic at-risk, and control children. No differences were found among the groups in the development of phonological knowledge.
Zakopoulou et al., 2011.	Greece	n = 582 5.4-8 years.	Longitudinal study. N test: visual perception, classification, laterality, spatial-temporal orientation, memory, reading and writing readiness, phonological processing, and grapho-motor skills.	Most reliable factors in the manifestation of dyslexia: “child drawing,” “name writing,” and “sound discrimination.” It refers to phonemic awareness, phonological coding, and phonetic segmentation difficulties.
Brunswick et al., 2012	UK	n =142 Preschool-half of 2nd grade.	Longitudinal study. British Ability Scales (block design, letter-like shape matching, digit recall, and word reading tests), phonological oddity task.	Phonological memory was the variable that most influenced future reading ability. Digit range was significantly correlated with future reading ability at each level.
Kim et al., 2012	Chile	n = 468 Preschool-1st grade.	Longitudinal study. Dynamic Indicators of Basic Early Literacy Skills (DIBELS): letter naming fluency, phoneme segmentation; Battery III Woodcock-Muñoz Tests of Achievement-Revised; Picture vocabulary subtest; word reading.	Individual differences in letter naming fluency and phonemic segmentation fluency, but not vocabulary, were positive predictors of word reading over time.
Ortiz et al., 2012	USA	n = 224 Preschool.	Longitudinal study. Stanford Achievement Test-Tenth Edition (SAT-10), Woodcock-Johnson-III (letter identification, picture vocabulary test), DIBELS Letter Naming Fluency, Diagnostic Evaluation of Language Variation Test (DELV).	The model used preschool predictors to explain approximately 56% of the variance in 1st-grade reading achievement. Letter reading and morphosyntactic skills were the strongest significant predictors.
Martínez-Pérez et al., 2012	France	n =74 Preschool-1st grade.	Longitudinal study. Letter knowledge test, phoneme discrimination task, New Language Examination Battery, NS objects, nonword reading, Peabody Picture Vocabulary Test, nonword delayed repetition task, serial order reconstruction task.	Phonological order memory ability, but not item ability, predicted independent variance in 1st-grade reading decoding abilities.

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Author and year	Country	Sample	Design and instruments	Results
Costa et al., 2013	France	n=150 Preschool-5th grade.	Longitudinal study. BSEDS (Bilan de Santé: Evaluation du Développement pour la Scolarité), Outil de Dépistage des Dyslexies Version 2 (ODEDYS) (dyslexia screening tool–Version 2), and l'Alouette reading test.	In 5th grade, preschool measures of PA (syllable deletion subtest) and alphabet knowledge predicted word reading.
Georgiou et al., 2013	Greece	n = 72 Kindergarten-1st grade.	Longitudinal study. Vocabulary adapted from Greek from the Dyslexia Early Screening Test (DEST), Das-Naglieri CAS battery, DEST, initial sound identification and syllable segmentation, RAN/RAS (rapid alternating stimulus) test battery colors and objects, Test of Early Mathematics Ability (TEMA-3), Test of Word Reading Efficiency (TOWRE).	Results indicated that pause time was the critical component in both the RAN-reading and RAN-mathematics relations and that it shared most of its predictive variance in reading and mathematics with processing speed and working memory.
Macdonald et al., 2013	USA	n = 131 Preschool-1st grade.	Longitudinal study. Rhyming, sound categorization, blending, segmentation, and manipulation skills tests; letter identification and rapid serial naming tests; Wide Range Intelligence Test (WRIT); Woodcock Reading Mastery Tests-Revised-UN.	Cognitive ability, phonemic awareness, and letter knowledge contributed significantly to the prediction of reading ability.
Piquard-Kipffer et al., 2013.	France	n =164 4-8 years.	Longitudinal study. ERTL4 Test, TVAP, pseudoword test, letter knowledge test, syllable, and phoneme segmentation test, phonological memory test (Sprenger-Charolles, Colé, Béchennec, & Kipffer-Piquard, 2005), the Alouette test.	1st study: phonemic discrimination was an important predictor of reading acquisition and reading at age 8. The proportion of children with reading disabilities was higher in the at-risk group than in the non-risk group. 2nd study: a high proportion of the variance in reading at age 8 (52.8%) was predicted by prereading level, letter name knowledge for vowels, phonemic segmentation (not syllable segmentation), and phonological memory.
Suárez-Coalla et al., 2013.	Spain	n = 50 Pre-readers of the second year of preschool.	Longitudinal study. Discrimination of initial phoneme, initial phoneme omission, pseudoword repetition, memory, and verbal fluency tasks; RAN; PROLEC-R.	Phonological processing was the best predictor of reading and writing accuracy in the first years of experience with the orthographic system. In contrast, rapid naming proved to be the task most closely related to reading speed.

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Author and year	Country	Sample	Design and instruments	Results
Carroll et al., 2014	UK	n = 53 (44 with familial risk for dyslexia with a three-year follow-up). 4-6 years	Longitudinal study. Clinical Evaluation of Language Fundamentals Preschool, Diagnostic Evaluation of Articulation and Phonology (DEAP), British Abilities Scales II Word Reading, phonological processing measurement tasks: nonword repetition, phonological awareness, mispronunciation detection, and nonword learning.	Children with reading difficulties show language and phonological processing deficits at school entry. Between-group differences in speech, language, and phonological processing do not fully explain the literacy deficits observed in the group at familial risk for dyslexia.
Dandache et al., 2014	Netherlands	n=62 Preschool-6th grade.	Longitudinal study. Alphabetic awareness task; rapid serial naming test; phonological awareness tasks: identification of initial and final sound, rhyming, phoneme deletion; nonword repetition and digit span test; one-minute reading test; Klepel.	Only PA and NS explained significant variance in the evolution of reading skills.
Papadimitriou et al., 2014.	Greece	n = 287 Preschool-2nd grade.	Longitudinal study. Phonological awareness tasks: syllable segmentation, initial phoneme recognition, syllable, and phoneme deletion; DEST: rapid naming and phonological memory, auditory discrimination, and motor skills; receptive vocabulary task; expressive vocabulary task; TORP: word and nonword reading efficiency and fluency and reading comprehension.	PA and phonological memory scores predict reading accuracy and fluency in first grade during preschool.
Catts et al., 2015	USA	n = 366 Preschool-1st grade.	Longitudinal study. DIBELS: naming fluency and initial sound fluency; CTOPP: NS and sound matching, dynamic screening of phonological awareness; nonword repetition, sentence imitation: TOLD-2P, Woodcock Reading Mastery Tests-Revised: Basic skills, Test of Word Reading Efficiency-2; Florida Assessment for Instruction in Reading: Oral.	A battery of tests containing measures of fluency in letter naming, PA, NS, or nonword repetition accurately identified good and poor readers at the end of 1st grade.
Duff et al., 2015	UK	n = 300 16-24 months to 5 years.	Longitudinal study. Receptive and Expressive One Word Picture Vocabulary, tests comprehensive, test of phonological processing diagnostic, Test of Word Reading Processes.	Child vocabulary accounted for 4% of the variance in the future PA, 11% in reading accuracy, 16% in vocabulary, and 18% in reading comprehension.

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Autor y año	País	Muestra	Diseño e instrumentos	Resultados
Nevo et al., 2015	Israel	n = 70 Preschool-5th grade.	Longitudinal study. Automated Working Memory Assessment (AWMA) battery, Elul battery.	Phonological memory predicted all reading skills in first grade and accuracy in second grade, but its predictive power declined, and it was not useful in later grades.
Thompson et al., 2015	UK	n = 230 3 and a half-8 years.	Longitudinal study. CELF-Preschool 2 UK (expressive and receptive vocabulary, word and sentence structure); TROG-2; Early Repetition Battery; alliteration matching; YARC (alphabetic knowledge, phoneme isolation, and phoneme deletion); NS colors, objects, and digits; Go/No-Go task; Heads-Toes-Knees-and Shoulders (HTKS); visual search task (apples task); The Working Memory Test Battery for Children (Pickering & Gathercole, 2001); The Auditory Continuous Performance Test; Movement Assessment Battery for Children-2; Word Reading (SWRT); and WIAT.	Familial risk status was the strongest predictor of dyslexia at age 8 years, more so than low language skills in preschool. Additional predictors in the preschool years include letter knowledge, PA, NS, and executive skills. By the time children enter school, language skills become significant predictors.
Zubrick et al., 2015	Australia	n = 2,792 4-10 years.	Longitudinal study. PPVT-III, ARS	Low school readiness at age 4 and low vocabulary ability at ages 4 and 8 had a moderate predictive relationship with low literacy at age 10.
Bigozzi et al., 2016	Italy	n = 450 Last year of preschool-3rd grade.	Four-year prospective cohort study. Emergent literacy skills assessed through tests that measured phonological awareness (sound pattern identification and production, phoneme identification), textual competence (test of relational concepts, language comprehension, and story production), and conceptual knowledge of the writing system. MT Battery, Battery for the Assessment of Developmental Reading and Spelling Disorders.	The three components of emergent literacy assessed at the beginning of the last year of preschool explained 13% of the variance in the reading performance of 1st graders. The only significant predictor was conceptual knowledge of writing systems. There was no significant predictor for reading in 3rd grade.

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Autor y año	País	Muestra	Diseño e instrumentos	Resultados
Binamé et al., 2016	France	n = 70 Preschool-2nd grade.	Longitudinal study. Phonological awareness test (identification of syllable and initial phoneme, deletion of syllables and initial phoneme), serial order reconstruction task, pseudoword repetition task, letter name knowledge, Raven's Color Progressive Matrices, Peabody Picture Vocabulary Test, revised, pseudowords reading, high-frequency words, and irregular words.	Serial order ability of phonological memory was a strong independent predictor of nonword reading and spelling abilities in grades 1 and 2 but was not related to word reading and spelling abilities. Phonological memory is a consistent and robust predictor of reading and spelling development.
Carroll et al., 2016	UK	n = 267 Mean age 4.6 years, with 4-year follow-up.	Longitudinal study. Phonological skills test (rhyme detection); rhyme detection test, phonological discrimination, and initial sound of DEST; rapid naming and digit span tasks, sound order test, shape copying and bead threading of DEST; Phonological Abilities Test; British Picture Vocabulary Scale; British Abilities Scale.	Only three variables were significant predictors of reading difficulties: PA and alphabetic knowledge and, to a lesser extent, phonological memory, which had no direct influence on reading in the sample as a whole.
Helland et al., 2016	Norway	n = 120 5-6 years to 11 years.	Longitudinal study. WPPSI™-III, Standardized Test of Decoding and Spelling, The Carlsten Reading Test, the computer-based English 2 Dyslexia Test.	Visuospatial memory and NS were early precursors of Norwegian literacy, but not PA. PA appeared as an early precursor in English. Verbal long-term memory was associated with literacy skills in both languages.
Moll et al., 2016	Czech Republic and Slovenia	n = 308 Preschool-1st grade.	Longitudinal study. Two alphabetic knowledge tasks: letter naming and letter writing. Two phonological awareness tasks: phoneme isolation task, phoneme matching. RAN objects and colors. Two phonological memory tasks: word repetition and pseudowords. One-minute reading test, standardized spelling test.	Precursors of dyslexia included oral language difficulties and code-related skills (phoneme knowledge, letter knowledge, and NS). A two-group latent variable path model shows that early language skills predict code-related skills, which, in turn, predict literacy skills.
Ozernov-Palchik et al., 2017	USA	n = 95 Preschool-2nd grade.	Longitudinal study. YARC (letter knowledge); CTOPP (choice and blending, nonverbal repetition); TOWRE-2 Sight Word, decoding efficiency; composite RAN (objects and colors); WRMT-3, TWS-5, GORT-5 (fluency).	Six performance profiles emerged: average performance, below average performance, high performance, PA risk, NS risk, and double deficit risk (both PA and NS). Falling into one of the profiles in preschool was significantly predictive of future reading performance.

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Author and year	Country	Sample	Design and instruments	Results
van Viersen et al., 2017	Netherlands	n = 51 with familial risk and dyslexia, 92 with familial risk without dyslexia, and 69 with no risk and no dyslexia. 17 months-8 years	Longitudinal study. Dutch MacArthur Communicative Development Inventories.	Early deficits in receptive and expressive vocabulary are associated with future reading performance. Early vocabulary expansion in FR-dyslexic children is characterized by a delay but not a deviation of the expansion. Vocabulary may be considered an additional risk factor for dyslexia.
Areces et al., 2018	Spain	n = 101 5-16 years.	Case-control study. Rapid Automatized Naming and Rapid Alternating Stimulus tests (RAN/RAS).	Naming tasks consisting of colors and alternating stimuli (letters-numbers and letters-numbers-colors) were effective in identifying reading difficulties.
Eklund et al., 2018	Finland	n = 88 with familial risk of dyslexia and 70 without familial risk of dyslexia. 2-15 years.	Longitudinal study. MacArthur Communicative Development Inventories, Peabody Picture Vocabulary Test-Revised (PPVT), Boston Naming Test (BNT), letter knowledge test, NEPSY (Initial phoneme identification and production, phoneme and syllable segment identification, word and pseudoword segmentation, and initial phoneme naming and word segment deletion), NS objects, PISA reading.	Overall, 68% of the variance in PISA reading was explained in the familial risk group and 44% in the no familial risk group. Familial risk puts children at elevated risk for developing long-term difficulties in literacy. Early language and pre-literacy skills were strong predictors of PISA reading at age 15.
Gellert et al., 2018	Denmark	n = 158 Preschool prior to the beginning of formal reading instruction.	Longitudinal study. Dynamic decoding test, letter knowledge test, static phonological awareness test (phoneme identification, phoneme synthesis), RAN objects, digits, accuracy test in words and nonword reading.	A combination of the dynamic decoding assessment and two traditional measures (letter knowledge and NS) resulted in very high prediction accuracy of the reading difficulties at the end of 2nd grade.
Fonseca et al., 2019	Argentina	n = 142 5-8 years.	Longitudinal study. Phonological awareness test (syllable segmentation, identification of initial and final syllable and initial phoneme), RAN/RAS test for colors, objects, letters, and numbers, LEE (reading and writing in Spanish).	NS colors was the best predictor for word and pseudoword reading fluency and word and pseudoword reading accuracy. Regarding reading efficiency, initial phoneme identification and syllable tapping predicted 39.8% variance, and this value did not increase significantly when adding NS of colors and objects.

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Author and year	Country	Sample	Design and instruments	Results
Furnes et al., 2019	Norway, Sweden, USA Australia	n = 489 American, 264 Australian, and 293 Scandinavian children. Preschool-2nd grade.	Longitudinal study. Wide Range Assessment of Memory and Learning, The Illinois Test of Psycholinguistic Abilities.	Across all countries, NS deficits showed a stronger effect on reading, while PA deficits showed stronger effects on spelling. NS and PA are separable deficits with different effects on reading and spelling.
Snowling et al., 2019	UK	n = 237 5½-6½-8-9 years.	Longitudinal study. CELF-Preschool 2 UK, Expressive One Word Picture Vocabulary Test, Sentence Structure sub-test (CELF 4), Experimental Sentence Imitation Task (ESIT), Test for Reception of Grammar (TROG-2), YARC (phoneme deletion), RAN objects, Early Word Reading Test, Wechsler Individual Achievement Test (WIAT-II).	Both speech perception and phoneme awareness are moderate to strong longitudinal predictors of reading ability at age 6½ years and are highly correlated.
Clayton et al., 2020	UK	n = 191 average of 4 years and 6 months.	Longitudinal study. Letter and sound knowledge, early word recognition, and sound deletion subtests of the York Assessment of Reading for Comprehension (YARC), RAN (colors and digits) subtests of the Comprehensive Test of Phonological Processing.	Automatic letter-sound associations are established early but do not predict variations in the reading development. PA, knowledge of the sounds of the letters, and alphanumeric NS were strong independent predictors of reading development.
Cunningham et al., 2020	UK	n = 780 4-9 years.	Longitudinal study. Component Phonological Skills Assessment Scales (CPSAS): phoneme repetition, pseudoword repetition, phoneme isolation, and phoneme deletion. British Ability Scales-2 School Age tests: recall of digits forward subtest and word reading test. Test of Phonological Structure (TOPhS): pseudoword repetition. Phonological Assessment Battery 2nd edition: phoneme deletion. LeST letter knowledge.	Phonological memory focused on serial order directly predicted reading, but only during the first two years of school. The relation between nonword repetition and reading was bidirectional throughout the 5 years of study: nonword repetition and reading predicted each other both directly and indirectly (through phoneme awareness).
Justi et al., 2020	Brazil	n = 213 Brazilian children. 6 years.	Two versions of the Letter-Name Knowledge task: one with 26 letters and one with 15 letters.	Both tasks could be used to detect children with reading and writing difficulties (areas under the curve of 0.83 and 0.80).

Note: NS = Naming speed; PA = Phonological awareness.

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Discussion

The results obtained have allowed us to confirm the predictive capacity of phonological awareness, naming speed, alphabet knowledge, and phonological memory in reading success. It is confirmed that these psycholinguistic skills, assessed prior to formal reading instruction and in the preschool stage, can be used to predict future reading difficulties and guide early interventions.

There is a broad consensus in the scientific community on the close relationship between reading acquisition and three dimensions of phonological processing: phonological awareness skills, rapid access to the phonological lexicon, and, to a lesser extent, phonological memory (Clayton et al., 2020; Dandache et al., 2014; Furnes et al., 2019; Suárez-Coalla et al., 2013; Papadimitriou et al., 2014; Thompson et al., 2015). These prereading measures, along with alphabetic knowledge, have a high correlation with early reading progress and are highly accurate in predicting future reading skills and developmental dyslexia when administered in early childhood education (Carroll et al., 2016; Catts et al., 2015; Eklund et al., 2018; Macdonald et al., 2013; Moll et al., 2016; National Early Reading Panel, 2010; Ozernov-Palchik et al., 2107; Piquard-Kipffer et al., 2013; Thompson et al., 2015; Torppa et al., 2010).

However, despite numerous descriptions of neurocognitive evidence for dyslexia in the literature, at present, the significance of each is still inconclusive (Helland et al., 2016; Suárez-Coalla et al., 2013; Furnes et al., 2011). These findings point to a change in the cognitive mechanisms underlying reading fluency during development (Suárez-Coalla et al., 2013), which together with the heterogeneity of the risk profiles, the different methodologies used in the different studies, the factors studied, and the characteristics of the orthographic systems analyzed, may explain why different publications on dyslexia have produced such diverse, and sometimes contradictory, results (Helland et al., 2016; Ozernov-Palchik et al., 2017).

According to Thompson et al. (2015), identifying children with dyslexia or at risk for dyslexia means assessing the likelihood that a set of variables will identify positive cases of dyslexia (sensitivity) to avoid false positives (specificity). It is well-established that dyslexia involves multiple cognitive-linguistic deficits (Pennington, 2006). Thus, it is difficult to find a single deficit that characterizes most poor readers (Carroll et al., 2016). In addition, a combination of variables has been shown to be more effective in predicting reading accuracy and fluency than measures of a single underlying factor (McDonald et al., 2013; Papadimitriou et al., 2014).

Research in the area of reading acquisition has provided strong evidence of the validity of certain precursors to predict, with a high level of reliability, whether a child will become a proficient or dyslexic reader through assessments conducted during the infant stage (Suarez-Coalla et al., 2013; Ozernov-Palchik et al., 2017; Thompson et al., 2015; Torppa et al. 2010; Wilson et al.,

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2010). Nevertheless, while significant progress has been made in identifying cognitive skills that predict literacy outcomes on a group basis, at the individual level, it is much more difficult to make accurate predictions (Bigozzi et al., 2016; Clemens et al., 2019; Ozernov-Palchik et al., 2017; Poulsen et al., 2017; Snowling, 2013; Thompson et al., 2015).

The results of Poulsen et al. (2017) indicated that reading measures improved substantially as predictors during the first six months of first grade, to the extent that late reading measures alone provided as much information as the early measures combined. These findings have suggested that identification of the dyslexic student should be delayed until at least the first grade.

However, other authors have demonstrated stability in the classification of at-risk status between preschool and elementary education (Ozernov-Palchik et al., 2017). Petersen et al. (2018) concluded that a very brief dynamic assessment can predict, with approximately 75-80 % accuracy, which early childhood education students will have difficulty learning to decode up to 6 years in the future. Similar results were obtained by Gellert et al. (2015). Given this lack of uniformity in the results obtained, we have not yet reached a point, in any language, where it is possible to identify with certainty the risk of reading difficulties in children entering school, and finding the optimal combination of screening indicators remains an international challenge (Lundetræ et al., 2018). This should encourage us to continue research on this topic in an attempt to reach conclusive results.

Conclusions

Phonological awareness, naming speed, phonological memory, and alphabet knowledge are good predictors of future reading ability, and their predictive power is greater in the initial stages of learning to read and write. It has not been possible to delimit the weight or specific contribution of each one of them. Perhaps, in order to reach decisive results, it is necessary to analyze in greater depth the underlying cognitive mechanisms, the methodological aspects, or the characteristics of the different orthographic systems.

Nevertheless, although the weight or contribution of each of the identified skills is not yet conclusive, considering that the combination of variables has been shown to be more effective than measures of a single underlying factor in predicting reading accuracy and fluency, the strength of the results obtained is clear and can be used by practitioners as a guide in both the screening and intervention process.

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Conflict of interest

The authors declare that there is no conflict of interest with any institution or commercial association.

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