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The relationship between Developmental Language Disorder and Dyslexia in European Portuguese school-aged children

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Abstract

Developmental Language Disorder[1] (DLD) and dyslexia are neurodevelopmental disorders which show similar behavioural manifestations. In this study, between-group comparisons and frequency analysis were combined to investigate the relationship between DLD and dyslexia. European Portuguese children aged 7-10 years, with DLD (N = 7) or dyslexia (N = 11) were recruited and compared to age-matched typically developing (TD) children (N = 21) on phonological processing, language and literacy measures. The between-group comparison revealed that for phonological processing, the clinical groups scored significantly below TD children on most tasks, yet the DLD group performed similarly to TD children for RAN speed and digit span. The clinical groups did not statistically differ in their phonological processing abilities. For language abilities, children with dyslexia did not differ from TD children, whilst children with DLD performed significantly below TD children on all measures and significantly below children with dyslexia for vocabulary. Finally, for literacy measures, there were no statistical differences between clinical groups which underperformed on all measures when compared to TD children. The frequency analysis showed that children with DLD exhibited a lower prevalence of RAN difficulties when compared to children with dyslexia, whilst children with DLD tended to show more frequent nonword repetition and phoneme deletion deficits. Additionally, whilst children with DLD consistently showed more prevalent language impairments, both clinical groups demonstrated similar prevalence rates of literacy deficits compared to TD children.

These findings lend support to the additional deficit model of Bishop and Snowling (2004) as children with DLD show more severe and prevalent language impairments than those with dyslexia, despite similar phonological and literacy difficulties.

Keywords: dyslexia, developmental language disorder, comorbidity

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[1] Also referred to as Specific Language Impairment (SLI)

1.1 Introduction

DLD is a neurodevelopmental disorder which affects the typical development of language abilities, despite normal nonverbal intelligence, hearing and environmental conditions (Bishop & Hayiou-Thomas, 2008) and that significantly impacts everyday social interactions and/or academic progress (Bishop, Snowling, Thompson, & Greenhalgh, 2017). However, recently the discrepancy criteria with nonverbal ability has been put into question as the level of nonverbal skills is not a reliable predictor of potential nor does it determine prognosis (Bishop, Snowling, Thompson, & Greenhalgh, 2016).

Children with DLD tend to display a wide range of receptive and expressive language deficits (Bishop et al., 2017), namely syntactic impairments (Van der Lely, 2005), reduced vocabularies (Coady, 2013), word finding difficulties (Marinellie & Johnson, 2002), phonological processing deficits (Claessen et al., 2013), which often persist into adulthood (Simkin & Conti-Ramsden, 2006). Given the highly heterogeneous profile of language impairments and the lack of agreement on the criteria used to identify and classify these difficulties, despite their high incidence in children, the CATALISE consortium has aimed to achieve consensus amongst experts to ensure adequate prevention and intervention practices (Bishop, Snowling, Thompson, & Greenhalgh, 2016). Nonword repetition, sentence repetition and grammatical inflection production have been explored as potential clinical markers for language impairment due to their strong genetic influence and independence of social background (Bishop, Adams, & Norbury, 2006). Additionally, nonword repetition has been shown to discriminate between parents of children with and without DLD, even in the absence of personal history of language impairments, thus providing evidence that nonword repetition may serve as a marker of familial risk for DLD (Barry et al., 2007; Leonard, 2014).

The heterogeneous symptomatology of DLD may be related to its neurological underpinnings as multiple structural and functional differences have been found in individuals with this disorder, including, but not limited to, smaller triangularis in the left hemisphere (Gauger et al., 2016); more frequent rightward asymmetry of language structures (Gauger et al., 2016); and atypical structure and function in the left inferior frontal and superior temporal areas (Badcock et al., 2012).

Considering that oral language skills can affect decoding and reading comprehension (Hulme & Snowling, 2016), when language difficulties persist beyond the preschool years, children with DLD are at greater risk for later literacy and academic difficulties (Rice, Taylor & Zubrick, 2004). In a longitudinal study, Hulme, Nash, Gooch, Lervåg and Snowling (2015) observed that language skills at 3.5 years was a significant predictor of the foundations for decoding (letter knowledge, RAN and phoneme awareness), whilst decoding skills at the age of 5.5 years were predicted by letter knowledge and phoneme awareness at 3.5. Finally, decoding at 5.5 and language at 3.5 were predictors of reading comprehension at 8 years of age. The risk of developing literacy difficulties increases with the number of impaired language domains (Botting et al., 2006). In cases where language impairments continue to school-entry, McArthur and colleagues (2000) observed that approximately 50% of the population may manifest reading difficulties beyond reading comprehension, which is common amongst this population (Leonard et al., 2013). Nonetheless, despite the high incidence of reading impairments in this population, some children with DLD still manage to develop adequate, or at least low average, reading and spelling abilities (Botting et al., 2006)

Similarly to DLD, developmental dyslexia is a specific learning disability with a neurological basis (Krishnan et al., 2016), characterised by difficulties with accurate and/or fluent word reading and poor spelling (Peterson & Pennington, 2012); and consistently accompanied by deficits in phonological awareness and rapid automatized naming (Araújo & Faísca, 2019; Landerl et al., 2013; Pennington & Lefly, 2001; Spanoudis et al., 2019).

According to the dual/route model (Coltheart, Rastle, Perry, Langdon & Ziegler, 2001), the literacy difficulties emerge due to an impaired orthographic and/or phonological procedure.

Thus, whilst the former individuals – children with surface dyslexia - show preserved nonword reading and impaired irregular word reading; the opposite pattern is observed in children with phonological dyslexia. Those with a mixed profile present impaired performance on both tasks (Sprenger-Charolles et al., 2011). These difficulties are not attributable to a general intellectual or sensory impairment nor to the lack of exposure to appropriate education (Williams & O'Donovan, 2006). Furthermore, even though reading comprehension is not one of the core problems associated with dyslexia, the inaccurate and slow word reading can ultimately impede adequate reading comprehension (Snowling, 2013).

Similarly to children with DLD, children with dyslexia are at increased risk for language impairments as the phonological difficulties experienced by children with dyslexia and their limited reading experience (Huettig et al., 2018) may have repercussions for language development, such as vocabulary (Snowling et al., 2016). Among British school-age children, DLD and dyslexia show similar prevalence rates of approximately 5% (Barry et al., 2007), with similar rates being found in the Portuguese population for dyslexia (Vale et al., 2011). No such study has been conducted for DLD in the Portuguese population. Prevalence increases to 30-50 % in first-degree relatives of individuals with dyslexia (Barry et al., 2007) and individuals with DLD (Snowling et al., 2007).

A neuroimaging meta-analysis has observed a universal underactivation in the left occipitotemporal cortex (including the visual word form area) in individuals with Dyslexia, with distinct brain dysfunction patterns depending on orthography depth (Martin et al., 2016). Orthographic consistency has been shown to influence the rate of reading acquisition across languages (Ziegler & Goswami, 2005) with children from the majority of more transparent European orthographies showing better foundation level accuracy and reading fluency when compared to children from deeper orthographies (such as English) (Seymour et al., 2003).

Based on orthographic and phonemic properties of European Portuguese this language is considered an asymmetric orthography of intermediate depth (Castro & Gomes, 2000;

Fernandes et al., 2008; Seymour et al., 2003), as it is more irregular for spelling than for reading (Albuquerque, 2012; Seymour et al., 2003; Sucena et al., 2009). Thus, one would expect children with reading impairments to show more marked spelling than reading difficulties (Landerl & Wimmer, 2008). Accordingly, Sucena and colleagues (2009) analysed the reading performance of European Portuguese children with and without reading impairments and found an intermediate pattern of performance in comparison to other languages. Since, as is the case with shallow languages, reading impairments in European Portuguese did not impede the development of decoding abilities at the level of normal beginning readers but, as is observed in more opaque languages, it precluded the adequate development of the orthographic lexicon.

1.2 Relationship between DLD and dyslexia

The relationship between DLD and dyslexia has been frequently analysed as these disorders have shown similarities at various levels (Catts et al., 2005; Spanoudis, Papadopoulos, & Spyrou, 2019). Firstly, language and reading impairments tend to have similarities at the diagnostic level, with both being diagnosed by exclusion criteria which may contribute to both populations being highly heterogeneous (Spanoudis, Papadopoulos, & Spyrou, 2019) and their aetiology unknown (Bishop, 2017; Catts et al., 2017). Plus, both disorders present similar prevalence rates in the general population and in first-degree relatives of individuals with dyslexia and DLD (Barry et al., 2007). Additionally, as previously mentioned, both children with dyslexia and children with DLD are at greater risk of showing comorbid language and reading impairments (Tomblin et al., 2000).

In addition, across languages, children with language and/or reading impairments have shown underlying similar phonological difficulties (eg. Brizzolara et al., 2006), especially in phonological short-term memory (Marshall et al., 2010), as well as deficits in working memory (DLD: eg. Baird et al., 2010; dyslexia: eg. Fostick & Revah, 2018), executive function and attentional control (DLD: Snowling et al., 2019; dyslexia: Romani et al., 2011).

Different explanatory models of the relationship between dyslexia and DLD have been proposed. The severity hypothesis proposes that dyslexia and DLD, grouped as language learning disorders, show no aetiological distinctions ((Tallal & Benasich, 2002), corresponding to variations in severity of the same underlying disorder, a phonological processing deficit, with DLD representing a more severe form of the impairment (Bishop and Adams, 1990). Thus, depending on the severity of the underlying disorder, children would present a reading impairment with intact language skills (dyslexia), where their phonological processing deficit would manifest itself in a greater difficulty in mapping speech sounds onto letters; or DLD where children experience difficulties in both language and reading abilities (Brizzolara et al., 2011; Catts et al., 2005). According to this model, the speech-sound representations of children with DLD may make it more difficult for children to process other people's speech, thus impairing language development (Tallal, 2000). Consequently, from this model, it would be expected that children with DLD always present reading difficulties and that both groups would present impaired in phonological processing tasks even though the children with DLD would be expected to show more marked difficulties (Catts et al., 2005).

Alternatively to the severity hypothesis, which proposes that dyslexia and DLD are on a single continuum, Bishop and Snowling's two-dimensional model (2004) postulates that dyslexia and DLD are distinct disorders that occupy different areas of a two-dimensional space, whilst showing similarities at the behavioural level. Therefore, while both disorders share a phonological processing deficit underlying the reading impairment, children with DLD are postulated to show an additional and independent cognitive deficit that causes language difficulties (Dorothy V.M. Bishop & Snowling, 2004). Similarly to the severity hypothesis, the two-dimensional model predicts a significant overlap between these disorders (Catts et al., 2005). However, this model does not specify whether the severity of the phonological difficulties differs between the two disorders. It also considers the phonological and language dimensions as being independent, thus not taking into consideration the impact of the relationship between the two domains (Nash et al., 2013).

The comorbidity model presents an alternative explanation for the relationship between DLD and dyslexia, positing that these represent distinct disorders with different cognitive deficits and behavioural manifestations (Catts et al., 2005; Nash et al., 2013), which can exist alone and simultaneously (Ramus et al., 2013). According to this model, dyslexia presents a core deficit in phonological processing abilities whilst DLD comprises different underlying deficit(s) that cause problems with language development (Catts et al., 2005). Furthermore, this model posits that the high overlap between the two disorders is a consequence of comorbidity, which refers to co-occurrence at greater than chance frequency of these two independent disorders (Catts et al., 2005). Pennington and Bishop (2009) provide a good insight into different comorbidity models that grant further explanations for the relationships between disorders that co-occur with more than average chance.

Finally, the multiple deficit model (Pennington, 2006) proposes that the aetiology of these developmental disorders is multifactorial, involving the interaction of multiple genetic or environmental risk and protective factors. Thus, according to this model the comorbidity arises because both disorders share one or more deficits, which in the case of dyslexia and DLD may entail, but not be reduced to, the co-occurring difficulties in phonological processing.

1.3 The present study

This study focuses on the relationship between DLD and dyslexia; both profiles tend to show similarities at the behavioural (e.g., reading, spelling) and cognitive level (e.g. phonological awareness, short-term memory) which has led researchers and clinicians to question whether DLD and dyslexia represent different manifestations of the same disorder, as proposed by the severity model (Tallal et al., 1996), or whether these represent distinct disorders, as proposed by the additional model (Bishop & Snowling, 2004), comorbidity model

(Catts et al., 2005) and multiple deficit model (Pennington, 2006). Thus, in order to better understand the relationship between these disorders and possibly analyse which explanatory model best fits the results, a comparison of language and literacy measures between school-aged European Portuguese speaking children with DLD and children with dyslexia was conducted. Furthermore, this study represents the first research on this topic conducted in European Portuguese, a more transparent orthography than English (Albuquerque, 2012). Given the impact of orthographic depth on literacy acquisition (e.g. Ziegler et al., 2010), it is thus important to examine whether the relationship between DLD and dyslexia varies in different orthographies.

Two sets of analyses were adopted to better understand the profiles of children with dyslexia and DLD: group comparisons and within-group analyses. Given that both groups are highly heterogeneous, it is essential to both understand not only the severity of the disorders but also their prevalence, as these different components of phonological processing, language and literacy skills may not be impaired to the same degree in all children.

Research questions:

1. Do children with dyslexia show more severe phonological impairments, particularly in phonological short-term memory (nonword repetition and digit span), rapid automatized naming, phoneme deletion, than children with DLD, as expected by the findings of studies with similar designs contrary to the predictions of the severity model (Tallal et al., 1996)?
2. Do children with dyslexia show language impairments, on measures of comprehensive grammar, expressive semantics or morphosyntax, contrary to what is expected by the severity (Tallal et al., 1996), the additional deficit (Bishop & Snowling, 2004) and the comorbidity (Catts et al., 2005) model?

3. Do children with DLD show intact phonological and/or literacy abilities, contrary to what is expected by the severity (Tallal et al., 1996) and the additional deficit (Bishop & Snowling, 2004) model?
4. Do children with dyslexia present more severe reading and spelling impairments than children with DLD, in similarity with the results from Bishop et al. (2009)?

Method

Participants

The present study comprises three different groups of children: 7 children with DLD, 11 children with dyslexia and 21 age-matched TD children. The children included in the study were second, third and fourth graders with a chronological age between 88 and 136 months. All children were monolingual European Portuguese speakers attending regular Portuguese elementary schools with non-verbal intelligence within normal limits (above the 16th percentile) ascertained through the application of Raven's Coloured Progressive Matrices (Raven, Raven & Court, 2009). In order to ensure that the groups were comparable except for diagnostic criteria, they were matched for age, gender, nonverbal abilities, as well as parental education and occupation (Table 1). The differences between groups for maternal education did not reach significance after controlling for multiple comparisons. Parental education was coded based on the level of education that the parents attained before leaving school, with an increasing order (from 1-completion of first cycle to 5-university frequency) representing more levels completed according to the Portuguese school system. In contrast, parental professions were coded based on the Portuguese Classification of Professions (Instituto Nacional de Estatística, 2010), with an increasing order corresponding to less specialised professions.

The age-matched TD group consisted of children with no history of language and speech difficulties according to parents and teachers report. Children with DLD and dyslexia included in the study all had a previous clinical diagnosis of DLD or dyslexia. Children with DLD had been on average diagnosed 22 months (range: 3-49 months) before assessments, whilst an average of 12 months (range: 2-17 months) had passed since children with dyslexia had been diagnosed. Finally, no participating children showed evidence of sensory/motor disorders or severe environmental deprivation as reported by teachers or parents. All groups comprise children from both the coastal line and more interior region. Children were allocated to either clinical group based on previous clinical diagnosis however, as will be evident in the within-group analysis, both clinical groups included children with comorbid reading and language difficulties as observed in task performance (performance 1.5 SD deviations below the mean; Table 6), with this pattern being more evident in the DLD group. The high level of unanticipated comorbidity may have derived from the fact that, commonly, in Portugal, Speech and Language Therapists are the professional group with primary responsibility for the diagnostic and intervention in language disorders, in similarity to other countries (Bishop et al., 2016); whilst children with dyslexia tend to work primarily with Psychologists.

Six children were excluded from the study: three children with dyslexia were removed from the study - one child with dyslexia was excluded from the study because it was not possible to completely evaluate their performance due to parental time restrictions; two children with dyslexia were excluded as their nonverbal intelligence was below the normal range on Raven's Coloured Progressive Matrices (these children scored on the 4^{th} and 10^{th} percentile) (Raven, Raven & Court, 2009); finally, three children who were identified as having a typical development by their parents and teachers showed below average performance on a few dependent tasks thus were not be included in the TD group.

One of the children with dyslexia had a speech impairment which made scoring his answers with reliability difficult, therefore the children's results were excluded from statistical analysis for the phoneme deletion and nonword repetition tasks. Additionally, the results for this participant and an additional child with dyslexia were removed for the reading tasks due to severe reading difficulties. The scores of these participants were included in the remaining analyses.

Ethical clearance for the study was provided by the Research Ethics committee at the University of Sheffield. Parents were invited to take part in the study by their children's teacher or Speech and Language Therapist, with the necessary written information, (i.e. information sheet, consent form, and questionnaire) being delivered before the session. Verbal consent was also obtained from the children.

Materials and Procedures

Firstly, in order to obtain more information about the environment and upbringing of the children, a parent questionnaire was constructed. The questionnaire focussed on gathering information regarding the family's place of residence, parent's schooling years, current professional situation, child's kindergarten frequency (as it is not mandatory in Portugal), family and child medical history. The information obtained with the questionnaire helped determine whether the child presented further developmental or environmental problems that would interfere with the language or literacy development. In such cases, the child would be excluded from the study since the inclusionary criteria were not met.

Secondly, a variety of tasks was used to measure children's nonverbal, phonological, language, and literacy abilities. This was carried out in a single session of approximately 1 hour, with children being advised to take a break anytime they felt it to be necessary. The administration order of the following tasks was random, except for Raven's Coloured Progressive Matrices (nonverbal intelligence; Raven, Raven & Court, 2009, in order to avoid confounding factors related to order of task presentation. The Raven's Coloured Progressive Matrices were always administered first as this allowed the exclusion of participants who did not meet the inclusion criteria, i.e. nonverbal intelligence above the 16th percentile. Furthermore, children were assessed in a quiet environment at the child's school or at a Speech and Language Therapy office.

Nonverbal intelligence

Nonverbal intelligence was assessed by Raven's Coloured Progressive Matrices (Raven, Raven & Court, 2009), with children below the 16th percentile being excluded from the study. Based on the criteria established for non-verbal intelligence, three children were excluded from the study. Such a precaution is common, to minimise the risk that the difficulties these children present are not just a manifestation of generalised lower functioning (Bishop et al., 2009).

Phonological processing skills

Phoneme deletion tasks

Children's phonemic deletion abilities were assessed using the two versions of the Bateria de Supressão Fonémica (Vale, 2016a; 2016b). Two phoneme deletion tasks were used, a nonword phoneme deletion task and a word phoneme deletion task, each of these comprising 24 items, arranged in increasing order of difficulty. The phonemes to be deleted were consonants and occupied the following positions: eight in the initial, final and intermediate position. In both tasks, children completed three practice items for this test, where the experimenter corrected any errors made, after those items no feedback was given. After five consecutive errors the task was discontinued.

In the nonword phoneme deletion task the experimenter orally presented nonword and asked the child to remove a specific phoneme and tell the experimenter the resulting phonological string. As an example: "nar" without the "n" would result in "ar". In the word phoneme deletion task, the opposite occurred, the experimenter asked the child to remove a specific phoneme from a word and the child was expected to say the resulting nonword. One point was attributed to each correct response. In cases when children provided more than one answer, only the last response was taken into account.

The order of presentation of the phoneme deletion tasks was random so that confounding variables, such as tiredness, practice effects or interactions between both tasks, could be avoided.

The internal reliability for both tasks was measured using Kuder–Richardson Formula 20 as it was treated as a dichotomous variable. The results show good internal reliability for both tasks, for the nonword phoneme deletion task ρKR_{20}= .81 and for the word phoneme deletion ρKR_{20}= .88.

Short-term Memory tasks

Two distinct tasks were selected to assess children's auditory and phonological short-term memory through a digit span task from WISC-III (Wechsler, 2004) and a nonword repetition task from the PAL-PORT - Bateria de Avaliação Psicolinguística das Afasias e de outras Perturbações da Linguagem (Festas, Leitão, Formosinho, Albuquerque, Vilar, Martins et al., 2006), respectively.

The list of nonwords from the PAL-PORT - Bateria de Avaliação Psicolinguística das Afasias e de outras Perturbações da Linguagem (Festas, et al., 2006) an adaptation of the PAL (Psycholinguistic Assessment of Language) (Caplan, 1992) was used. This list was originally intended for spelling purposes. It consists of a list of 56 disyllabic nonwords that vary in phonological complexity. Children were told that they would be presented with made-up words that they should repeat exactly, with one point being given per correct response. Each word was presented live to the child, with no repetitions of the nonwords being allowed.

For data analysis only 52 nonwords were used as the internal reliability for the 56 nonwords was below the recommended threshold (.70; Tavakol & Dennick, 2011). After the elimination of the recommended items the internal reliability for the nonword repetition task is considered adequate (ρKR_{20}= .70).

Rapid Automatised Naming (RAN) tasks

The Bateria de Avaliação Neuropsicológica de Coimbra - Coimbra's Neuropsychological Assessment Battery (BANC; Simões et al., 2008) was administered as a measure of the child's Rapid Automatised Naming (RAN) skills. The battery includes two RAN tests (colours and digits). In each test, the child is asked to name as fast as possible, with the time on task, 50 visual stimuli presented on a card and organized in five lines with 10 stimuli each, which are repeated in random sequences. The stimuli of the RAN digit test are 2, 4, 6, 7 and 9. The stimuli of the RAN colour test are blue, yellow, red, black, and green. The time spent on task was recorded.

The results in the digit rapid naming task of one child with dyslexia were not used as the child's knowledge of numbers was insufficient to complete the task.

Letter knowledge

The letter knowledge task from ALEPE - Avaliação da Leitura em Português Europeu (Sucena & Castro, 2012) was used to assess children's knowledge of letter names or sounds. In this task, children were given 23 cards with a single lower-case letter on it and asked which letter it was. Both the name and the sound of the letter were accepted responses. The cards were given to the child in random order. One point was given to each correct response.

Language skills

Listening Comprehension task

The Portuguese version of The Test for Reception of Grammar (TROG; Bishop, 1983) was used to assess oral comprehension of syntax. This is a multiple-choice test in which the child is shown four pictures while a sentence is read aloud by the examiner. The child is then required to select the picture that illustrates the sentence. The level of complexity increases progressively. The items cover a range of grammatical knowledge and responses are scored as correct or incorrect, with a maximum score of 80. A block is only considered passed if the child responds correctly to all items within that block. The assessment is interrupted after 5 consecutively failed blocks.

Expressive Morphosyntax task

The morphosyntactic task – "Reflexão morfossintática" of the Avaliação da Linguagem Oral (Oral language evaluation) (Sim-Sim, 2006) was also used to assess children's language competencies. In this task the child is asked to judge whether the sentences said by the investigator are grammatically correct and if they are not, the error is expected to be detected and corrected. The task is composed of 22 items, of which 3 are considered to be control items. Furthermore, the investigator provides the child with three examples of agrammatical phrases and their correction before the start of the task. The scoring method used consisted of giving 1 point to the correct decision regarding the grammaticality of the sentence, after that, each correction could be given 0 points if the correction was incorrect; 0.5 points when the changes made by the child resulted in a grammatical sentence different from the goal and 1 point when the child was able to correct the errors and provided the expected answer. Control phrases were assigned with 1 point when the child was able to correctly determine that no error was present.

Expressive Vocabulary task

Expressive vocabulary was tested with the vocabulary subtest of the Portuguese standardization of Wechsler Intelligence Scales for Children (Wechsler, 2004). The vocabulary subtest from WISC-III (Wechsler, 2004) is a measure of the child's verbal fluency, word knowledge, and word usage (Nicholson & Alcorn, 1994). The child is asked to give oral definitions of 30 words. Scoring varies between 0 and 2 according to the quality of the responses. The task is interrupted after 4 consecutive incorrect responses.

Literacy skills

Reading tasks

Reading of words, nonwords and connected text were assessed by means of 2 Portuguese batteries. The Prova de Análise e Despiste de Dislexia (Carreteiro, 2005) was used to evaluate children’s word and nonword reading abilities, whilst the timed text O Rei (Carvalho, 2010) was chosen to evaluate children’s reading fluency and accuracy.

In the tasks of word and nonword reading one point was given to each word or nonword read correctly. The maximum score for word reading was 73 points whilst only 37 for the nonword reading task. In the text reading, on the other hand, one point was given to each word incorrectly read. Additionally, it was also registered the time each child took to read the text of 281 words.

The internal reliability was measured the word (ρKR_{20}= .88) and nonword (ρKR_{20}= .86) reading tasks, with results showing good reliability scores for both tasks.

Spelling tasks

The word spelling task from (Albuquerque, 2012) consists of thirty-four multisyllabic words that were dictated one-by-one to the child, giving the children enough time to spell the words without time pressure. Factors such as word regularity, extension, frequency and syllable structure were considered for word selection. Words were considered irregular when its spelling did not follow the rules of European Portuguese grapheme-phoneme correspondence. According to Albuquerque (2012), 73.52 % of the words have high or intermediate frequency and 67.55% a CV syllable structure. One point was given to each word correctly spelled. Accentuation errors were counted and analysed separately from spelling errors.

The internal reliability was measured for both regular (ρKR_{20}= .86) and irregular (ρKR_{20}= .79) words, indicating good reliability for both tasks.

Results

The descriptive statistics for the control (age and nonverbal IQ) and dependent variables namely phonological processing, language and literacy skills are presented in Tables 2-5, including the mean, median and standard deviations (SD), as well as the significance of the differences between the groups and effect sizes.

Prior to statistical analyses of the raw scores, outliers were detected for experimental variables through the analysis of scatter plots and z-scores. For the purpose of the current study, outliers were defined as coefficients beyond at least 2.33 SD below or above the group's mean, thus representing the bottom/top 1% of the data. Since the presence of outliers may be unrepresentative and detrimental to statistical analysis, winsorisation of the extreme values was conducted by replacing the outliers by the value correspondent to 2.34 SD above or below the group's mean (Field, 2018). Only 2.63% of the RAN digit accuracy data and 2.56 % of the letter knowledge data was winsorised. The data in Tables 3-5 contain all data post-winsorisation.

Due to the presence of nominal/ordinal variables in the control data, and some non-normal variables – namely all measures of RAN except colour RAN speed, nonword repetition, letter knowledge, morphosyntax, spelling of regular words and word accentuation - amongst the experimental measures, to examine the differences between groups Kruskal-Wallis tests were conducted. Where the difference between the groups was significant, the Kruskal-Wallis tests were followed by Mann-Whitney tests for pairwise comparisons. A p-value cut-off of .05 was adopted and corrected for multiple comparisons using the Bonferroni approach as suggested by Field (2018). Effect sizes were calculated according to Tomczak and Tomczak (2014).

Additionally, a within-group analysis of the frequency of deficits within clinical groups was performed. A deficit was considered to be present, when the score obtained by the child was at least 1.5 SD above – a criteria used only for measures of speed or number of errors produced – or below the mean of the age-matched TD group. The adoption of this cut-off value was done for comparability purposes with previous work (e.g. Ramus et al., 2013; Talli et al., 2016).

Dependent variables

Phonological processing skills

Group comparisons

The Kruskal-Wallis tests revealed no significant differences between groups on RAN accuracy (colours, $\chi^2(2) = 2.67$, $p = .26$, $\eta^2 = .02$, and digits, $\chi^2(2) = 3.39$, $p = .18$, $\eta^2 = .04$); and letter knowledge, $\chi^2(2) = 4.36$, $p = .11$, $\eta^2 = .07$. Yet, a group effect was found for RAN speed for colours, $\chi^2(2) = 12.52$, $p = .002$, $\eta^2 = .29$; and digits, $\chi^2(2) = 9.71$, $p <.001$, $\eta^2 = .22$; word phoneme deletion accuracy $\chi^2(2) = 21.36$, $p <.001$, $\eta^2 = .55$; nonword phoneme deletion accuracy, $\chi^2(2) = 24.25$, $p <.001$, $\eta^2 = .64$; digit span, $\chi^2(2) = 10.45$, $p = .005$, $\eta^2 = .23$; nonword repetition, $\chi^2(2) = 15.12$, $p = .001$, $\eta^2 = .37$.

Post-hoc comparisons (Mann-Whitney U tests) revealed significant differences between the performance of each of the two clinical groups and the TD group for nonword ($U = 0.50$, $p <.001$, $r = -.74$ for DLD vs TD; $U = 12.50$, $p <.001$, $r = -.58$ for dyslexia vs TD) and word phoneme deletion ($U = 2.50$, $p <.001$, $r = -.72$ for DLD vs TD; $U = 26.00$, $p <.001$, $r = -.60$ for dyslexia vs TD); and nonword repetition ($U = 16.50$, $p =.001$, $r = -.58$ for DLD vs TD; $U = 31.00$, $p = .001$, $r = -.57$ for dyslexia vs TD). For RAN speed (colours RAN: $U = 38.00$, $p = .001$, $r = -.54$; digits $U = 42.50$, $p = .007$, $r = -.48$); and digit span, $U = 35.50$, $p = .001$, $r = -.56$, the performance of children with dyslexia was significantly different than TD children, while children with DLD and TD performed similarly on these measures after correction for multiple comparisons (p = .05/11 = .0045) (RAN speed colours: U = 25.50, p = .008, r = -.48; RAN speed digits U = 30.50, p = .02, r = -.43; and digit span, U = 41.00, p = .09, r = -.33). No significant differences were found between clinical groups on phonological reading related skills after corrections for multiple comparisons (colour RAN speed: U = 37.00, p = .93, r = -.03; digit RAN speed: U = 30.00, p = .669, r = -.12; digit span: U = 37.00, p = .93, r = -.03, nonword phoneme deletion: U = 25.00, p = .37, r = -.24; word phoneme deletion: U = 14.00, p = .043, r = -.50).

Within-group analyses

Frequency of letter knowledge deficits was considerable in both groups, with a higher incidence in children with dyslexia – DLD: 28.6%; dyslexia: 45.5%. A similar pattern was observed for RAN abilities. Whilst the frequencies of the rapid naming deficits were similar for both groups for digit RAN accuracy and for colour RAN speed skills, digit RAN accuracy deficits – DLD: 20% vs dyslexia: 45.5% – and colour RAN speed deficits – DLD: 28.6% vs dyslexia: 50% – were more frequent in the dyslexic group than in the children with DLD.

A distinct pattern was observed for phoneme awareness, with impairments for both nonword phoneme deletion – DLD: 100%; dyslexia: 80% – and word phoneme deletion – DLD: 85.7%; dyslexia: 60% – being more frequent in the DLD group than in the group of children with dyslexia. Similarly, the incidence of nonword repetition deficits is considerably higher in children with DLD than in children with dyslexia – DLD: 71.4%; dyslexia: 30%.

Finally, similar percentages of children with deficits in digit span abilities were found in both clinical groups – DLD: 57.1%; dyslexia: 63.6%.

Language skills

Group comparisons

A significant group effect was found for TROG, $\chi^2(2) = 11.53$, $p = .003$, $\eta^2 = .26$, for vocabulary, $\chi^2(2) = 15.41$, $p < .001$, $\eta^2 = .37$; and morphosyntax, $\chi^2(2) = 14.48$, $p = .001$, $\eta^2 = .35$.

The Mann-Whitney revealed that the group with DLD significantly underperformed when compared to TD children on all language measures, TROG: $U = 14.00$, $p < .001$, $r = -.60$; vocabulary: $U = 5.00$, $p < .001$, $r = -.69$; morphosyntax: $U = 3.00$, $p < .001$, $r = -.71$. No significant differences were found between clinical groups for TROG: $U = 15.50$, $p = .04$, $r = -.49$ and morphosyntax $U = 14.00$, $p = .03$, $r = -.52$. For vocabulary, children with DLD underperform when compared to children with dyslexia, $U = 8.50$, $p = .004$, $r = -.64$ and age-matched TD children, $U = 5.00$, $p < .001$, $r = -.69$.

No differences were found between age-matched TD children and children with dyslexia for each of the language measures (TROG: $U = 74.50$, $p = .104$, $r = .30$; vocabulary, $U = 72.50$, $p = .09$, $r = -.30$; morphosyntax $U = 76.50$, $p = .123$, $r = -.27$).

Within-group analyses

The results of the frequency analyses of the deficits within-groups revealed a higher prevalence of language impairments in the DLD group, with the majority of children with DLD showing impairments on each of the language measures: TROG – DLD: 85.7%; dyslexia: 45.5%; vocabulary – DLD: 85.7; dyslexia: 36.4% – and expressive morphosyntax – DLD: 85.7%; dyslexia: 27.3%.

Literacy skills

Group comparisons

A highly significant group effect was found for word reading, $\chi^2(2) = 26.43$, $p<.001$, $\eta^2=.72$, nonword reading, $\chi^2(2)= 22.05$, $p<.001$, $\eta^2=.59$, reading accuracy, $\chi^2(2)= 21.76$, $p<.001$, $\eta^2=.58$, and speed, $\chi^2(2)= 19.52$, $p<.001$, $\eta^2=.52$; spelling of regular words, $\chi^2(2)= 21.72$, $p<.001$, $\eta^2=.55$, spelling of irregular words, $\chi^2(2)= 24.68$, $p<.001$, $\eta^2=.63$, and for word accentuation, $\chi^2(2)= 19.25$, $p<.001$, $\eta^2=.49$.

Post hoc comparisons for literacy measures, revealed that age-matched TD children show a significantly higher mean than children with dyslexia (word reading: *U*=1.00, *p*<.001, *r*=-.78; nonword reading: *U*=12.00, *p*<.001, *r*=-.68; reading accuracy: *U*=11.00, *p*<.001, *r*=-.69; reading speed: *U*=16.50, *p*<.001, *r*=-.64; spelling regular words: *U*=21.00, *p*<.001, *r*=-.67; spelling irregular words: *U*=13.00, *p*<.001, *r*=-.74; word accentuation: *U*=17.50, *p*<.001, *r*=-.69) and children with DLD (word reading: *U*=0.00, *p*<.001, *r*=-.74; nonword reading: *U*=3.50, *p*<.001, *r*=-.70; reading accuracy *U*=6.00, *p*<.001, *r*=-.68; reading speed: *U*=7.50, *p*<.001, *r*=-.66; spelling regular words: *U*=4.00, *p*<.001, *r*=-.71; spelling irregular words: *U*=1.00, *p*<.001, *r*=-.73; word accentuation: *U*=20.50, *p*=.003, *r*=-.55) on all literacy measures. No differences were found between clinical groups (word reading: *U*=27.50, *p*=.68, *r*=-.11; nonword reading: *U*=28.00, *p*=.71, *r*=-.09; reading accuracy, *U*=22.50, *p*=.35, *r*=-.24; reading speed: *U*=31.00, *p*=1.00, *r*=-.01; spelling regular words: *U*=37.50, *p*=.93, *r*=-.02; spelling irregular words: *U*=31.50, *p*=.54, *r*=-.15; word accentuation: *U*=27.50, *p*=.36, *r*=-.22).

Within-group analyses

The rates of incidence were equal for both clinical groups, with all children in both groups showing impairments in word and nonword reading abilities – DLD: 100%; dyslexia: 100%.

The incidence rates of speed impairments in text reading are similar amongst children with DLD and children with dyslexia, being only slightly lower in children with DLD – DLD: 71.42%; dyslexia: 77.8%. For text reading accuracy, children with DLD showed more frequent text reading accuracy impairments than children with dyslexia – DLD: 85.7%; dyslexia: 66.7%.

For written abilities, there was a consistent pattern across all measures, with children with DLD showing more frequent spelling impairments for the overall task – DLD: 100%; dyslexia: 81.8; regular words – DLD: 85.7; dyslexia: 81.8; irregular words – DLD: 100%; dyslexia: 81.8%, with the exception of word accentuation DLD: 14.3%; dyslexia: 30%.

Discussion

This study aimed to explore the relationship of children with DLD and/or dyslexia in the European Portuguese language due to the lack of research on this topic. Thus, it may contribute to a better understanding of the impact of orthographic depth on the relationship between these disorders; but also brings together a more comprehensive analysis of the language and literacy abilities of children with DLD and/or dyslexia as, according to Talli et al. (2016), only a few studies have simultaneously analysed the phonological, language and literacy abilities of children with DLD and/or dyslexia. The latter may provide especially useful for clinicians given the high prevalence of comorbidity between disorders.

Hence, the composite analysis of the behavioural similarities and distinctions between dyslexia and DLD may aid the conceptualisation of these disorders within explanatory models.

Phonological abilities

It has been hypothesised that children with dyslexia show more severe phonological impairments than children with DLD (Catts et al., 2005). Nonetheless, in the present study, no statistically significant differences were found between clinical groups on all phonological processing measures, which included RAN, phoneme deletion, digit span, nonword repetition and letter knowledge. While the clinical groups underperformed in most phonological measures, both groups exhibited preserved RAN accuracy for both tasks. On the letter knowledge task, whilst the group comparison revealed no differences between clinical groups and TD children, the within-group analyses indicates that almost half the dyslexic children show impaired performance on the task. Thus, revealing individual differences in performance.

A substantial number of studies conducted in this field, across languages, also found no statistical differences between dyslexia and DLD with comorbid reading impairments on measures of phonological processing (for digit span: Rispens & Baker, 2012; for nonword repetition: Kim & Lombardino, 2013; for phoneme deletion: Catts et al., 2005; Farquharson et al., 2014; Kim & Lombardino, 2013; Robertson et al., 2013; Spanoudis et al., 2019; for RAN: Kim & Lombardino, 2013; Spanoudis et al., 2019; Talli et al., 2016).

Nonetheless, slight differences emerged in these tasks. For nonword repetition, previous studies comparing the performance of children with dyslexia and children with DLD have found two distinct profiles: children with comorbid dyslexia and DLD either perform similarly or worse than children with dyslexia. Both distinct profiles for nonword repetition performance emerged in the current study. In the statistical analysis, no significant differences were found between groups; in similarity with the results obtained by Kim and Lombardino (2013) and Spanoudis et al. (2019). However, the majority of studies found that the comorbid group tends to perform significantly worse than children with dyslexia (Nithart et al., 2009; Talli et al., 2016; Cantiani et al., 2015). On the other hand, children with DLD in the present study showed less severe impairments in colour and digit RAN speed and digit span, as no statistical differences between the performance of the DLD group and age-matched children were found.

Even though the non-significant difference between children with DLD and TD children may result from lack of power (Mccrum-gardner, 2010), this pattern was also noticeable in the frequency analysis of the phonological deficits within clinical groups as compared to TD children. Overall, in this study, children with DLD exhibited lower prevalence of RAN difficulties when compared to children with dyslexia, with the opposite pattern arising for nonword repetition and phoneme deletion.

Rapid automatized naming has been suggested to underpin some of the processes involved in reading as it involves the abilities to name as quickly as possible the visual stimuli presented to the participant (Kirby et al., 2010), thus this speed of visual activation is thought to allow the combination of letters and orthographic information into words (Wolf et al., 2000). Furthermore, RAN has been found to not only predict reading competence (Kirby et al., 2003; Kirby et al., 2008; Landerl & Wimmer, 2008) but also to underpin the brain areas thought to be impaired in dyslexia (Misra et al., 2004). Thus, the higher incidence of rapid automatized naming deficits in the group with dyslexia is not surprising (Spanoudis et al., 2019). The absence of statistically significant differences between groups with DLD and dyslexia for RAN may be related to the presence of comorbid reading impairments in the group with DLD (Spanoudis et al., 2019; Talli et al., 2016). Interestingly both groups demonstrated between performance for colour RAN than digit RAN, a pattern was also found by Brizzolara et al. (2006). This pattern could potentially explain differences in orthographic knowledge, as digit RAN has been found to be more associated with word-specific orthographic knowledge than non-alphanumeric (colour) RAN which more highly correlates with general orthographic knowledge.

The higher prevalence of nonword repetition impairments in the DLD group was expected as nonword repetition has been suggested as a clinical marker for DLD due to its high sensitivity and specificity in distinguishing between those with and without language disorders across languages (de Bree et al., 2007; Dollaghan & Campbell, 1998; Girbau & Schwartz, 2007; Weismer et al., 2000). Bishop et al. (1996) demonstrated that deficits in nonword repetition were still observed in children with a history of language impairment who no longer met the criteria for DLD, suggesting that nonword repetition may be used as a behavioural marker for heritable forms of language impairments. The distinct pattern of evidence for the two short-term memory tasks may reflect the reliance on prior lexical knowledge for the digit span task, whilst the nonword repetition task would rely on prior phonological knowledge (Archibald & Gathercole, 2007; (Deevy et al., 2010).

Overall, there seems to be a tendency for less frequent and severe scores on RAN and digit span in children with DLD when compared to children with dyslexia. Children with dyslexia, on the other hand, show less frequent phoneme deletion and nonword repetition impairments. Therefore, the better performance on digit span of children with DLD when compared to children with dyslexia may be related to an overall better processing speed ability, as observed in RAN speed measures (Montgomery & Windsor, 2007). Hence, even though the clinical groups show different profiles of phonological processing impairments, both children with DLD and children with dyslexia exhibit phonological deficits in the three main areas: manipulating phonological representations (phoneme deletion), phonological short-term memory (nonword repetition and digit span) and automatic accessing phonological representations (RAN) (Marshall et al., 2010). Finally, the presence of phonological impairments in both populations supports the explanation that difficulties in this domain may contribute to reading deficits in dyslexia and DLD (Ramus, 2003).

Language abilities

Children with DLD are expected to show more frequent and severe language impairments than children with dyslexia, as reflected by diagnostic criteria for both disorders (APA, 2013).

However, language difficulties have also been found in the dyslexic population, especially vocabulary deficits (Rice et al., 2010; van Viersen et al., 2017).

Comparisons of the language abilities of children with DLD and/or dyslexia revealed no significant differences between clinical groups on listening comprehension, assessed through the TROG. However, the raw score difference between clinical groups was relatively large, thus the non-significant result may be due to lack of power. Additionally, the frequency analysis indicates that almost twice the number of children with DLD had scores 1.5 standard deviations below TD children on the TROG when compared to children with dyslexia. This pattern of results was also found by (Robertson et al., 2013).

For expressive vocabulary, children with DLD underperformed when compared to children with dyslexia and TD children. A similar pattern was found in the frequency analysis, with vocabulary difficulties three times as prevalent in children with DLD when compared to children with dyslexia. Similar results for expressive vocabulary were found by Bishop et al. (2009). Several studies obtained analogous findings for receptive vocabulary (Fraser et al., 2010; Robertson et al., 2013; Talli et al., 2016).

For morphosyntax, in similarity with the results for TROG, children with DLD significantly underperformed when compared to TD children. No differences between clinical groups and between children with dyslexia and TD children were found. However, the practical difference between clinical groups was large, thus the non-significant pairwise comparison may be due to the sample size. The practical difference found between clinical groups is in agreement with the frequency analysis which revealed a percentage of morphosyntatic deficits 3 times higher in children with DLD when compared to children with dyslexia. Fraser et al. (2010) also found that children with DLD tend to show a worse performance on grammaticality judgement and sentence correction when compared to children with dyslexia.

These results are in conformity with the hypothesis that children with DLD exhibit more frequent and severe language impairments than the group with dyslexia (Rosen, 2003), with the performance of children with dyslexia occupying at least an intermediate position between children with DLD and TD children (Helenius et al., 2009). Although children with dyslexia have been consistently found to have reduced vocabularies (Ramus et al., 2013), in this study they showed similar scores to TD children. Nevertheless, these findings were possibly affected by the presence of comorbid language impairments, since only five children presented intact language abilities. Yet, the aetiology of the language difficulties may be distinct to those of the DLD group, as these may be a by-product of their reading problems, instead of a primary deficit as observed in DLD.

Literacy abilities

Even though it has been hypothesised that children with dyslexia show more severe literacy impairments than children with DLD (McCarthy et al., 2012), a different pattern emerged in the current study. Children with dyslexia and DLD did not significantly differ in all reading and spelling measures, with both groups underperforming when compared to the TD group. Additionally, the frequency analysis revealed that children with DLD present more prevalent difficulties with text reading accuracy and spelling of irregular words; whilst children with dyslexia showed more frequent accentuation difficulties. This may be related to the fact that all children with DLD presented comorbid reading impairments, since these children demonstrated difficulties in at least three of the seven reading and spelling tasks. Nonetheless, one child with DLD showed low average text reading accuracy, whilst another exhibited low average text reading accuracy and speed abilities.

Studies comparing the performance of children with DLD with comorbid reading impairments and children with dyslexia in decoding (Snowling et al., 2019), text reading (e.g. Talli et al., 2016), word/nonword reading (e.g. Talli et al., 2016) and spelling (McCarthy et al., 2012; Snowling et al., 2019; Spanoudis et al., 2019) also found no statistically significant differences between the groups with DLD and dyslexia.

The high incidence of children with DLD with comorbid reading impairments in this study may be due to the fact that this sample was clinically referred, whilst children with dyslexia were recruited both in schools and clinical settings. According to Ramus et al. (2013) clinically referred samples are not representative of the population with DLD, as they tend to comprise more children with comorbid reading difficulties. Thus, the lack of children with DLD without reading impairments in this study may be due to sampling instead of indicating that all Portuguese European children with DLD will present comorbid literacy difficulties. Additionally, it may indicate that the commonalities observed in this study at the level of phonological processing skills and literacy skills between clinical groups are due to the comorbidity between DLD and dyslexia, thus not ruling out the possibility that a distinct pattern of results could emerge when comparing individuals with DLD-only and those with dyslexia.

In the study conducted by Catts et al. (2005), children with DLD with preserved phonological short-term memory also showed adequate reading abilities. Nevertheless, in the current study, similarly to Talli et al. (2016), four children with DLD with preserved short-term memory (nonword repetition and/or digit span abilities) exhibited reading impairments. Yet, three of these children exhibited deficits in RAN, which is thought to independently contribute to variance in early reading skills (Petrill et al., 2006).

Finally, children from transparent languages tend to show better reading accuracy abilities than those from opaque languages, with more severe difficulties in this population manifesting in reading fluency and spelling. However, children with DLD and/or dyslexia in the present study exhibited deficits in all literacy measures, independently of the modality (Frith, 1980) thus providing evidence for a decoding deficit. Interestingly, one child showed simultaneously affected reading abilities and adequate spelling abilities, even though European Portuguese is more irregular for spelling than for reading (Albuquerque, 2012).

Relationship between DLD and dyslexia

In this section, the predictions of each explanatory model of the relationship between DLD and dyslexia will be reviewed and analysed to determine whether they are compatible with the results obtained in the current study.

The findings of the current research lend support to the view that DLD and dyslexia are separate neurodevelopmental disorders, even though they show great similarities (Bishop & Snowling, 2004), as distinct phonological processing and language profiles emerged in the pairwise group comparisons.

The severity hypothesis postulates that dyslexia and DLD should be categorised as one disorder, with DLD representing a more severe form of dyslexia. Therefore, according to this model, children with DLD are expected to present higher severity of phonological impairments when compared to children with dyslexia (Tallal, Allard, Miller & Curtiss, 1997). These premises are not in consonance with the results of the current study as children with DLD exhibit similar phonological impairments to children with dyslexia for the majority of the phonological tasks, with the exception of RAN speed and digit span, in which they showed a better performance.

Secondly, this model proposes that the reading difficulties would be more severe in children with DLD than in children with dyslexia (Catts et al., 2005). This assumption does not coincide with the results of the current study since, even though text reading accuracy and spelling deficits are more frequent in children with DLD, the statistical analysis revealed no significant differences between clinical groups.

Moreover, this model postulates that children with DLD would always exhibit reading impairments, which rejects the possibility of children with DLD presenting adequate literacy acquisition (Ramus et al., 2013). Even though previous comparative studies have comprised children with DLD in their samples (Catts et al., 2005), all children with DLD in the current research presented comorbid reading and/or spelling impairments. Even so, two children with DLD still exhibited text reading accuracy and/or fluency low average skills, which demonstrates that children with DLD may show at least a few preserved literacy abilities. Besides, the word and nonword reading tasks may have been too difficult for children with reading difficulties as all children with dyslexia and DLD scored at least 1.5 standard deviations below the mean scores of age-matched children. Finally, this model does not account for the language difficulties experienced by children with dyslexia in the current research.

The additional deficit model, proposed by Bishop and Snowling (2004), assumes that phonological processing deficits are the underlying cause of both DLD and dyslexia. Accordingly, these disorders diverge depending on the presence of comorbid language deficits, with DLD representing the population with simultaneous phonological and non-phonological (language) impairments. In the current research, phonological processing difficulties were encountered in both clinical groups, as all children with DLD or dyslexia exhibited some form of phonological processing deficits. However, this model does not specify whether the phonological processing deficits are expected to be found across all modalities in both disorders or whether different phonological profiles are expected for dyslexia and DLD. Moreover, the phonological processing deficits experienced by children with DLD and dyslexia were selective, and children showed literacy and/or language impairments independently of the modality and/or number of affected phonological processing abilities. One example of this being a child whose phonological difficulties were manifested only in digit span and nonword phoneme deletion accuracy.

Furthermore, some authors have interpreted that this model also posits that children with DLD would always show reading difficulties (Catts et al., 2005), yet, one child with DLD presents low average text reading accuracy and fluency skills, which demonstrates a somewhat preserved reading acquisition. Finally, this model, in similarity with the severity model, does not explain the existence of language impairments in children with dyslexia which were found in some children in the current research and in previous literature (eg. Spanoudis et al., 2019; Talli et al., 2016).

The comorbidity model postulates that dyslexia and DLD are two separate disorders with distinct causes and behavioural manifestations (Catts et al., 2005; Nash et al., 2013). The core deficit in dyslexia is hypothesised to be in phonological processing abilities, whilst children with DLD are thought to show impairments in language development (Catts et al., 2005). Thus, it would be expected, based on this model, that children with dyslexia display more severe phonological processing deficits. This assumption is not met in the current research, as both clinical groups present similar phonological processing deficits. Furthermore, this model only predicts the existence of language impairments in DLD, however, albeit language impairments were more frequent and severe in children with DLD, they were also found in children with dyslexia.

Although no single explanatory model could account for all the findings of the present study, the additional deficit model of Bishop and Snowling (2004) seems to be in a better position to explain the relationship between DLD and dyslexia. According to this model, children with dyslexia and DLD can be distinguished based on the performance in non-phonological language tasks. In the current study, children with DLD demonstrate more severe and frequent language difficulties across measures than children with dyslexia, as predicted by this model. Furthermore, this model also predicts the overlap between disorders at the phonological and reading level and acknowledges the possibility of these disorders showing distinct reading impairments profiles. Nevertheless, no considerations are made regarding the distinct profiles or severity of the phonological processing deficits found in these populations; nor does this model account for the language difficulties experienced by children with dyslexia.

It is also important to note that the current results can not directly speak to the reliability of the multiple deficit model (Pennington, 2006) also outlined in the introduction. This model posits a multifactorial aetiology, but without making specific predictions regarding the behavioural manifestations of DLD and dyslexia. Thus, while the model has strong explanatory breadth, it is very difficult to subject it to empirical scrutiny

The current research presents a few limitations. The recruitment of children with DLD may represent a limitation as, even though attempts were made to include children identified through schools, all children that participated in the study were clinically referred. Additionally, the study comprises only small samples of children with DLD and dyslexia, which combined with group assignment being established based on the clinicians' diagnoses, resulted in both groups comprising children with comorbid dyslexia and DLD. A larger sample size of children from these populations would have allowed further analysis of the subgroups of children without comorbid language or reading impairments.

Finally, the nonword repetition task used may represent a limitation as it contained only disyllabic nonwords. Clinical groups have been found to struggle and show distinct profiles with increasing syllable length (Catts et al., 2005).

The findings of the current study have clear implications for assessments and interventions with children with dyslexia and DLD. Some children with dyslexia presented comorbid language difficulties, hence it would be important for clinicians to conduct a more comprehensive analysis of the literacy and language abilities of children with these disorders. Furthermore, since children with dyslexia and DLD exhibited an overall phonological processing deficit, a broader analysis and intervention on both accuracy and speed modalities would be valuable for these populations. The great difficulties in identifying children with DLD in school settings may reveal that school personnel are less informed about the manifestations of language impairments when compared to dyslexia. Thus, efforts directed towards increasing the knowledge of educational professionals may prove critical for the identification and intervention with children with DLD. Finally, future studies assessing the relationship between dyslexia and DLD may additionally consider including measures beyond language and literacy, such as executive and procedural learning task as these populations have been found to show an impaired performance on these skills (Snowling et al., 2019).

Data availability statement

The data that support the findings of this study are openly available in the Open Science Framework at https://osf.io/dhx8t/, DOI 10.17605/OSF.IO/DHX8T

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Table 1. Descriptive statistics and significant differences between groups in control variables

Control variables			Groups			Group comparisons
			DLD	DD	CAC	
Age		Mean rank	13.29	21.77	21.31	$\chi^2(2) = 2.98$
		Md	96.00	108.00	109.00	$p = .23$
						$\eta^2 = .08$
Gender			-	-	-	$\chi^2(2) = 1.37$ $p = .51$ $\eta^2 = .04$
Nonverbal intelligence (raw scores)		Mean rank	10.07	19.23	23.71	$\chi^2(2) = 7.68$
		Md	23.00	29.00	30.00	$p = .02$
						$\eta^2 = .20$
Nonverbal intelligence (percentiles)		Mean rank	12.64	18.95	23.00	$\chi^2(2) = 4.51$
		Md	50.00	70.00	70.00	$p = .11$
						$\eta^2 = .12$
Parental education	Maternal	Mean rank	23.36	11.32	23.43	$\chi^2(2) = 9.52$
		Md	4.00	3.00	4.00	$p = .009$
						$\eta^2 = .25$
	Paternal	Mean rank	18.36	16.09	22.60	$\chi^2(2) = 2.72$
		Md	3.00	3.00	3.00	$p = .26$
						$\eta^2 = .07$
Parental professions	Maternal	Mean rank	18.21	23.41	18.81	$\chi^2(2) = 1.44$
		Md	5.00	5.00	5.00	$p = .49$
						$\eta^2 =.04$
	Paternal	Mean rank	16.29	23.55	19.38	$\chi^2(2) = 2.02$
		Md	5.00	7.00	5.00	$p = .36$
						$\eta^2 =.05$

Notes. DLD – Developmental Language Disorder; DD – Developmental Dyslexia; CAC – Chronological age controls

Table 2. Descriptive statistics for children with DLD, children with dyslexia and age-matched TD group

Control variables		Means and Standard Deviations		
		DLD	DD	TD
Number of participants		7	11	21
Age (months)		101.00	108.82	107.14
		(14.55)	(15.12)	(8.77)
Nonverbal intelligence	raw scores	24.71	28.55	29,86
		(4.42)	(3.53)	(3,50)
	percentile	53.57	64.73	74.10
		(21.74)	(24.32)	(18.22)

Notes. DLD – Developmental Language Disorder; DD – Developmental Dyslexia; TD – age-matched Typically Developing children

Table 3. Descriptive statistics and significant differences between groups in phonological skills

Phonological Tasks				**Descriptive statistics (raw scores)**			**Significant differences and effect size between pairwise comparisons**		
				DLD	DD	TD	DLD vs. DD	DLD vs. TD	DD vs. TD
RAN	Colours	Accuracy	Mean	1.14	1.78	.74			
			SD	.42	.55	.14			
			Median	1.00	1.00	0.5			
			N	7	11	21			
		Speed (ms)	Mean	61.86	55.22	44.10		DLD>TD*	DD>TD
			SD	6.82	3.28	2.13		*r*= -.48	*r*= -.54
			Median	52.00	53.00	41.00			
			N	7	11	21			
	Digits	Accuracy	Mean	.50	.61	.17			
			SD	.29	.37	.09			
			Median	0.00	0.00	0.00			
			N	7	10	21			
		Speed (ms)	Mean	36.43	36.44	27.43		DLD>TD*	DD>TD
			SD	4.28	3.93	1.24		*r*= -43	*r*= -.48
			Median	32.00	36.00	27.00			
			N	7	10	21			
PA	Nonword		Mean	12.00	14.44	19.81		DLD<TD	DD<TD
			SD	1.09	.96	.41		*r*= -.74	*r*= -.71
			Median	12.00	14.00	20.00			
			N	7	10	21			
	Word		Mean	8.29	13.67	18,90		DLD<CA	DD<CA
			SD	1.51	1.18	2,88		*r*= -.72	*r*= -.60
			Median	9.00	12.00	19.00			
			N	7	10	21			

Digit span	Mean	11.00	10.67	13.67		DD<TD
	SD	1.41	.47	.64		*r*= -.56
	Median	10.00	10.00	14.00		
	N	7	11	21		
Nonword repetition	Mean	49.86	49.78	53.38	DLD<TD	DD<TD
	SD	1.06	1.01	.44	*r*= -.58	*r*= -.57
	Median	50.00	50.00	54.00		
	N	7	10	21		
Letter knowledge	Mean	22.00	21.78	22.48		
	SD	.31	.49	.13		
	Median	22.00	22.00	21		
	N	7	11	23.00		

Notes. RAN, Rapid Automatised Naming; PA, Phoneme Awareness; *did not reach significance

Table 4. Descriptive statistics and significant differences between groups in linguistic skills

Linguistic skills tasks		**Descriptive statistics (raw scores)**			**Significant differences and effect sizes between pairwise comparisons**		
		DLD	DD	TD	DLD vs. DD	DLD vs. TD	DD vs. TD
	Mean	56.86	63.33	64.38		DLD<TD	
TROG	SD	2.16	.91	.42		*r*=-.60	
	Median	57.00	62.00	64.00			
	N	7	11	21			
	Mean	11.86	20.33	22.38	DLD<DD	DLD<TD	
Vocabulary	SD	1.37	1.21	.91	*r*= -.64	*r*= -.69	
	Median	12.00	19.00	22.00			
	N	7	11	1			
	Mean	18.14	25.33	29.00	DLD<DD	DLD<TD	
Morphosyntax	SD	2.40	2.47	.82	*	*r*= -.71	
	Median	20.50	26.00	29.00	*r*= -.52		
	N	7	11	21			

Note. TROG, Test Of Receptive Grammar (Bishop, 1983); *did not reach significance

Table 5. Descriptive statistics and significant differences between groups in literacy abilities

Literacy tasks		**Descriptive statistics (raw scores)**			**Significant differences and effect size between pairwise comparisons**		
		DLD	DD	TD	DLD vs. DD	DLD vs. TD	DD vs. TD
Word reading	Mean	49.86	53.33	65.14		DLD<TD	DD<TD
	SD	2.39	1.33	.52		*r*=-.74	*r*=-.78
	Median	53.00	52.00	65.00			
	N	7	9	21			
Nonword reading	Mean	15.86	17.33	26.91		DLD<TD	DD<TD
	SD	5.93	5.15	2.98		*r*=-.70	*r*=-.68
	Median	17.00	15.00	27.00			
	N	7	9	21			
Text reading accuracy	Mean	25.29	17.67	6.19		DLD<TD	DD<TD
	SD	5.47	2.54	.72		*r*=-.68	*r*=-.69
	Median	24.00	19.00	6.00			
	N	7	9	21			
Text reading speed (ms)	Mean	360.73	360.89	165.00		DLD<TD	DD<TD
	SD	62.59	64.86	7.84		*r*=-.66	*r*=-.64
	Median	351.00	285.00	158.00			
	N	7	9	21			
Spelling regular words	Mean	13.14	14.00	18.10		DLD<TD	DD<TD
	SD	.63	.93	.35		*r*=-.71	*r*=-.67
	Median	13.00	14.00	18.00			
	N	7	11	21			
Spelling irregular words	Mean	6.29	6.44	10.29		DLD<TD	DD<TD
	SD	.61	.78	.29		*r*= -.73	*r*= -.74
	Median	7.00	6.00	10.00			
	N	7	11	21			
Word accentuation	Mean	3.14	3.30	1.57		DLD<TD	DD<TD
	SD	.34	.48	.23		*r*=-.55	*r*=-.69
	Median	3.00	3.00	0.00			

	N	7	10	21

Table 6. Frequency of scores above/below average per participant and group

Subjects	Control variables		Phonological abilities										Language abilities			Literacy abilities							
	Age	NV IQ	RAN colours acc	RAN colours speed	RAN digits acc	RAN digits speed	Digit span	NR	PD total acc	NW PD acc	W PD acc	LK	TROG	Morpho syntax	Vocab	Nonword reading	Word reading	Text reading speed	Text reading acc	Spelling	Spelling regular	Spelling irregular	Accentuation
DD1	90	27	2.5	77	2	45	10	49	22	13	9	20	66	35	20	13	50	542	30	18	12	6	4
DD2	116	33	2	61	0	38	9	47	22	10	12	23	63	29.5	17	20	51	473	26	19	14	5	3
DD3	106	29	1	49	3	28	9	48	26	14	12	23	60	21.5	16	20	52	229	12	28	18	10	3
DD4	123	35	5	53	0	28	12	49	26	15	11	21	65	31.5	22	18	48	390	19	21	14	7	3
DD5	122	28	3.5	45	0	25	10	44	26	15	11	23	66	30	24	20	53	172	19	16	11	5	3
DD6	115	23	0.5	53	0	37	10	48	33	17	16	22	62	24	26	26	61	285	11	27	18	9	3
DD7	90	25	2	67			8					11.05	59	26	19					0	0	0	
DD8	93	25	0	68	1	59	6	37	9	5	4	21	56	23	11					5	5	0	3
DD9	108	29	0	53	0	29	12	47	29	14	15	23	60	28	19	23	56	196	9	21	14	7	4
DD10	136	30	0.5	46	0	35	13	39	29	12	17	22	67	14.5	23	24	52	214	10	22	15	7	3
DD11	98	30	1	60	0.5	63	11	48	40	20	20	19	61	14	16	15	53	747	23	12	10	2	4
DLD1	96	23	1	50	0	32	9	46	22	13	9	21	61	10	12	20	46	274	16	18	11	7	3
DLD2	89	26	0	48	0	34	10	41	31	16	15	23	59	22	12	22	56	353	14	23	16	7	2
DLD3	95	20	3	86	2	31	9	46	13	10	3	22	50	20.5	7	18	55	203	26	21	13	8	3
DLD4	100	21	0	43	0	27	10	45	22	12	10	21	57	22.5	10	18	55	351	24	18	12	6	3
DLD5	95	23	2	85	1	53	7	48	25	15	10	22	33	8	11	16	43	668	43	15	12	3	3
DLD6	99	27	1.5	69	0	52	14	50	14	8	6	23	57	23.5	12	6	41	472	46	21	14	7	5
DLD7	133	33	0.5	52	0.5	26	18	45	15	10	5	22	65	20.5	19	24	53	202	8	20	14	6	3

% of children with -/+ 1,5 SD

	RAN colours acc	RAN colours speed	RAN digits acc	RAN digits speed	Digit span	NR	PD total acc	NW PD acc	W PD acc	LK	TROG	Morpho syntax	Vocab	Nonword reading	Word reading	Text reading speed	Text reading acc	Spelling	Spelling regular	Spelling irregular	Accentuation
Dyslexia	45.5	45.5	30	50	63.64	30	80	80	60	45.45	45.45	36.36	27.27	100	100	77.78	66.67	81.81	81.81	81.81	30
Developmental Language Disorder	20	42.86	28.57	28.57	57.14	71.43	100	100	85.71	28.57	85.71	85.71	85.71	100	100	71.42	85.71	100	85.71	100	14.29

Note. DD, Developmental Dyslexia; DLD, Developmental Language Disorder; NR, Nonword repetition; PD, Phoneme deletion; NW PD, Nonword phoneme deletion; W PD, Word phoneme deletion; LK, Letter Knowledge; TROG, Test for Reception of Grammar