



SEÇÃO: ARTIGOS

What research can tell us about the interaction between dyslexia and bilingualism: an integrative review

O que as pesquisas podem nos informar sobre a interação entre dislexia e bilinguismo: uma revisão integrativa

Lo que la investigación puede decirnos sobre la interacción entre dislexia y bilingüismo: una revisión integradora

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Abstract: Dyslexia is a reading difficulty of neurological basis which is often associated to a deficit at the phonological level of reading – but not restricted to it. In this review, we sought to identify relevant research conducted on the interaction between dyslexia and bilingualism in the last twenty years. For this purpose, eleven studies were selected from CAPES Journals Portal. Results of these studies reached contrasting conclusions, some indicating a continuum of dyslexic traces across the languages, while others emphasized the role of interacting factors such as orthographic depth and language granularity modulating the manifestations of dyslexia in each language. The implications of these findings for education are also discussed.

Keywords: Reading Difficulties. Dyslexia. Bilingualism. Education.

Resumo: Dislexia é uma dificuldade na leitura que tem bases neurológicas, comumente associada a um déficit no nível fonológico da leitura – mas não restrito a isso. Nessa revisão, procuramos identificar pesquisas relevantes no que tange a interação entre a dislexia e o bilinguismo nos últimos vinte anos. Para tal, onze estudos foram selecionados do Portal de Periódicos da Capes. Os resultados apresentaram conclusões contrastantes, alguns indicando um *continuum* de traços de dislexia nas duas línguas, enquanto outros enfatizaram o papel de fatores relacionados, como níveis de profundidade das ortografias e granularidade das línguas atenuando a manifestação de dislexia em cada língua. As implicações desses achados para o ensino e aprendizagem também são discutidos.

Palavras-chave: Dificuldades na leitura. Dislexia. Bilinguismo. Educação.

Resumen: La Dislexia es una dificultad en la lectura que presenta orígenes neurológicos, comúnmente asociada a una discapacidad en el nivel fonológico de la lectura – pero no limitada a eso. En esta revisión, buscamos identificar investigaciones relevantes a lo que toca la interacción entre la dislexia y el bilingüismo en los últimos veinte años. Para alcanzarlo, fueron seleccionados once estudios en el Portal de Periódicos de la Capes. Los resultados presentan conclusiones contrastantes en las cuales algunas enseñan un continuo de huellas de la dislexia en las dos lenguas mientras otras enfatizan el papel de factores relacionados, como niveles de profundidad de las ortografías y la granularidad de las lenguas disminuyendo la manifestación de la dislexia en cada lengua. Las implicaciones de estos hallazgos para la enseñanza y el aprendizaje también son discutidas.

Palabras clave: Dificultades en la lectura. Dislexia. Bilingüismo. Educación.



Introduction

Brazilian researchers in psycholinguistics have had a growing interest in the intersection of this field with education. Recent examples are the book "*Psicolinguística e Educação*", edited by Marcus Maia (2018), and the thematic issue of *Journal Ilha do Desterro* entitled "Psycholinguistics: Implications for the Classroom" edited by Mailce Borges Mota and Augusto Buchweitz (2019). Both publications share the same goal: to demonstrate how psycholinguistic studies meet the demands of educators and students. Such endeavor is certainly relevant in times of political attacks to science in Brazil.

One topic that has gathered considerable attention of both Brazilian and worldwide researchers is reading difficulties², and in this paper we focus on one specific difficulty namely dyslexia. Simply put, dyslexia is a reading and writing difficulty of neurobiological origin, as Kuerten, Mota and Segaert (2019) explain in a recent review on the topic. In Brazil, there are several projects focusing on this dyslexia, to name a few, *Instituto ABDC*, which is a non-profit organization aimed at sharing information about dyslexia around the country; *PROJETO ACERTA (Avaliação de Crianças Em Risco de Transtorno de Aprendizagem)* which aims at identifying, in their two centers in Florianópolis and Natal, learning disabilities early in life (TEIXEIRA; LIMBERGER; BUCHWEITZ, 2016). One of the labs involved in the latter project investigates the neurobiology of learning difficulties, which is held at *Pontifícia Universidade Católica do Rio Grande do Sul*. In fact, recent research in this field has been interested in investigating the neural characteristics of bilinguals with dyslexia (PARK; BADZAKOVA-TRAJKOV; WALDIE, 2012).

With these issues in mind, we felt the need to carry out a more thorough investigation of the relationship (if any) of bilingualism and dyslexia. In this paper, we seek to review recent studies that investigated a possible interaction between dyslexia and bilingualism. More importantly, we

focus on the implications of these findings for teaching and learning to read, especially in the context of language acquisition.

This paper is structured in the following manner: first, we bring a brief theoretical background where we define dyslexia and bring four main theories that attempt to explain its causes and describe its characteristics. Second, we describe the methodological procedures for selecting the articles that compose our review. Third, we summarize the studies on dyslexia and bilingualism. Last, we sum up the main findings attempting to draw some major considerations on how these findings might contribute to teaching and learning.

1 A brief theoretical background

The field of reading difficulties research has been divided into two domains: a) difficulties at the decoding level and b) problems in the construction of meaning, at the comprehension level (HULME; SNOWLING, 2014; KRONBICHLER; KRONBICHLER, 2018). Difficulty with decoding seems to stem from phonological deficits (e.g. spelling), since "reading is parasitic on speech" (MATTINGLY, 1972, p. 133); that means, there is a strong relationship between learning to read and being able to associate sounds and letters; in other words, difficulty in the grapheme-phoneme correspondence. In contrast, comprehension difficulties are associated with vocabulary knowledge, morphological and pragmatic skills. Dyslexic reading is situated within the first realm. In fact, this view of dyslexia is commonly the most cited one, but as we shall depict along this paper, not all types of dyslexia have to do with phonological processing (RAMUS, 2003; KUERTEN; MOTA; SEGAERT, 2019).

According to the International Dyslexia Association (2002), dyslexia can be categorized as a neurobiologically originated difficulty in recognizing words accurately or fluently, decoding and spelling. Many scholars agree that these difficulties are linked to the phonological

² Some scholars use the term disability (GUNDERSON; D'SILVA; CHEN, 2011, for a review), while others use disability and difficulty interchangeably (VELLUTINO; FLETCHER, 2005, for instance). In this paper, we have opted for the term difficulties, granted that with appropriate intervention, dyslexia can be ameliorated, as we shall discuss along the paper.

processing of language (VELLUTINO; FLETCHER, 2005; DEHAENE, 2012; PINHEIRO; SCLAR-CABRAL, 2018). To be more precise, dyslexics have a specific impairment at the decoding level (linking graphemes to their corresponding phonemes), a condition which often prompts the use of lexical strategies (e.g. whole-word recognition), especially when the reader is confronted with irregular or unfamiliar words.

Dyslexia might be acquired, as in the case of lesions, or developmental, evolving during the literacy process. In a recent review on dyslexia, Kuerten, Mota and Segaert (2019) draw from the ideas of Morton and Frith (1995) to explain developmental dyslexia. In their article, four major psycholinguistic theories are approached: the phonological deficit theory, the double-deficit theory, the magnocellular theory, and the cerebellar theory. Each of them will be outlined below.

According to the phonological deficit theory, poor phonological awareness would result in difficulties with counting syllables and in phoneme deletion/substitution tasks, and/or poor verbal short-term memory, evidenced by impaired repetition of sequences of sounds/letters and non-words. Another feature is slow lexical retrieval, causing low performance in rapid naming tasks. That means, dyslexic readers have trouble recalling words quickly/under time pressure (RAMUS, 2004, apud KUERTEN; MOTA; SEGAERT, 2019).

A second theory is the double-deficit theory, which advocates that dyslexic reading is not entirely explained by difficulties in phonological processing (decoding). In addition to that, dyslexics also have a deficit in rapid serial/automatized naming - RAN, resulting in less fluent reading (LOVETT; STEINBACH; FRIJTERS, 2000; WIMMER; MAYRINGER; LANDERL, 2000; WOLF; BOWERS, 2000). Dyslexic readers may either present one of these traces or both.

Under a neurocognitive perspective, the magnocellular theory defends that dyslexia is associated with abnormalities in the neural visual system, more specifically, in the magnocellular pathway, which rapidly transmits visual input to the occipital and parietal brain regions.

Neuroimaging studies indicate that magnocells are smaller in dyslexics, causing a decrease in visual and auditory sensitivity (LOVEGROVE *et al.*, 1980; LIVINGSTONE *et al.*, 1991; SKOTTUN, 2000; STEIN; TALCOTT; WALSH, 2000; STEIN, 2001).

The last theory brought by Kuerten, Mota and Segaert (2019) assumes that the magnocellular system carries information to the cerebellum; thus, abnormalities in this system also affect that part of the brain. This is the cerebellar deficit theory (NICOLSON; FAWCETT, 2008), according to which a dysfunction in the cerebellum has been found to be linked with dyslexic reading.

Since decoding problems are a salient characteristic of dyslexia, orthographic depth has been referred to as a linguistic factor associated to this condition. In a nutshell, the concept refers to how reliable print-to-speech correspondences are (SCHMALZ *et al.*, 2015). For instance, in consistent orthographies, also known as transparent or shallow orthographies, the grapheme-phoneme correspondence is clear, such as in Italian and Spanish. Differently, in inconsistent orthographies, also known as opaque or deep orthographies, the correspondence between graphemes-phonemes is less straightforward. In English, for example, the same grapheme *ch* is pronounced differently in "chocolate", "choir" and "chef" (CHUNG; HO, 2010; TAINURIER; ROBERTS; LEEK, 2011).

Attempts have been made to explain how cross-linguistic influences such as orthographic depth interact with dyslexic reading. In their Psycholinguistic Grain Size Theory, Ziegler and Goswami (2005) proposed that reading in more transparent orthographies induces smaller grain decoding (from sublexical units such as letters and phonemes); in contrast, opaque orthographies are processed in large-grain units (e.g. whole word). Thus, it is hypothesized that learning to read in both transparent and opaque languages would help dyslexics compensate for deficits in phonological decoding by transferring phonological awareness and sublexical decoding abilities from the consistent to the inconsistent orthography. Although widely accepted, the

deficit in phonological processing "typifies the idea of a phonological deficit as exclusive in nature" (KUERTEN; MOTA; SEGAERT, 2019, p. 256).

More recently, studies on dyslexia have investigated its interaction with the bilingual mind (CHUNG; HO, 2010; LALLIER *et al.*, 2018), given the assumption underlying several studies is that there might be a bilingual advantage for dyslexics. For instance, Lallier and colleagues (2018) proposed that the reading difficulties posed by dyslexia should be ameliorated due to the bilingual experience, which was further investigated in Lallier and collaborators (2018).

In order to achieve the goal of tracing the current state of studies in this field, we carried out an online research in *Periódicos Capes* (www.periodicos.capes.gov.br) from late May to early July, 2019. This website is a Brazilian online journal portal which makes available more than 45 thousand national and international articles from over 21,500 journals. The relevance of this database relies on its coverage, encompassing studies from a wide range of countries and areas. The former aspect is important since the present review includes works both in the areas of Psycholinguistics and education. Yet, a more thorough search, including different databases, is advised in future studies to provide a more comprehensive picture of the field. Finally, it is also important to mention that this paper was initially written as a requisite for the Graduate course "The implementation of reading in the brain" offered in 2019 at the Graduate Program in English (PPGI-UFSC).

The search was conducted under the search-strings "dyslexia" and "bilingualism", both only in the English language. As for a temporal criterium, only works published within the last

twenty years were selected. Among the results obtained, the first eleven articles that appeared in the search engine were selected to form the scope of the present analysis. Default screen position was used as criteria because, in this website, results are ordered by relevance. Among these, one article deals with brain data, while the others use behavioral methods. Park, Badzakova-Trajkov and Waldie (2012) conducted a neurologically-oriented study. The other ten studies follow a behavioral perspective: Chung and Ho (2010); Joshi, Padakannaya and Nisanimath (2010); Tainturier, Roberts and Leek (2011); Hedman (2012); Lallier *et al.* (2018); Van Setten *et al.* (2017); Vender *et al.* (2018); Valdois *et al.* (2014); Wydell and Butterworth (1999); and Wydell and Kondo (2003). Interestingly, the majority of the studies are very recent, a fact which highlights the current interest in this topic. The fact that only one neuroimaging study was found also points to lack of evidence on the interaction between dyslexia and bilingualism – an issue we discuss in the concluding remarks, extending to its relationship with education. Finally, in order to analyze the data from these studies, we bring supporting literature from likely recent Brazilian and foreign publications.

2 What research can tell us about dyslexia and bilingualism

As aforesaid, we carried out a search at the most reliable scientific database available in Brazil in order to investigate what research has shown, in the last twenty years, in terms of the relationship between dyslexia and bilingualism. The studies reviewed are summarized in **Table 1**.

TABLE 1 – Summary of studies reviewed

Author/ Year	Participants	Procedures	Results/discussion
Park, Badzakova-Trajkov and Waldie (2012)	One dyslexic English-German bilingual (35 y.o.); one English-German bilingual control (31 y.o.); one monolingual control (28 y.o.)	Brain activation in lexical decision tasks; Judgment tasks of nonverbal shape, letter-case, regular word, irregular word and nonword	The dyslexic bilingual showed less activation on the inferior frontal area of the left hemisphere in relation to the other participants, but compensatory – yet poor – right hemisphere activation
Wydell and Butterworth (1999)	AS, an English-Japanese bilingual boy with monolingual dyslexia in English (16 y.o.)	Reading aloud; word/nonword judgement; Spoonerism task; phoneme deletion/addition tasks; rhyme judgements	Evidence of greater incidence of phonological dyslexia in languages with opaque orthography
Wydell and Kondo (2003) (Follow up of Wydell and Butterworth, 1999)	AS, an English-Japanese bilingual with monolingual dyslexia in English; eight controls (20 y.o. - same as AS)	Orthographic/Phonological lexical decision tasks and the Spoonerism Test	Confirmation AS is a phonological dyslexic. The deficit does not affect Japanese because it cannot be decomposed phonemically. With intervention, proficient reading can be achieved
Chung and Ho (2010)	84 primary school students – Chinese as L1; Cantonese as a medium language	Measures of nonverbal intelligence, word reading, rapid naming, phonological awareness, morphological awareness, and visual-orthographic knowledge	Chinese-English children with dyslexia had difficulties learning English; reading problems in Chinese persisted in English (cross-linguistic transfer)
Joshi, Padakannaya and Nisanimath (2010)	Two English-Kannada bilinguals (16 y.o.). One was dyslexic; the other, hyperlexic. Eight monolingual typical readers as controls (13,25 y.o.)	Mental ability test; decoding tests; comprehension tests	Reading problems occurred despite the orthographic depth of the languages, meaning that the grapheme-phoneme correspondence was not the source of problems
Tainturier, Roberts and Leek (2011)	Seven Welsh-English aphasic bilinguals (56-74 y.o.)	Pseudoword reading; reading aloud abstract and concrete words; a lexical decision task; a written word comprehension task	Decoding at the lexical level took place both in English and Welsh, contradicting the Orthographic Transparency Hypothesis
Hedman (2012)	10 Spanish-Swedish bilinguals (14;9 y.o.) with reading/writing problems; 10 Spanish-Swedish bilinguals with no reading/writing problems (14,5 y.o.)	Non-word repetition task; digit-span task; spoonerism task; rapid naming task; phonological mobilization task	Results indicated a continuum of phonological processing and decoding difficulties across languages

Author/ Year	Participants	Procedures	Results/discussion
Valdois <i>et al.</i> (2014)	A French-Spanish bilingual girl with no phonological impairment but a Visual Attention Span deficit	Effect of VA span training; fMRI sessions before/ after training to check for improvement in reading performance across the two languages	VA span abilities were positively influenced by remediation and remained at the level of controls 10 months after intervention. Evidence for VA span disorder as a key component in dyslexia
Van Setten <i>et al.</i> (2017)	77 Dutch adolescents (mean age 14): 25 high-risk dyslexics; 25 high-risk non dyslexics; 27 low-risk non dyslexics (control group)	Word reading fluency, spelling and vocabulary compared across the two languages; Dutch pseudoword and loanword reading; phonological awareness; rapid automatized naming; verbal short term and working memory	L1 reading performance was a strong predictor of L2 reading; support for the genetic view of dyslexia and the persistence of family risk
Lallier <i>et al.</i> (2018)	60 Welsh-English bilinguals	Dyslexia Adult screening Test; nonsense passage reading; pseudoword and irregular word reading aloud; spelling to dictation; two phonological awareness tasks; VA span task	Results endorsed the researchers' claim on cross-linguistic transfer from more consistent to less consistent orthographies
Vender <i>et al.</i> (2018)	106 children: 24 Italian monolingual dyslexics, 30 Italian monolingual typical children; 22 bilingual dyslexic children with Italian as L2; 30 bilingual typical children with Italian as L2	Parents' interview on the children's age of first bilingual exposure, length of exposure and socioeconomic status. A test of cognitive level, reading and lexical ability; working memory capacity and on generation of plural noun inflexions of nonwords	Evidence for a bilingual advantage for dyslexic readers. Bilingual dyslexics seem to further develop their morphological and metalinguistic abilities compared to monolingual dyslexics, surpassing monolingual children with no reading difficulties in some conditions

Source: elaborated by the authors.

We first approach the work of Park and colleagues (2012) which deals with brain data, and then proceed to the behavioral studies in chronological order. In addition, the studies conducted by the same research group are presented in sequence in order to facilitate the observation of their progress.

Park, Badzakova-Trajkov and Waldie (2012) investigated the neural bases of dyslexia and bilingualism using a widely known neuroimaging technique known as Functional Magnetic Resonance Imaging (hereafter fMRI) which consists of measuring the oxygenation of specific brain

areas, taken that "neural activity leads to changes in the amount of oxygen nearby in the brain" (WILLEMS; CRISTIA, 2018, p.266). According to the authors, there is plenty of evidence that language processing in bilinguals is more widely spread in brain in relation to monolinguals. Similarly, dyslexics also have more spread activation in the brain when compared to typical readers. Such findings have recently led researchers to investigate the brain of dyslexic bilinguals, as shall be discussed as it follows.

As stated, Park, Badzakova-Trajkov and Waldie investigated the neural basis of dyslexia, which

consisted in comparing brain activation of a dyslexic English-German bilingual (35-year-old woman) to the activation of an English-German bilingual control (31-year-old woman) and a monolingual control (28-year-old woman). In order to reach their objective, the researchers scanned participants while they performed a series of lexical decision tasks, divided into five conditions - nonverbal shape judgement; letter-case judgment; regular word judgement; irregular word judgement and nonword judgement (PARK; BADJAKOVA-TRAJKOV; WALDE, 2012).

The results have shown that brain activation differs from the dyslexic bilingual, the control bilingual, and the control monolingual (PARK; BADJAKOVA-TRAJKOV; WALDE, 2012). Differences in brain activation were more evident during linguistic tasks. For instance, the dyslexic bilingual showed less activation (hypoactivation) on the inferior frontal area of the left hemisphere in linguistic tasks in relation to the other participants. Hyperactivation in homologous right hemisphere areas such as the inferior frontal and the fusiform gyri suggest a sort of compensatory activation for left hemisphere malfunctioning, which is consistent with previous findings in studies involving dyslexics. Park and colleagues add that this compensation is poor, since the right hemisphere is not specialized in phonological processing. The researchers conclude by reiterating that bilingual dyslexic readers recruit rather different cortical resources given their atypical right-hemisphere lateralization for language.

These results have some implications for education. First, it provides clear evidence that dyslexia has a neurobiological basis (BUCHWEITZ *et al.*, 2018), which helps demystify the assumption that this reading difficulty is related to lack of motivation and/or interest (SHAYWITZ, 2008, for a review). Second, bilingualism might provide an advantage for dyslexics in domain general cognitive functions - also known as Executive Functioning (EF). Such inference can be drawn

from two recent findings, to mention, 1) evidence suggesting that bilingualism enhances Executive Functioning³ (WALDIE *et al.*, 2020); and 2) reading difficulties being associated with poor domain-general functioning (KERSHNER, 2019). In other words, since bilinguals have some sort of advantage in executive functioning, being bilingual may help dyslexics in domain general cognitive control. However, our assumptions are inferences made based on recent findings, given that, to the best of our knowledge, no previous study has investigated EF in dyslexic bilinguals.

Under a qualitative vein, Wydell and Butterworth (1999) conducted a case study of AS, an English-Japanese bilingual adolescent boy (aged 16 years old) with monolingual dyslexia in English. This study was the first to approach "a bilingual and biscriptal boy who is severely dyslexic in just one of the languages" (WYDELL; BUTTERWORTH, 1999, p. 273-274). The boy's parents were Anglo-Australian, but he was educated in Japan until 18 years of age. The experiment consisted of a) reading aloud and judging whether the stimulus was a word or nonword; b) a Spoonerism task⁴; c) phoneme deletion/addition tasks; and d) rhyme judgements. Results pointed to a phonological deficit which impaired only the more inconsistent language, i.e., English. This finding endorsed the "hypothesis of granularity and transparency", which claims that opaque languages like English require "a fine-grain tuning of the orthography-to-phonology mapping" (WYDELL; BUTTERWORTH, 1999, p. 300). This inconsistency, according to the authors, would explain the problems of readers with phonological dyslexia in only one language: an interplay between a cognitive deficit and the specific requirements of the orthography of one of the languages to be learned.

Nevertheless, this claim is later criticized by Ziegler and Goswami (2005) in the same article in which they propose the Psycholinguistic Grain Size Theory. These authors propose that, since phonological awareness is a key component

³ Executive Functioning refers to "a set of general-purpose control mechanisms, often linked to the prefrontal cortex of the brain, that regulate the dynamics of human cognition and action" (MIYAKE; FRIEDMAN, 2012, p. 8).

⁴ According to Wydell and Butterworth (1999), the Spoonerism task highly demands the phonological component of language which consists of exchanging the first phonemes of two words, such as car park - par cark).

in learning to read, this holds true for both consistent and inconsistent languages. Therefore, developmental dyslexia might occur in both types of orthographies; still, language transparency and granularity would act as mediating - not determinant - factors, resulting in nuances in the manifestation of dyslexia across languages (ZIEGLER; GOSWAMI, 2005, for a full discussion).

A few years later, Wydell and Kondo (2003) further analyzed AS's case, by replicating tests with AS in order to check for the persistency of phonological impairment. It is important to highlight that during this study, AS had been an undergraduate student in Science in an English-speaking country, and he had been taking remedial classes in reading and writing in English a year before his application and throughout his first year in the course. In spite of these remedial lessons, Wydell and Butterworth (1999) suspected that his phonological ability remained faulty.

For this experiment, eight control participants aged 20 (same as AS) at the time underwent Orthographic/Phonological lexical decision tasks and the Spoonerism Test. For the first task, the words were extracted from textbooks AS had used in junior-high school, in order to guarantee that he had had previous exposure to stimuli. The second tasks were the same used in Wydell and Butterworth (1999). Results confirmed that AS was a phonological dyslexic, since the types of errors made enabled researchers to identify the use of larger-grain strategies. The fact that this deficit does not affect Japanese was justified by the fact that this language cannot be decomposed phonemically (like English) neither in Kanji nor in Kana. In addition, this study provided evidence for the persistence of dyslexia over time. Despite the authors' claim that "AS has a core phonological deficit which led to his dyslexia", it is interesting to note that "AS had successfully completed a BSc in science in an English-speaking country" (WYDELL; KONDO, 2003, p. 43), which suggests that despite this reading difficulty, with the appropriate intervention people are able to function as a reader in society.

Chung and Ho (2010) were particularly interested in investigating whether there would be a cross-

linguistic transfer of reading difficulties (dyslexia) between two distinct written systems, to say, English and Chinese. The authors hypothesized that phonological awareness tasks would have a relationship with reading in English and Chinese. Such hypothesis comes from the Psycholinguistic Grain Size Theory which claims that readers of inconsistent orthographies rely on larger sublexical units (ZIEGLER; GOSWAMI, 2005). In consistent orthographies, in contrast, there can be a reliance on smaller units, such as graphemes or letters. Chung and Ho also hypothesized that problems in phonological awareness would affect reading in English more deeply than reading in Chinese, considering that English is an alphabetical system and therefore relies on the grapheme-phoneme correspondence. Chinese, on the other hand, contains a logographic orthography in which the characters represent morphemes (CHUNG; HO, 2010). Last, the authors predicted that "reading-related cognitive skills would be related to reading in the L1 and L2 and that these skills could be transferred across two languages" (CHUNG; HO, 2010, p. 199).

Eighty-four primary school students who spoke Cantonese as a medium language and Chinese as a primary language took part in the study. The participants were split into three groups: dyslexics (mean age 9.9 years old), control (chronological age - mean age 9.9 years old) and control (reading level - mean age 7.8 years old). In order to test their hypotheses, several tasks were used, to say, measures of nonverbal intelligence, word reading, rapid naming, phonological awareness, morphological awareness, and visual-orthographic knowledge (CHUNG; HO, 2010, for a detailed account).

The researchers found that Chinese-English children with dyslexia had difficulties learning English, as evidenced by their impaired performance in rapid naming, visual-orthographic knowledge, phonological and morphological awareness in the two languages. Reading problems in Chinese persisted in English, adding to the assumption of a cross-linguistic transfer of reading difficulties from the L1 to the L2. The authors explain that the difficulties stem from different sources in each language: in English,

phonological problems were associated with the English script, which is represented at the phonemic level. This finding corroborates the Psycholinguistic Grain Size Theory, since Chinese is a larger grain size language (Chinese reading does not rely on linguistic units at the phonemic level). Last, Chung and Ho (2010) briefly describe the pedagogical implications of their study, such as the incorporation of L2 metalinguistic awareness tests in instructional programs. This implication is grounded on the evidence that Chinese-English speakers showed cross-language transfer in rapid naming, visual-orthographic knowledge, phonological and morphological awareness. The authors explain that this transfer was only noticed in the direction from the first to the second language but not from the L2 to the L1, which suggests that "specific metalinguistic processes are universally relevant to any script" (CHUNG; HO, 2010, p. 207).

Joshi, Padakannaya and Nishanimath (2010) conducted a battery of tests which aimed at exploring the nature of reading difficulties of two bilingual users of English and Kannada - one of the languages used in South India (JOSHI; PADAKANNAYA; NISHANIMATH, 2010). The performance of the two participants (16 years old) was compared to eight monolingual typical readers (13.25 years old). MS was a bilingual hyperlexic and VN was a bilingual dyslexic. Joshi, Padakannaya and Nishanimath (2010) explain the difference between the two conditions: "dyslexics have poor decoding skills but good linguistic comprehension skills, while hyperlexics have good decoding skills but poor comprehension skills" (JOSHI; PADAKANNAYA; NISHANIMATH, 2010, p. 101). These definitions were given based on English-speaking monolinguals. Therefore, the rationale of the study relies on exploring whether the same definition sustains for bilinguals with different orthographic background.

The battery of tests encompassed a mental ability test; decoding tests (letter-character naming and nonword reading in English and Kannada; regular and irregular words in English; English word reading; Kannada word reading) and comprehension tests (listening comprehension;

word level - synonym judgement; passages; reading comprehension; questions format; cloze format; spelling and dictation; speed of processing; letter-character naming; word naming in English and Kannada; phonological awareness tasks; and phoneme awareness tasks). Joshi, Padakannaya and Nishanimath (2010) found that the hyperlexic participant indeed had good decoding in comparison to his comprehension abilities in both languages, while the dyslexic participant had poor decoding which resulted in poor comprehension as well. The authors concluded that reading problems occurred despite the orthographic depth of the languages, meaning that the grapheme-phoneme correspondence was not the source of problems in reading in their study.

The study carried out by Tainturier, Roberts and Leek (2011) aimed at investigating whether there would be a difference in reading in a consistent language (in this case Welsh) as opposed to reading in an inconsistent or opaque language (English) among bilinguals with acquired dyslexia. The researchers depart from the consensus that there are two decoding procedures: lexical (whole word) processing, which is used in reading common/regular words, and sublexical (grapheme-phoneme) processing, employed in pseudoword and unfamiliar/non-frequent word reading. Tainturier, Roberts and Leek (2011) were interested in investigating the claim that consistent languages would rely more heavily in sublexical processes - and whether dyslexia (difficulty in sublexical processing) would be related with more deficits in these transparent languages.

Seven Welsh-English bilingual participants (between 56 to 74 years old) took part in the study. All participants were aphasic, having acquired dyslexia as a sequela of a stroke. The first experiment consisted of a comparison between reading words versus pseudowords across the two languages. As expected, the results showed that words were better read than pseudowords. Interestingly, participant's performance in this task was similar in the two languages, contrary to Ardilla's the claim that in consistent orthographies

reading relied only on "sublexical orthography to phonology conversion processes" (ARDILA, 1991, *apud* TAINTURIER; ROBERTS; LEEK, 2011, p. 557). The second experiment consisted in having participants read aloud a list of real words of high- and low-imageability (or abstract and concrete words), under the premise that concrete words are read more easily by individuals with brain damage (TAINTURIER; ROBERTS; LEEK, 2011). This factor is believed to be evidence of lexical reading because sublexical processing would not be affected by word concreteness/imageability. The results showed that high-imageability words were read better, a finding that does not support the hypothesis that Welsh is read sublexically. The third experiment consisted of a lexical decision task aimed at testing participants' capacity to distinguish words from pseudowords. Each language was tested separately. The fourth experiment consisted of written-word comprehension task in which participants were asked to match a word to a picture (among picture distractors) to depict the word meaning. Results from these two experiments showed that decoding at the lexical level (and not sublexically) took place both in English and Welsh, contradicting the hypothesis that reading in Welsh is grounded on phonological mechanisms. Overall, their study did not support the hypothesis that orthographic depth is determinant of reading processes (TAINTURIER; ROBERTS; LEEK, 2011).

So far, studies have been mainly interested in investigating dyslexia in reading tasks. Differently, Hedman (2012) aimed at tracing the profile of dyslexic bilinguals to check whether reading and writing problems were due to poor second language acquisition or developmental dyslexia. To be more precise, the study investigated the extent to which phonological processing and decoding skills would differ between dyslexic and non-dyslexic bilinguals. The former group was composed of ten Spanish-Swedish users (mean age 14.9) identified by their teachers with reading and writing problems, while the latter was composed of ten Spanish-Swedish bilinguals

with no reading or writing problems (mean age 14.5). The battery of tests included a non-word repetition task to test phonological memory; a digit-span task to measure phonological short-term memory; a spoonerism task to measure metalinguistic skills; a rapid naming task (since slow naming is indicative of dyslexia); and a phonological mobilization task to measure meta-phonological processing (lexical retrieval). Hedman (2012) differed from previous studies since she assessed reading at the word level (reading words and non-words aloud) and the text level (reading text aloud). Participants were tested in both languages.

Data from phonological processing and decoding tests was divided into the categories "no low", "low" and "very low" scores within each language in order to devise a detailed bilingual dyslexia *continuum*. Results ranged from high indication of dyslexia (critical phonological problems concomitant with very low level of decoding) to fair scores in both phonological processing and decoding. Overall, results indicated a *continuum* of phonological processing and decoding difficulties across languages. Bilingual dyslexics showed greater difficulty in decoding (evidenced by their low performance on reading aloud non-words, real words, and text) and significant phonological impairment. In the bilingual control group, no participants performed at a very low rate in phonological nor in decoding tests.

Hedman (2012) argues that a significant number of participants were under-identified regarding their level of dyslexia. There were also occurrences of over-identification (participants labelled as dyslexics who performed within the normal range). Over-identification of bilinguals as dyslexics might be related to their technical problems in writing. Last, Hedman (2012) explains that the results would have been different if participants had been tested only in one language, which suggests a need to examine both languages, in bilinguals, when profiling dyslexia. One important aspect to consider in Hedman's study is that the author briefly mentions that participants read better in Spanish than in Swedish

– differences that might be due to orthography. In concluding, the researcher highlights that the bilingual dyslexia *continuum* can be used as a tool for assessment of the degrees of reading difficulty regarding, comprising phonological processing and decoding in L1 and L2.

A few years later and under a mixed-methods approach, both behavioral and neural measures were used in the case study carried out by Valdois and colleagues (2014). Their investigation focused on dyslexic reading stemming from visual attention (VA) span deficits, which are believed to have a different effect on reading in inconsistent (French) and consistent (Spanish) orthographies. In addition, the researchers were interested in assessing the results of VA span remediation sessions. A French-Spanish bilingual girl with no phonological impairment but a VA span deficit underwent VA span training. fMRI sessions were conducted before and after training to check for improvement in reading performance across the two languages. In the behavioral tests, as expected, her reading speed in pseudoword and whole reading tasks were faster in Spanish than in French. Results pointed to the participant's VA span abilities as positively influenced by remediation compared to pretesting and immediate testing (T0, T1 and T2) and remained at the level of controls 10 months after intervention. Neuroimaging data before and after training revealed that fewer errors were made after training; brain imaging showed further activation after training, especially in the bilateral SPL and the left IPL, the central parietal lobe. Thus, this study provides further evidence on the visual attention span disorder as a key component in dyslexia, in addition to the more explored phonological deficit. As the authors put, the deficit does not seem to be "a general visual disorder or a letter identification problem, but [...] a specific parallel visual disorder, namely VA span disorder." (VALDOIS *et al.*, 2014, p. 137).

Under a more genetically-oriented perspective, Van Setten and colleagues (2017) investigated differences in reading and spelling between Dutch and English, the effect of dyslexia in English (L2), and the persistence of dyslexia in Dutch (L1) over

time. The participants were 77 Dutch adolescents (mean age 14 years) divided into three groups: 25 high-risk dyslexics, and 25 high-risk non-dyslexics, and 27 low-risk non-dyslexics (control group). The risk of dyslexia was established based on the results of reading tests that participants' parents took, grounded on the hypothesis that if parents are dyslexic, their children are likely to be dyslexic as well. The dyslexic participants were selected based on their reading scores during previous reading assessments of the Dutch Dyslexia Program (VAN SETTEN *et al.*, 2017, for a full account).

Participants' word reading fluency, spelling and vocabulary was compared across the two languages; in addition, Dutch pseudoword and loanword reading fluency, phonological awareness (PA), rapid automatized naming (RAN), and verbal short term and working memory were also tested. Results showed that the dyslexics had severe deficits in both reading and spelling in the two languages compared to the other groups; the deficit persisted across time. These findings endorse the case for a strong phonological deficit in dyslexia. In addition, the comparison between participants' reading skills in L1 and L2 demonstrated that L1 reading performance is a strong predictor of L2 reading. To be more precise, the authors suggested that "adolescents with dyslexia had not only a literacy impairment in Dutch, but generally also in ESL" (VAN SETTEN *et al.*, 2017, p. 15). Interestingly, the fact that the English orthography was not consistent did not impair L2 reading, spelling, nor vocabulary. Participants with high risk of dyslexia had similar performance as compared to dyslexics and those with low risk of dyslexia, which supports the genetic view of dyslexia and the persistence of family risk of dyslexia.

More recently, Lallier and colleagues (2018) investigated the effect of orthographic consistency on the manifestations of dyslexia among a group of Welsh-English bilinguals. The hypothesis underlying their study was that the reading skills from the more consistent orthography (Welsh) would be transferred to the less consistent orthography (English) and thus facilitate processing of the phonological

components of the less consistent language. This assumption is grounded on the aforementioned Grain Size Theory, according to which reading in more consistent orthographies induces the use of sublexical units such as letters and phonemes; in contrast, inconsistent orthographies are processed in larger units (e.g. whole word). Thus, learning to read in two languages (one being consistent and the other inconsistent) would help dyslexics compensate for deficits in phonological decoding by transferring their stronger phonological awareness and sublexical decoding abilities from the consistent to the inconsistent orthographic system.

Participants of this study were 60 adults divided in four groups: skilled monolinguals, dyslexic monolinguals, skilled bilinguals and dyslexic bilinguals. Data collection consisted of a test for adults with dyslexia (Dyslexia Adult screening Test – DAST); a nonsense passage reading; a list of pseudowords and irregular words to be read aloud; spelling to dictation; two phonological awareness tasks; and a VA span task. Results endorsed the researchers' claim on cross-linguistic transfer from more consistent to less consistent orthographies, evidencing the importance of attending to the linguistic background of dyslexic readers.

Evidence for a bilingual advantage in dyslexia was found by Vender and colleagues (2018). The researchers assessed participants' ability to generate plural noun inflexions of nonwords - a tool known as the Wug Test, designed by Berko (1958). One hundred and six children participated in the study: 24 Italian monolingual dyslexics, 30 Italian monolingual typically developing children, 22 bilingual dyslexic children with Italian as L2 and 30 bilingual typically developing children with Italian as L2.

The variables considered were the following: data on the age of first bilingual exposure and length of exposure was collected with a questionnaire for the parents. Socioeconomic status was also considered in interviews with parents. In addition, a test was administered to certify that all participants had a standard cognitive level. Reading abilities were measured

on a standardized reading test. A receptive vocabulary test was measured participants' lexical abilities, and digit span tasks (in which sequences of digits of increasing length were shown to participants, who were asked to repeat them forwards or backwards) were used to assess working memory capacity.

Scores for nonverbal intelligence and receptive vocabulary were similar across participants. As expected, monolingual and bilingual dyslexics performed worse compared to controls. Dyslexics also performed poorer in working memory span tests, although bilingual dyslexics outperformed their monolingual counterparts. Overall, results from the Wug Test pointed to a bilingual advantage. The tasks with determiners showed that dyslexic readers performed more poorly in the production of plural articles of nonwords. As for the plural inflection of invented nouns, bilinguals, including dyslexics, performed better than the two groups of monolinguals. From these findings, the authors concluded that bilingual dyslexics seem to further develop their morphological and metalinguistic abilities compared to monolingual dyslexics, even surpassing monolingual children with no reading difficulties in some conditions.

Prior to the discussion of the results, we would like to draw attention to the methods used across the studies reviewed. Non-word reading tasks were used to assess phonological awareness, departing from the knowledge that familiar words are read via lexical decoding, while reading words that are uncommon or unknown forces phonological decoding. The studies conducted by Wydell and Butterworth (1999), Joshi, Padakannaya and Nishanimath (2010), Tainturier, Roberts and Leek (2011), Park, Badzakova-Trajkov and Waldie (2012), Hedman (2012), and Vender *et al.* (2018) used such method to assess phonological awareness, which is believed to be a central problem in dyslexia. Reading aloud was used by Chung and Ho (2010), Tainturier, Roberts and Leek (2011), Wydell and Kondo (2003), Hedman (2012), Valdois *et al.* (2014). This method enables access to the reader's long-term memory representation of the spoken words, which allow researchers to

infer the availability of the lexical representation (TAINTURIER; ROBERTS; LEEK, 2011). Another recurrent tool was spelling for dictation (JOSHI; PADAKANNAYA; NISHANIMATH, 2010; LALLIER *et al.*, 2018). Lallier *et al.* (2018), Wydell and Butterworth (1999) and Wydell and Kondo (2003) used the Spoonerisms task, in which the initial phonemes of a pair of words are changed, e.g. car park – par cark. The aforementioned task focuses on testing the phonological component of dyslexic readers, since there is evidence for its impairment. Under a different perspective, the VA span test was used by Lallier *et al.* (2018) and Valdois *et al.* (2014) in order to investigate the role of visual attention impairment in dyslexia.

Next, we move to the final remarks of this review.

Conclusion

The present review aimed at tracing the most recent and relevant findings in the field of dyslexia and its interface with bilingualism. In order to do so, eleven articles were selected from Capes journals portal and reviewed in order to identify the main conclusions and underlying theories of each study, which will be brought together to discussion in this section.

In terms of neuroscientific findings, there is still plenty of room to explore how dyslexia and bilingualism interact. Park, Badzakova-Trajkov and Waldie (2012) showed that dyslexic bilinguals resort to alternative cortical resources in the right hemisphere due to their atypical reading, which demonstrates that dyslexia has indeed a neurobiological basis. This finding is relevant in the sense that it helps to deconstruct some commonsense beliefs in attributing dyslexia to low intellectual abilities, poor schooling, poor family structure or even laziness (SHAYWITZ, 2003; PINHEIRO; SCLiar-CABRAL, 2018). In fact, Pinheiro and Scliar-Cabral (2018) explain that despite dyslexia persisting throughout life, people who receive the appropriate intervention might function quite well in reading and writing. Yet, neuroscience has a long path in approaching educational settings. There is a considerable gap between research in psycholinguistics and

classroom practices which remains an unsolved issue. Attempts to conduct studies with greater ecological validity, including the educators' perceptions and evaluations (HEDMAN, 2012) are necessary steps towards the connection between these two realms, as we further argue in the end of this section.

The discussion on whether there was a bilingual advantage permeated the studies. This claim was supported in some studies with dyslexics (LALLIER *et al.*, 2018; VENDER *et al.*, 2018). In addition to that, these authors put that "bilingual individuals can adapt their resources to the orthographic properties of the target language", which seems to imply that the bilingual brain has some advantage in relation to monolinguals which might be persistent in atypical readers. In fact, the debate on whether there is such bilingual advantage is far from an end. A clear example is a very recent study by Waldie and colleagues (2020) who investigated the cognitive and neural correlates of written language in typical bilinguals, whose findings show a benefit in Executive Functioning in bilinguals. Whilst discussing Park, Badzakova-Trajkov and Waldie's (2012) study, we highlighted that poor domain general cognitive functions are generally associated with reading difficulties. Considering the aforementioned claim that bilinguals might have improved EF, these benefits could be extended to reading difficulties. However, research is needed to ground such claim.

In a recent discussion brought by Finger, Brentano and Fontes (2018) in which they present the multilingual scenario in Brazil, the authors highlight the many advantages brought by the bilingual experience, such as the domain general abilities (attention, memory, and executive functions) which seem to be determinant for school achievement. From this data, we highlight that children should be given the opportunity to learn an additional language, so that the benefits of the bilingual experience could be extended to other cognitive domains throughout life. In addition to that, studies carried out with a Brazilian population have not been found in our search, which opens up opportunities for future research.

Moreover, two important aspects that permeated the studies reviewed were orthographic depth and grain size (ZIEGLER; GOSWAMI, 2005), considered interacting factors with dyslexic reading in bilinguals and reaching contrasting conclusions. Joshi, Padakannaya and Nishanimath (2010) found a similar phonological deficit in English and Kannada in spite of the difference in orthographic consistency between the two languages. Tainturier, Roberts and Leek (2011) also found that orthographic depth did not play a prominent role in the reading ability of English-Welsh dyslexic bilinguals, since their performance was similar in the two languages investigated. Interestingly, Van Setten *et al.* (2017) found that orthographic consistency did not affect L2 reading in the case of a consistent L1 but inconsistent L2.

Notwithstanding, more studies endorsed the claim of orthographic consistency as an influential factor. Chung and Ho (2010) found evidence of cross-linguistic transfer of reading difficulties from L1 (Chinese) to L2 (English) dyslexic readers, which might be explained with basis on the difference in psycholinguistic units across the two languages. Yet, reading problems related to phonological processing were greater in English than in Chinese. Hedman (2012) also acknowledged the fact that orthographic depth had played a role in the performance of her participants, since they scored better in reading in Spanish. Recently, Lallier *et al.* (2018) found evidence for transfer of reading skills from more consistent to less consistent orthographies, a factor which seems to modulate the manifestations of dyslexia.

However, and as stated by Ziegler and Goswami (2005), it would be too assertive to say that consistency and granularity alone explain differences in bilingual atypical reading. Other put, in all languages, reading relies on phonological processes - including the ones with clear grapheme-phoneme correspondence. Thus, more research is needed in order to clarify the extent to which orthographic depth is an influential factor in bilingual atypical reading.

The possibility of transfer of the dyslexic

weakness in decoding (CHUNG; HO, 2010; JOSHI; PADAKANNAYA; NISHANIMATH, 2010; TAINTURIER; ROBERTS; LEEK, 2011; VAN SETTEN *et al.*, 2017) and the fact that it is modulated by language consistency (VALDOIS *et al.*, 2014; LALLIER *et al.*, 2018) has its implications for education. Language teachers need to be aware of the differences in orthographic depth between the learners' L1 and L2, especially in the case of dyslexic readers. Importantly, and as stated by some researchers, dyslexic bilinguals need guidance to develop metacognitive awareness, making use of strategies to cope with their difficulties in reading.

This review scrutinized the current rationale underlying studies in dyslexia, supporting the claim for its phonological component, the role of the visual attention span, its neurological underpinnings and its relation with bilingualism. As stated by Joshi, Padakannaya and Nishanimath (2010), this reading difficulty seems to "cut across linguistic boundaries", affecting performance in languages of different consistency and granularity - variables which notwithstanding moderate the manifestations of dyslexia. Still, it remains a complex phenomenon which calls for further discussion and research, especially regarding bilingual dyslexics and how the two - or more - languages known interact and improve or impair reading ability. In addition to that, the implications of these studies for education were explored by few studies (WYDELL; BUTTERWORTH, 1999; WYDELL; KONDO, 2003; CHUNG; HO, 2010; HEDMAN, 2012). We address this issue in the next lines.

The closer dialog between research in dyslexia and education is necessary for a number of reasons. Failure in the early identification of reading difficulties at school has a range of consequences for dyslexics, starting in school and persisting throughout adult life. To be more precise, dyslexics might fall behind their peers which might lead to low self-esteem, early depression and school evasion. Regarding the latter, Pinheiro and Scliar-Cabral (2018) explain that it might contribute to positioning in the job market. Although educators play an essential

role in early identifying this reading difficulty, investments in education are fundamental to guarantee physical infrastructure for dealing with reading difficulties. Last, we share Maia's (2018) expectations, as put in the foreword of *Psicolinguística e Educação* (our translation), that the psycholinguistic studies inspire both educators and policymakers so as to ensure full support to Brazilian students, acting as an instrument for social change.

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