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Word-level spelling of children with dyslexia and developmental language disorder

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Samenvatting

Veel kinderen met dyslexie en met een taalontwikkelingsstoornis (TOS) hebben moeite met spellen. Het is niet bekend of deze problemen hetzelfde zijn voor beide groepen, omdat er weinig directe spellingvergelijkingen tussen deze twee groepen kinderen zijn gemaakt. In deze studie vergeleken we de woorddictee-uitkomsten en foutenpatronen van kinderen (leeftijdsrange 8.2-10.4 jaar) met dyslexie (n=31), TOS (n=30) en een leeftijdsgematchte controlegroep (n=31). Daarnaast verdeelden we de TOS-groep in kinderen met TOS met leesproblemen (TOS+LP, n=18) en zonder leesproblemen (alleen-TOS, n=12). Tot slot voerden we regressieanalyses uit om te bepalen welke taal- en lees(gerelateerde) vaardigheden invloed hebben op spellingsuitkomsten.

Zowel de dyslexie- als TOS-groep vertoonden spellingproblemen. Deze waren het meest uitgesproken voor de TOS+LP-groep. Wat betreft foutsoorten maakten de dyslexie- en TOS-groepen meer fouten in alle categorieën dan de controlegroep. De dyslexie, alleen-TOS en TOS+LP-groepen lieten eenzelfde patroon zien wat betreft het spellen van woorden met foneem-grafeemassociaties die niet helemaal klankzuiver zijn (gauw als *gouw), met woorden waarin fonologie-orthografie-en morfologie moeten worden gecombineerd (pittig als *pitteg) en met regelwoorden (metro als *meetro). De dyslexie en TOS+LP-groepen lieten ook meer fouten zien in klankzuivere foneemgrafeemkoppelingen (boek als *beok) en met orthografische kennis (leenwoorden). De regressieanalyses lieten een sterke bijdrage zien van woordlezen en snelbenoemen aan woordspelling. Regressieanalyses zonder deze lees(gerelateerde) vaardigheden lieten een beperkte bijdrage van morfologie zien aan de spellingsuitkomsten.

Deze resultaten bevestigen dat kinderen met dyslexie en TOS spellingprobemen hebben, zeker kinderen met TOS+LP. Ze wijzen naar de belangrijke bijdrage van woordleesvaardigheid en snelbenoemen voor spellen, en een beperktere bijdrage van morfologie.

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Samen geven ze de noodzaak weer van systematisch spellingonderwijs en ondersteuning voor kinderen met dyslexie en TOS, alsook het belang van mondelinge taalondersteuning.
Trefwoorden: Spelling, Dyslexie, Taalontwikkelingsstoornis, Lezen, Taal

Abstract

Spelling is challenging for children with dyslexia and for children with Developmental Language Disorder (DLD), but it is not clear as yet whether the difficulties are the same in both groups of children, as few direct comparisons between spelling outcomes of these groups have been reported. We therefore compared the mean word dictation spelling outcomes of children (age range 8.2-10.4 years) with dyslexia (n=31), DLD (n=30) and typically developing (TD) age-matched peers (n=31) as well as the error types. Additionally, we divided the group of children with DLD into those with (DLD+RD, n=18) and without word reading difficulties (DLD-only, n=12). Finally, we conducted concurrent regression analyses to establish which language- and literacy-related abilities contribute to spelling.

Both the groups with dyslexia and DLD displayed spelling problems. These were most pronounced for the subgroup of children with DLD+RD. The error type analyses showed that the groups with dyslexia and DLD made more errors in all categories than the TD group. Furthermore, the dyslexia, DLD-only and DLD+RD groups showed similar errors with phoneme-grapheme associations that were not entirely transparent (gauw [quick] as *gouw), with mappings of phonology-orthography and morphology (pittig [spicy] as *pitteg), and errors concerning spelling rules (metro [metro] as *meetro). The dyslexia and DLD+RD groups also showed more errors in transparent phonology-grapheme mappings (boek [book] as *beok) and orthographic knowledge (loanwords, hyphenation). The regression analysis showed a strong contribution of word reading and rapid automatized naming to spelling. When these measures were excluded, morphology contributed significantly, but to a lesser extent.

The findings confirm the spelling problems of children with dyslexia and with DLD, especially the severe problems of children with DLD+RD. They also point to the importance of word-reading ability and rapid automatized naming for spelling, as well as to a smaller contribution of morphology. Together, the findings show the need for systematic spelling instruction and intervention for children with dyslexia and DLD, as well as support of oral language.
Keywords: Spelling, Dyslexia, Developmental Language Disorder, Reading, Language

Introduction

Being able to write is an important component of a learner's language ability. For the writer, more effortful spelling adds to the cognitive load during the writing process. This, in turn, might affect text production fluency and quality, leading to written texts that are more difficult to understand (Berninger & Swanson, 1994; Graham et al., 1997). For the reader, correct

spelling ensures focus on the content of a message; spelling errors disturb this process (Graham et al., 2011). Learning to spell is therefore essential and requires instruction (Graham & Santangelo, 2014). However, despite instruction, not everyone becomes a fluent speller, especially when spelling words that are not spelled like they sound. In this study, we compare spelling performance of two groups of children who are likely to exhibit spelling difficulties, children with dyslexia and children with developmental language disorder (DLD), to that of typically developing (TD) peers.

Spelling acquisition

Models of spelling (and reading) development state the importance of phonology (phonemes) and orthography (graphemes) and their associations (Ehri, 2000; Perfetti & Hart, 2002; Seidenberg & McClelland, 1989; Treiman & Kessler, 2014). Indeed, phonological skills, rapid automatized naming (RAN) and word reading have been reported to be important contributors to spelling outcomes (Georgiou et al., 2020; Lervåg & Hulme, 2010; Moll et al., 2014). Furthermore, interventions focused on phonological skills, phoneme-grapheme connections and word reading generally lead to improvement of spelling (meta-analyses by Galuschka et al., 2014, 2020). These findings indicate that word reading and reading-related cognitive variables contribute to spelling.

Oral language abilities are also assumed to contribute to spelling outcomes, as connections between spoken/oral language and orthography are assumed to facilitate orthographic knowledge (Perfetti & Hart, 2002; Seidenberg & McClelland, 1989; Treiman & Kessler, 2014). Studies have confirmed that spelling outcomes are influenced by morphosyntax and vocabulary (Apel et al., 2012; Ouellette, 2010; van Weerdenburg et al., 2011) and that interventions in morphology positively affect spelling outcomes (Bowers et al., 2010; Devonshire & Fluck, 2010; Goodwin & Ahn, 2013; Galuschka et al., 2020). Nevertheless, direct effects of morphosyntactic abilities and vocabulary on spelling outcomes are not always attested, especially when other factors, such as orthographic knowledge, are accounted for (Kim et al., 2013; McArthy et al., Werfel et al., 2021).

Spelling in developmental dyslexia

One group of children who show spelling difficulties are children with dyslexia, referring to children who show severe and persistent difficulties with word reading and spelling despite adequate literacy instruction (American Psychiatric Association, 2013; Lyon et al., 2003). As the primary difficulty of children with developmental dyslexia resides in grapheme-phoneme associations, measures tapping these associations (word reading and RAN) can be taken as cognitive correlates of spelling difficulties in this group.

The relationship between oral language abilities and spelling in children with dyslexia is less clear. One language domain at risk for suboptimal development in dyslexia is vocabulary (Duff et al., 2015; Torppa et al., 2010; van Viersen et al., 2017, but see a recent study showing that vocabulary deficits are not necessarily attested in children with dyslexia (Adlof et al., 2021)). Similarly, for morphology, some studies have reported that children

with dyslexia have more difficulty with morphology than their age-matched peers without dyslexia (Casalis et al., 2004; Fowler & Liberman, 1995), but these difficulties are not always present or severe and persistent in dyslexia (Elbro & Arnbak, 1996; Quémart & Casalis, 2013) or are only present in those children with dyslexia who have comorbid language difficulties (Catts et al., 2005). It thus seems that for children with dyslexia, orthographic difficulties are most pervasive, and the role of suboptimal development of oral language as a potential source for spelling problems is less clear.

Different spelling error types have been reported for children with dyslexia. For instance, phonological errors have been found (Caravolas & Volín, 2001; Hoefflin & Franck, 2005)[1], but these seem to occur mostly in more opaque orthographies. Morphosyntactic and orthographic errors[2] are more frequent, especially in more transparent orthographies (Angelelli et al., 2004; Landerl & Wimmer, 2000; Protopapas et al., 2013). It has been proposed that the difficulties of children with dyslexia indicate a delay in internalizing the systematicity of the orthographic system (Protopapas et al., 2013). This refers to spelling words that are sensitive to the orthographic context and to words that require application of orthographic rules (also on the basis of morphological inflection). Thus, the spelling difficulties that children with dyslexia display have a clear literacy basis but may also be influenced by oral language abilities.

Spelling in Developmental Language Disorder

A second group of children who show spelling difficulties are children with DLD. These children are diagnosed with difficulties in multiple areas of oral language, including vocabulary and morphosyntax in the absence of a known biomedical cause, intellectual disability, and/or unfavourable psycho-social/educational conditions (Bishop et al., 2017). The term DLD is now commonplace.[3] Two recent meta-analyses show that children with DLD often show lower spelling outcomes than their age-matched peers (Joye et al., 2019; Graham et al., 2020). As a substantial number of children with DLD also develop reading difficulties (Eisenmajer et al., 2005; McArthur et al., 2000; Snowling et al., 2019; cf. Catts et al., 2005), it is likely that part of these spelling difficulties stem from literacy-related difficulties. Indeed, Vandewalle and colleagues (2011) found that Flemish children with both language and reading disorders obtained lower spelling outcomes than children with a language disorder only. Furthermore, the meta-analysis by Joye et al. (2019) confirmed the tight relationship between reading and spelling difficulties in children with DLD as well as the role that phonology plays in spelling.

Findings on the extent to which language difficulties of children with DLD influence their

[1] Phonological errors are errors in which the word's phonological form is altered, leading the written word to be pronounced differently from the one intended (i.e., phonetically incorrect).

[2] Orthographic errors refer to words in which the word's correct pronunciation is maintained, but in which the written representation is altered by substituting alternative graphemes for the same phonemes (i.e., phonetically accurate).

[3] We will refer to DLD when describing previously conducted studies, even when previous studies have referred to these children as children with specific language impairment.

spelling outcomes are less pronounced. There are indications that oral language abilities contribute to spelling. For instance, van Weerdenburg and colleagues (2011) showed that several language abilities (verbal-sequential processing, auditory perception, speech production and lexical-semantic abilities) contributed to spelling outcomes seven months later for 7-year-old children with DLD and controls. It should, however, be noted that in their study, verbal-sequential processing had the highest predictive value of spelling outcome. This factor contained RAN, a task strongly related to word reading (Moll et al., 2014). Also, in the study by van Weerdenburg et al. (2011) word reading was not entered as a contributor of spelling, so it cannot be assessed whether both language and literacy contributed to spelling. Furthermore, a study by Larkin et al. (2013) did not find a contribution of vocabulary and morphosyntax to concurrent spelling outcomes in their sample of 11-year-old children with DLD and two control groups. Similarly, in a study by Werfel et al. (2021), the spelling outcomes of first-grade children with DLD were determined mainly by word reading and phonological awareness, not vocabulary and morphosyntax. These findings are therefore not conclusive about the contribution of language abilities to spelling outcomes in children with DLD.

With respect to the types of errors children with DLD make in their spelling, phonologically unacceptable errors seem to be more prevalent than orthographically unacceptable errors (Broc et al., 2013; Joye et al., 2020; Larkin & Snowling, 2008; McCarthy et al., 2012). Also, children with DLD have difficulty in spelling morphologically inflected targets (Deacon et al., 2014; Joye et al., 2020; Larkin et al., 2013; Silliman et al., 2006; Windsor et al., 2000). These findings on spelling errors have been confirmed in a recent scoping review (Broc et al., 2021). Thus, children with DLD's language difficulties are visible in both oral and written language (Windsor et al., 2000), but it is not clear whether both oral language and literacy skills (Bishop & Clarkson, 2003; Silliman et al., 2006) or mainly literacy skills (Mackie et al., 2013; McCarthy et al., 2012; Werfel et al., 2021) contribute to their spelling outcomes.

Comparing spelling in children with dyslexia and children with DLD

Spelling difficulties are likely to occur both for children with dyslexia and for children with DLD. One question is whether the difficulties are (partly) the same. Relatively few direct comparisons between spelling outcomes of these groups have been reported. Such information is needed to inform spelling instruction and additional intervention, as it needs to be clear whether the areas of difficulty (and thus required instruction) are the same or different. Some studies have compared teenagers and adolescents' spelling (Goulandris et al., 2007; Puranik et al., 2007) and most concern children at primary school age (Alloway, 2017[4]; Bishop et al., 2009; Larkin & Snowling, 2008; McCarthy et al., 2012; Scuccimarra et al., 2008; Snowling et al., 2019). The comparisons have rendered mixed findings. One pattern of findings is that the DLD group performs as poorly on spelling as the group with dyslexia

[4]Alloway et al. (2017) do not provide statistical testing. Calculation of effect sizes between the groups show that their sample of children with DLD performed more poorly than their sample of children with dyslexia (d'= .487) and their control group (d'= -2.249). The spelling outcomes of children with dyslexia were also lower than those of the control group (d'= -1.427), but the effect size was smaller than that of DLD and control group.

(Goulandris et al., 2007; Larkin & Snowling, 2008; Puranik et al., 2007), another that the DLD group shows poorer spelling than the control group, but still better than that of children with dyslexia (Snowling et al., 2019) and a third that the DLD group outperforms the dyslexic groups and cannot be distinguished from the group of typically developing peers (Bishop et al., 2009; McCarthy et al., 2012).

Furthermore, studies that have included both groups with one disorder (dyslexia-only and DLD-only) as well as a combined group (DLD+poor word reading/dyslexia[5]) show a pattern of DLD-only obtaining better spelling results than dyslexia-only and DLD+poor word reading showing poorest performance (Bishop et al., 2009; McCarthy et al., 2012; Snowling et al., 2019). Furthermore, Brizzolara et al. (2011) and Scuccimarra et al. (2008) found that children with DLD+poor word reading and dyslexia-only obtained similar spelling outcomes, which were significantly lower than those of typically developing peers. Together, the findings suggest that children with combined DLD+poor word reading show poorest spelling performance, that children with dyslexia-only show spelling problems and that they are present for children with DLD-only, but less severe.

All previous spelling comparisons of dyslexia and DLD included comparisons of mean spelling outcomes between the groups. Only two studies compared the types of errors made (Larkin & Snowling, 2008; McCarthy et al., 2012). The findings of these two studies are not the same: Larkin and Snowling (2008) found that their DLD group obtained a lower score compared to the dyslexia and control group on the measure of phonologically acceptable spellings, possibly indicating a more severe phonological deficit in this group. In contrast, findings of McCarthy et al. (2012) showed that the DLD and TD groups did not differ from each other on most error types (phonological, graphemic, semantic error), except the orthographic pattern errors (DLD > TD).[6] Both groups outperformed the DLD+dyslexia and dyslexia groups on all error categories, except the graphemic errors, in which the pattern was reversed. The DLD+dyslexia and the dyslexia groups did not differ from each other. As findings are not consistent, further comparisons between spelling outcomes of children with dyslexia and DLD are needed to clarify whether (and how) the spelling difficulties overlap.

Present study

In the present study, we aimed to answer the question to what extent spelling outcomes are related to literacy and/or oral language difficulties. Three specific questions were addressed. The first was whether children with dyslexia, DLD and TD children show differences in mean spelling dictation outcomes. Although we expect lower outcomes for the DLD and dyslexia

[5]Studies vary in the inclusion criteria of children with poor word reading; some rely on poor word reading at one time point, whereas others rely on a formal diagnosis of dyslexia, in which severity of the word reading difficulties as well as persistence/didactic resistance are established. We use the general category of poor word reading and refer to dyslexia when this has been formally established.

[6]In their study, this category referred to incorrect sound-symbol correspondences (beb for bed), incorrect rules for combining letters (whent for went), incorrect patterns that govern spelling within the root/base word (lader for ladder) and incorrect positional constraints on spelling patterns (neckst for next) (McCarthy et al., 2012, p. 16).

groups compared to the spelling of TD children, we expect more heterogeneity in the DLD group (Joye et al., 2019) than in the group of children with dyslexia. A subgroup of children with DLD+poor word reading is expected to be present and is expected to perform most poorly on spelling (Bishop et al., 2009; McCarthy et al., 2012; Snowling et al., 2019).

The second question was whether the pattern of errors differed for the children with dyslexia and with DLD. On the basis of the literature, both the dyslexia and DLD groups are likely to show more difficulty with targets that are non-phonologically transparent. For the dyslexia group, errors might be especially pervasive for words requiring knowledge of (morphological-)orthographic rules and conventions (Protopapas et al., 2013). For the DLD group, errors are anticipated in words requiring inflection in general (Deacon et al., 2014; Joye et al., 2020), including those that use orthographic conventions for morphological inflections. Furthermore, words with irregular orthographic patterns might also be difficult for this group, as they demand connections between semantics and orthography (Wolter & Apel, 2010).

The final question was whether across all children spelling outcomes are predicted by literacy(-related) abilities as well as oral language abilities or whether there is a dominant contribution only of the literacy(-related) abilities. Word reading is expected to be a dominant contributor to spelling outcomes (Georgiou et al., 2020), as is the reading proxy of RAN (Moll et al., 2014). With respect to oral language abilities, there is some evidence for a unique contribution to spelling (van Weerdenburg et al., 2011), but this finding has not been consistent (Kim et al., 2013; Larkin et al., 2013; McCarthy et al., 2012; Werfel et al., 2021). We included measures of general cognitive ability as control variables: nonverbal intelligence, sustained attention and short-term and working memory in the verbal and visuospatial domain.

Methods

Participants

There were three groups of children: 1) a group of children with dyslexia ($n = 31$, 13 females, mean age 9.4 years, SD .58, range 8.4-10.4), 2) a group of children with DLD ($n = 30$, 8 females, mean age 9.3 years, SD .59, range 8.2-10.4), and a group of TD age-matched peers ($n = 31$, 10 females, mean age 9.3 years, SD .63, range 8.2-10.4). Children were included if at least one of their parents was a native speaker of Dutch and if Dutch was the dominant home language (next to Dutch-only at school). Children with dyslexia were recruited through treatment centres and Facebook support groups for parents. Children with DLD were recruited through four national DLD organizations in the Netherlands, an association for parents of children with DLD, and through self-employed speech therapists. The typically developing children were recruited from three different primary schools across the Netherlands.

The groups did not differ in age ($F(2, 91) = .344$, $p = .710$) and in gender distribution ($\chi(2) = 1.643$, $p = .442$). Socio-economic status (SES) was determined on the basis of the children's

home or school postal codes, depending on the testing location. The reported SES scores indicate the social status of a given neighbourhood in comparison to other neighbourhoods in the Netherlands: the score consists of a combined score taking mean income, mean educational level and mean working status of the people living in a particular postal code into account (NISR, 2017, open source data). The mean score is 0, with higher scores indicating higher socio-economic status. Mean SES for the DLD group was .208 (.79), for the dyslexia group .247 (1.21) and for the TD group -.063 (1.05). There was no main effect of SES ($F(2, 89) = .816$, p = .446, $\eta_p^2 = .018$).

Children with dyslexia all had a prior formal diagnosis of dyslexia. Such a diagnosis is made by a licensed clinician (psychologist) on the basis of establishing both the severity (≤10th percentile) and the persistence of the literacy deficit, as well as on the basis of excluding other factors that might impact on opportunities to learn to read and spell (SDN et al., 2016). All children with dyslexia only had a diagnosis of dyslexia, meaning that there was no comorbid DLD (or other disorders). Three children with dyslexia spoke an additional language next to Dutch.

Children with DLD all had a prior formal diagnosis of DLD made by a licensed clinician. The criteria of diagnosis were (a) performance at least 1.5 standard deviations below the norm on two out of four subscales (speech production, auditory processing, grammatical knowledge, lexical semantic knowledge) of a standardized language assessment test battery administered by a licensed clinician, (b) no diagnosis of autism spectrum disorder, attention deficit hyperactivity disorder, or other physiological problems, c) nonverbal intelligence in the normal range (NVLF, 2016; Siméa, 2017). None of the children spoke another language next to Dutch. Two of the children with DLD had been formally diagnosed with dyslexia and for eight, there were documented suspicions of developmental dyslexia by the speech and language therapists.

The group of TD children was age-matched to the children with dyslexia and with DLD. It consisted of children without parental or teacher concerns regarding language and literacy development and no known behavioural problems. The children were randomly selected for participation in order to ensure that our sample included children across the range of language and literacy abilities.

We administered literacy, language, and non-verbal intelligence measures to confirm group inclusion and to compare the groups. With respect to reading, a timed word reading task (Eén Minuut Test, EMT, [One Minute Test]; Brus & Voeten, 1999) and timed pseudoword reading task (Klepel; van den Bos et al., 1994) were used. The cut-off score for poor performance was a standard score ≤ 6 (≤10th percentile), see Instruments and Table 1. A MANOVA with timed (pseudo-)word reading and group (Dyslexia, DLD, TD) shows a multivariate effect ($F(4,178) = 20.238$, $p < .001$, $\eta_p^2 = .313$). Follow-up ANOVAs for timed word and timed pseudoword reading were also significant, see right-hand columns of Table 1. Posthoc analyses indicate that the pattern of performance is Dyslexia < DLD < TD ($p < .01$).

With respect to language, we administered a receptive vocabulary task (Peabody Picture Vocabulary Test-III-NL, [PPVT-III-NL]; Schlichting, 2005), morphology and sentence repetition task (Clinical Evaluation of Language Fundamentals - Dutch version, [CELF-4-NL], Kort et al., 2008), see Instruments and Table 1. A MANOVA with group and the language outcomes

shows a multivariate effect ($F(4, 178) = 14.529$, $p < .001$, $\eta_p^2 = .334$). Follow-up ANOVAs for the language measures separately are significant (right-hand columns of Table 1). Posthoc analyses establish that the pattern of performance for vocabulary and sentence repetition is DLD < Dyslexia, TD and for morphology (word structure) DLD < Dyslexia < TD.

Finally, the Raven Progressive Matrices subtest (Raven & Raven, 2003) was used to measure nonverbal intelligence. Children had to obtain a percentile score of at least 17%, a score in the lower bound of the normal range. The groups did not differ from each other on this measure, see right-hand columns of Table 1.

Table 1: Means and Standard Deviations of Reading and Language Outcomes per Group

Language measure	Dyslexia	DLD	TD	$F(2,89)$	η_p^2
Word reading (EMT)#	3.2 (2.1)	5.3 (3.7)	10.1 (2.4)	47.409**	.517
Pseudoword reading (Klepel) #	4.4 (1.5)	5.9 (3.1)	11.1 (2.3)	68.524**	.606
Receptive vocabulary (PPVT)%	56.4 (19.7)$_a$	32.3 (21.1)	58.2 (23.6)$_a$	13.714**	.236
Sentence repetition (CELF ZH)#	9.4 (2.0)$_a$	4.8 (2.3)	9.7 (2.1)$_a$	35.636**	.445
Word structure (CELF WS)@ !	26.5 (1.4)	21.9 (4.3)	27.8 (1.5)	38.736**	.465
Non-verbal IQ (Raven)$	57.6 (24.3)	60.3 (21.8)	58.7 (27.5)	.093	.002

Note. Subscripts in the group columns indicate that groups do not differ from each other significantly in case of posthoc testing. # standard score. % percentile score. $ norm score. @ raw score. ! results on the raw score remain the same when age is entered as a covariate. ** $p < .001$.

Instruments

Word spelling. A word dictation task was used to assess spelling (*Schoolvaardigheids-toets Spelling*, SVS, [School Skill Test Spelling]; de Vos & Braams, 2015). The task consists of 30 targets, divided in two blocks of 15 targets. Targets are embedded in sentences and repeated after each sentence. An example is: 'Dat poesje blijft erg klein. Schrijf op 'klein'.' ['That pussycat remains very small. Write down 'small'.']. The targets differ partly per grade: in grade 2, blocks 2 and 3 are presented; in grade 3 blocks 3 and 4 and in grade 4 blocks 4 and 5. Reliability of the (two versions of the) SVS is reported to be 0.82 or higher (Expertgroep Toetsen PO, 2016).

On the basis of the number of incorrectly spelled items (max 30), raw correct (max 30) and percentile scores were calculated. Furthermore, the number of incorrect items per error type was generated. The SVS software generates this output based on targets and realizations. The dictation tasks of the present sample contained 14 error categories, see Table 2 below for the categories and examples of errors.[7] We categorized these errors as being part of one of 5 main categories: 1) transparent phoneme-grapheme associations, 2) less

[7]The errors made by the groups in the categories of the SVS dictation task (see Method, Table 2) are displayed in Supplementary Figures 3 and 4.

transparent phoneme-grapheme associations, 3) phonology, orthography, morphology required, 4) spelling rules (requiring systematic operations on phonology, orthography, morphology), and 5) orthographic knowledge. These categories are presented in Table 2 (fourth column). In the transparent phoneme-grapheme category (1), an error is made when the mapping between the phoneme and grapheme is straightforward as there are no alternative spellings and the phoneme grapheme required reflects the phonology. In the less transparent phoneme-grapheme category (2), there are errors in targets in which a connection between phonemes and graphemes needs to be made that is complicated by homographs (e.g., ei/ij, au/ou) or by complex phonology (e.g., schr /sxr/). Category 3 refers to errors when a combination of phonology, orthography and morphology is required, such as spellings of bound morphemes. Category 4 refers to spelling rule errors, and thus to spelling rules that are taught explicitly, such as open and closed syllables (and vowel length) and final consonant spelling (e.g., Gills & Ravid, 2006). These also require integration of phonology, morphology and orthography. Finally, category 5 refers to errors related to orthographic knowledge and conventions (such as loanwords, hyphens, spacing).

Note that more than one error could occur in the 30 target items, for instance *pittig* [spicy] could be spelled as **piteg* and thus include both an error in open and closed syllables (*itt* as **it*, category 7) as well as in bound morphemes (*ig* as **eg*, category 11). The total number of errors was also tallied.

Literacy(-related) skills

Word reading. A timed word reading test (*Eén Minuut Test*, EMT, [One Minute Test]; Brus & Voeten, 1999) and a timed pseudoword reading test (*Klepel*; van den Bos et al., 1994) were used to evaluate word reading fluency. During the task, the child has one and two minutes, respectively, to read aloud as many (pseudo)words as possible. The number of syllables of the targets increases in length. The score is the number of correctly read (pseudo)words (maximum of 116 in each task). Standard scores were calculated on the basis of these raw scores.

RAN. RAN letters (a, d, o, p, s) was assessed with a subtest of the test for Continuous Naming and Word Reading (*Continu Benoemen & Woorden Lezen*; van den Bos & Lutje Spelberg, 2007). The children were shown a sheet with five columns of ten letters each and were asked to name all 50 letters as quickly and accurately as possible. The score on the RAN subtests is reported as the number of seconds required to complete the task: a higher score thus corresponds to weaker performance.

Language skills

Receptive vocabulary. The Dutch version of the Peabody Picture Vocabulary Test (PPVT-III-NL; Schlichting, 2005) was used to measure receptive vocabulary knowledge. Children were shown four pictures on the screen with an orally presented target word. They were asked to point to the picture that best resembled this target. Each set contained 11 items, with a total of 17 sets. Testing and scoring proceeded according to the manual. Raw scores were

Table 2: Spelling Error Categories (de Vos & Braams, 2015) (Column 2), Examples from Current Dataset (Column 3) and Categories Applied in the Current Study (Column 4)

Nr	Category (de Vos & Braams, 2015)	Examples of errors in present study	Categories in present study
1	Letters or digraphs that can be spelled only in one way	Error in digraph *oe* for /u/: *boek* as **beok* or **bok* [book]	Transparent phoneme-grapheme (1)
2	Letters and letter combinations with pronunciations that lead to incorrect spelling	Error in digraph nk for /ŋk/: *plank* as **plangk* [plank] Error in f/v: fatsoen as *vatsoen [decency] Error in /i:/ as i/ie: *ski* as **skie* [ski]	Less transparent phoneme-grapheme (2)
3	Vowel or consonant cluster	Error in eeuw/ieuw/uw: *schaduw* as *schaduuw* [shadow] Error in sch or schr: *ongeschikt* as **ongescrikt* [unsuited]	Less transparent phoneme-grapheme (2)
4	Non-transparent consonant cluster or digraph	Error in ou/au/ouw for /au/: *gauw* as **gouw* or **gou* [quick] Error in ei/ij for /ɛi/: *trein* as **trijn* [train]	Less transparent phoneme-grapheme (2)
5	Loanwords	Spelling *procent* as **prosent* [percent]	Orthographic knowledge (5)
6	Abbreviations, additions, symbols	Spelling *'s avonds* as* *s'avonds* [at night]	Orthographic knowledge (5)
7	Open and closed syllables (requiring either one grapheme for a long vowel or a double consonant)	Spelling *metro* as **meetro* [metro] Speling *koffie* as **kofie* [coffee]	Spelling rule (Phonology-Orthography-Morphology) (4)
8	Compounds: as one word or separate, using a merging -s and hyphenation	Spelling *tekort* as **te kort* [deficit as too short] and *te kort* as **tekort* [too short as deficit]	Orthographic knowledge (5)
9	Vowel clash, demanding diaeresis, hyphen or being spelled as one	Spelling *skieën* as **skiejen* [to ski]	Orthographic knowledge (5)
10	Extension rules to discover underlying sound. In Dutch, final devoicing takes place, obscuring underlying voicing values (hond is pronounced /hOnt/, but the plural is honden /hOnd@n/	Spelling *neven* as **nefen* [cousins/nephews] Spelling *gemiddeld* as **gemiddelt* [average]	Spelling rule (Phonology-Orthography-Morphology) (4)
11	Bound morphemes (prefix, suffix) and silent vowels	*pittig* as **pitteg* [spicy]	Phonology-Orthography-Morphology (3)
12	Diminutives. In Dutch, these are dependent on the target stem (-je, tje, kje, pje, nkje)	Spelling *kettinkje* as **kettingje* [small necklace]; *fotootje* as **fototje* [small photo]	Spelling rule (Phonology-Orthography-Morphology) (4)
13	Suffix of loanwords (-eit, -isch)	Spelling *majesteit* as **majestijd* ([ajesty]	Orthographic knowledge (5)
14	Contractions spelled with a middle –e-	Spelling *onafscheidelijk* as **onafschijdlijk* [inseparable]	Phonology-Orthography-Morphology (3)

converted to percentile scores.

Sentence repetition was assessed through the Dutch version of the CELF-4 recalling sentences task (CELF-4-NL; Kort et al., 2008). In this task the experimenter presents a sentence and the child is asked to repeat it. The sentences increase in length and complexity as the task progresses. Testing and scoring proceeded according to the manual. Raw scores were converted to standard scores.

Morphology was evaluated through the Dutch version of the CELF-4 word structure task (CELF-4-NL; Kort et al., 2008). In this task, the experimenter presents a sentence and a picture to the child. The child is required to complete the sentence on the basis of the target frame of the experimenter and the picture, such as 'Deze jongen staat en deze jongen…[zit]' ['This boy stands and this boy… [sits]']. Different types of morphology are assessed, in-

cluding pronouns, nouns (diminutives and plurals), verbs (tense, compound verbs, subject-verb agreement), and adjectives (comparatives and superlatives). Responses were coded as (in)correct and the total raw score was calculated (max 30). These scores were not transformed to percentile scores, as these norm scores are available only up to 8 years.

Background variables: General cognitive skills

Non-verbal IQ was assessed through Raven's Standard Progressive Matrices (Raven & Raven, 2003), which is a standardized measure of nonlinguistic intelligence. Raw scores were converted to percentile scores.

Memory skills. Short-term and working memory were assessed in the verbal and in the visuospatial domain. For the verbal domain, we used the standardized forward and backward digit span tasks in the CELF-4-NL (Kort et al., 2008). Testing and scoring proceeded according to the manual. In the forward version of the task, children had to repeat sequences of digits that increased between 2 and 9 digits in the correct order. In the backward version, children had to repeat the sequences in the reversed order. Raw scores were converted to standard scores. For the visuospatial domain, we used a non-standardized Dutch adaptation of the Dot Matrix task in the Alloway Working Memory Assessment (AWMA; Alloway, 2007) that also contained a forward and backward version. Children were shown a matrix (4 x 4) in which dots appeared according to sequences of increasing length. After presentation, children had to point to the locations on the matrix where the dots had appeared (forward version: in the same order, backwards version: in the reversed order). Testing and scoring proceeded according to the manual. The maximum score was 36 (six trials per block and a maximum of six blocks).

Sustained attention was measured using the Dutch version of the Score! Subtest of the Test of Everyday Attention for Children (TEA-Ch; Schittekatte et al., 2007). This is an auditory task in which children listen to 10 audio fragments that contain between 9 and 15 target sounds. The child's task is to (silently) count the number of target sounds per fragment, taken to reflect their ability to maintain attention over time. Raw scores represent the number of items answered correctly out of 10.

Procedure

This sample of children was part of a larger project, Progracy, in which comparisons between children with dyslexia and TD children and children with DLD and TD children were made. This larger project focused on the relation between statistical learning and language proficiency: children that participated also performed three statistical learning tasks in addition to the tasks reported on in this paper. The full test battery took two to four sessions of one hour each, spread over 2 to 3 weeks for each child. Each test session started with a statistical learning task and was then followed by a set of cognitive and language measures. The sessions consisted of the following clusters: 1) word reading, verbal and visuospatial memory tasks and a nonadjacent dependency statistical learning task, 2) sentence recall, word structure, sustained attention, non-verbal intelligence tasks, and a serial reaction time task, and

3) spelling, vocabulary, RAN tasks and a visual statistical learning task. The order in which participants performed the different sessions was counterbalanced. The study has been approved by the ethics committee of the Faculty of Humanities of the University of Amsterdam in 2016.

Results

Q1: Mean spelling outcomes

Prior to group comparisons on the spelling outcomes, data screening was conducted. There were no outliers (±3.27 SD from the mean on the spelling score). The data were not normally distributed for the percentile score (left-skew; $W(50) = .929$, $p = .005$) but were for the raw score ($W(50) = .971$, $p = .248$) and the total number of errors ($W(50) = .973$, $p = .308$).

The mean percentile scores confirm the poor performance of the dyslexia group ($M = 9.1$, $SD = 12.7$) and the average performance of the TD group ($M = 46.7$, $SD = 24.9$). They indicate that mean performance of the DLD is poor ($M = 11.10$, $SD = 14.6$). The raw spelling scores and the total number of errors are presented in Table 3, along with statistical testing outcomes (ANOVAs). For the raw scores, performance is ranked: TD > Dyslexia, DLD. For the total number of errors it is TD > Dyslexia > DLD.

On the basis of the word reading outcomes, we found that 18/30 children with DLD (60%) displayed poor reading (standard score ≤6) on either or both word reading tasks. They were classified as DLD+reading difficulties (RD). The mean spelling percentile score of the DLD+RD group was very low (M = 4.00, SD = 4.8). For the DLD-only group it was 21.8 (SD = 17.9). The raw spelling outcomes were subsequently analyzed through ANOVAs for the four groups (DLD+RD, DLD-only, Dyslexia, and TD), see lower section Table 3. The pattern of outcomes for the raw score and total error score is TD > DLD-only, Dyslexia > DLD+RD. In sum, the spelling scores indicate that spelling outcomes are poor and delayed for both the DLD and dyslexia groups, and, within the DLD-group, most clearly for the DLD+RD group.

Table 3: Mean Spelling Outcomes (SD) per Group and Statistical Outcome

Outcome	Dyslexia		DLD	TD	$F(2,89)$	η_p^2
Raw score (max 30)	6.87 (3.7)a		6.27 $(4.9)_a$	18.6 (4.9)	72.790**	.621
Number of errors#	36.29 (2.4)		44.50 (2.4)	17.06 (2.4)	34.481**	.437
	Dyslexia	DLD+RD	DLD-only	TD		
Raw score (max 30)	6.87 $(3.7)_a$	3.61 (3.0)	10.25 (4.3)a	18.6 (4.9)	64.258**	.687
Number of errors#	36.29 $(2.4)_a$	53.06 (14.2)	31.67 $(9.8)_a$	17.06 (2.4)	36.573**	.555

Note. Subscripts indicate that groups do not differ from each other significantly. ** $p < .001$. # the number of errors of all categories added up.

Q2: Spelling errors

Figures 1 and 2 present the number of errors for each of the five spelling categories for the three groups (Figure 1: Dyslexia, DLD, TD) and four groups (Figure 2: Dyslexia, DLD-only, DLD+RD, TD).7 Generally, the number of errors is highest for errors related to spelling rules (category 4) and phonology-orthography-morphology-mappings (category 3). For the three groups (TD, DLD, Dyslexia), the pattern of performance for all different categories is TD > Dyslexia > DLD. For the four groups, this is TD > DLD > Dyslexia, DLD+RD. Note that the DLD+RD group makes more errors in all error categories, including errors in transparent phoneme-grapheme mappings (category 1) and phonology-orthography mappings (category 2).

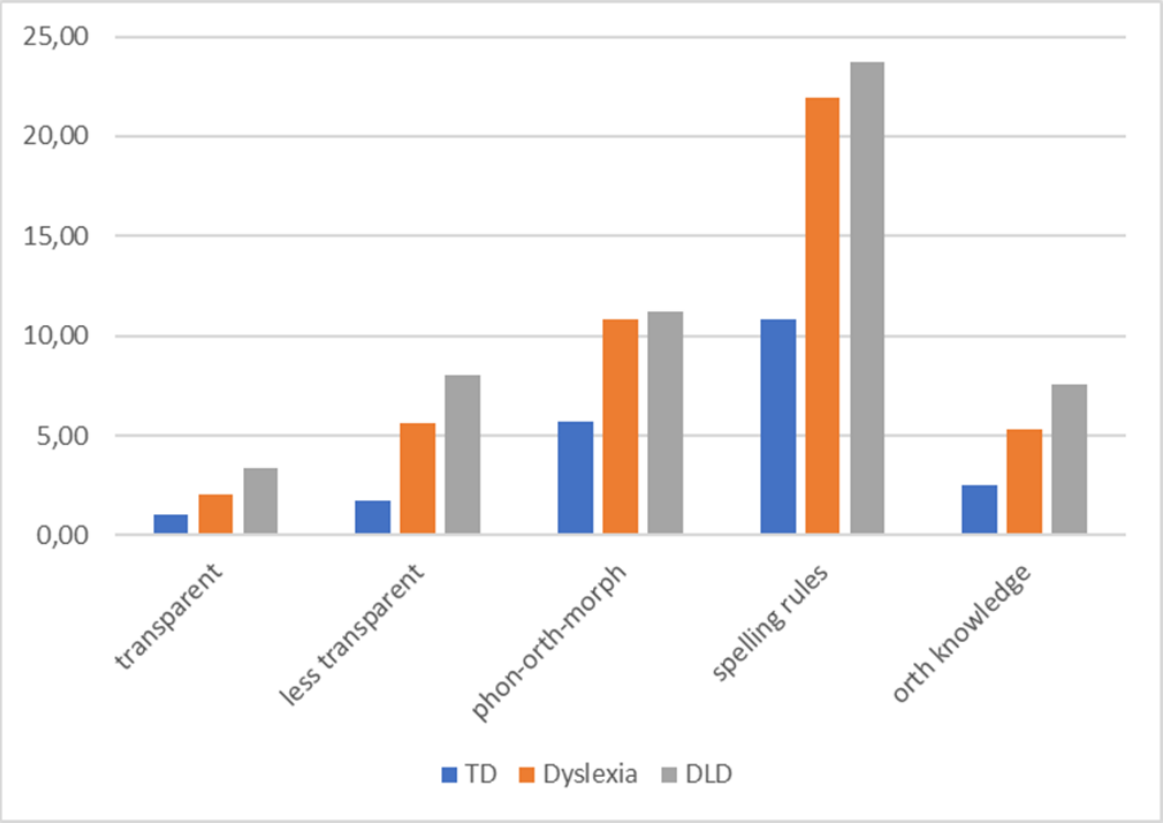

Figure 1: Number of Errors by Spelling Category (Table 2. Column 4) for Three Groups

A MANOVA with the five different error categories and group (Dyslexia, DLD, TD) shows a multivariate effect (Wilk's Lambda (10, 170) = 7.427, $p < .001$, $\eta_p^2 = .304$). Follow-up ANOVAs show significant effects on all five categories: (1) transparent phoneme-graphemes $F(2, 89) = 13.353$, $p < .001$, $\eta_p^2 = .231$, (2) less transparent phoneme-graphemes $F(2, 89) = 28.296$, $p < .001$, $\eta_p^2 = .389$, (3) phonology-orthography-morphology $F(2, 89) = 10.185$, $p < .001$, $\eta_p^2 = .186$, (4) spelling rules $F(2, 89) = 19.770$, $p < .001$, $\eta_p^2 = .308$, and (5) orthographic knowledge

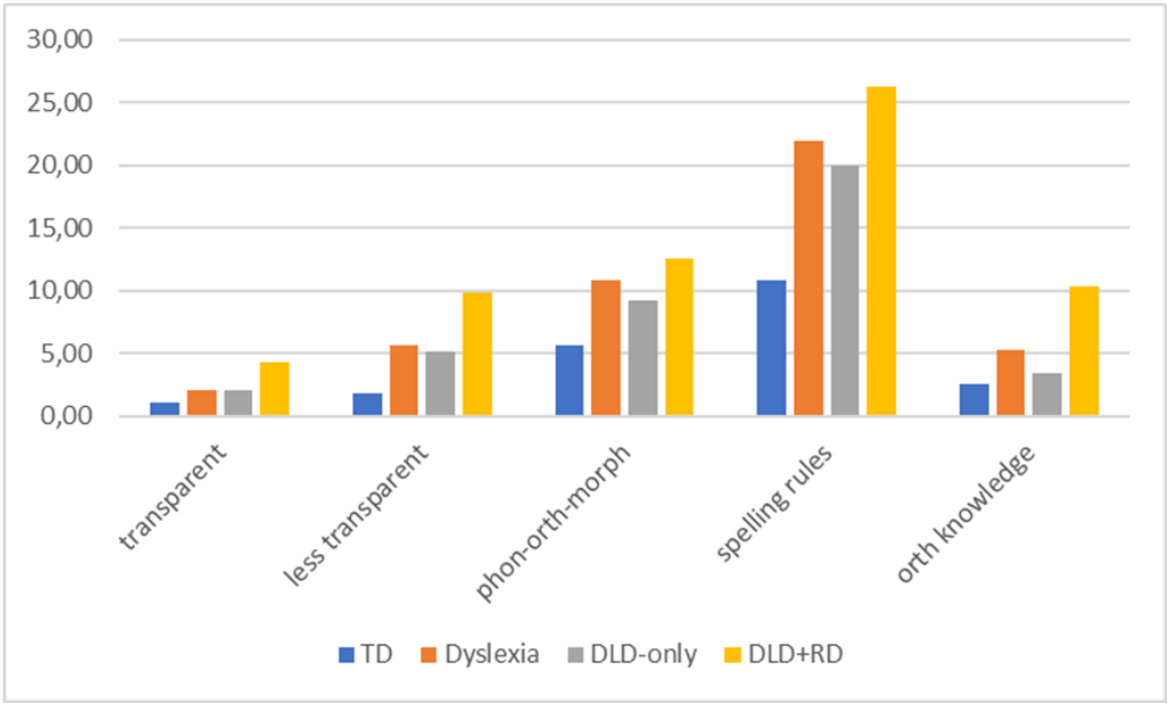

Figure 2: Number of Errors by Spelling Category (Table 2. Column 4) for Four Groups

$F(2, 89) = 7.525$, $p = .001$, $\eta_p^2 = .145$). Posthoc comparisons (all Games-Howell) show that for the errors in transparent mappings (category 1), the pattern is TD > Dyslexia > DLD; for the other four categories, this is TD > Dyslexia, DLD. Thus, the control group always makes fewer errors and the DLD and dyslexia groups resemble each other in the number of spelling errors that require more than transparent phoneme-grapheme mapping.

When the MANOVA is conducted for the four groups (Dyslexia, DLD-only, DLD+RD, TD), there is also a multivariate effect (Wilk's Lambda $(15, 258) = 7.262$, $p < .001$, $\eta_p^2 = .298$) and there are main effects for all categories separately: (1) transparent phoneme-graphemes $F(3, 92) = 14.062$, $p < .001$, $\eta_p^2 = .324$, (2) less transparent phoneme-graphemes $F(3, 92) = 28.277$, $p < .001$, $\eta_p^2 = .491$, (3) phonology-orthography-morphology $F(3, 92) = 7.820$, $p < .001$, $\eta_p^2 = .210$, (4) spelling rules $F(3, 92) = 14.943$, $p < .001$, $\eta_p^2 = .337$, and (5) orthographic knowledge $F(3, 92) = 10.486$, $p < .001$, $\eta_p^2 = .270$). On the categories less transparent phonology-orthography (2), phonology-orthography-morphology (3) and spelling rules (4), posthoc comparisons (all Games-Howell) show that there are no indications of differences between the three clinical groups (Dyslexia, DLD-only, DLD+RD). The TD group outperforms the three groups on these three categories. In terms of errors in transparent phoneme-grapheme mappings (category 1), the TD group makes fewer errors than the dyslexia and DLD+RD groups. Furthermore, the DLD+RD group makes more errors than the Dyslexia group. There are no indications that the DLD-only group differs from the dyslexia group and from the DLD+RD group. For the orthographic knowledge errors (5), the TD group makes

fewer errors than the Dyslexia and DLD+RD group and the DLD+RD group makes significantly more errors than the DLD-only group.

In sum, the three group comparison (Dyslexia, DLD, TD) shows that the TD group makes fewer errors of each category. The two clinical groups resemble each other in the types of errors made, except that the DLD group makes more errors with transparent phoneme-grapheme correspondences (category 1). For the four group comparison, there was no evidence for or against a difference between the three clinical groups (Dyslexia, DLD-only and DLD+RD), as they show a similar number of errors of less transparent phoneme-grapheme mappings (category 2) and phonology-orthography-morphology associations (category 3) and spelling rules (category 4). For errors in transparent phoneme-grapheme mappings (category 1) and orthography (category 5), the DLD+RD-group shows most difficulties.

Q3: Factors contributing to spelling performance

In order to evaluate whether literacy, language, and general cognitive skills contribute to the spelling outcomes, regression analyses were conducted with raw spelling score as dependent variable. Group was not entered as a separate variable, as there is no a-priori assumption that variables contributing to spelling performance differ between the groups (Werfel et al., 2021).

The independent variables focused on literacy (timed word reading and RAN), language (receptive vocabulary, sentence repetition, and morphology), and general cognitive ability (sustained attention, verbal memory, visuospatial memory, and non-verbal IQ). Mean outcomes on these variables are presented in Table 4. With respect to timed word reading, only the real-word reading task was included, as there was a strong correlation between the real and pseudoword reading task, both on raw $r(92) = 0.92$, $p < .001$ and standard scores $r(92) = 0.89$, $p < .001$.

Data screening for the 11 independent variables yielded one significant multivariate outlier (using Mahalanobis distance calculations), with the probability of multivariate outliers set at $t < .01$. As this multivariate outlier came from a clinical group (DLD), the outlier status was not considered problematic and the data were included in the sample.

Correlations between the independent variables are presented in Table 4 and correlations with the raw spelling score in Table 5. There are strong and significant correlations between timed word reading and RAN, and between the language measures (vocabulary, morphology and sentence repetition). As they are still all below the .7 value, all variables were retained in the regression analyses. Furthermore, as sustained attention, visuospatial memory and non-verbal IQ did not correlate with spelling outcomes, these background variables were excluded from the regression analyses.

A subsequent regression analysis with the spelling correct score was significant ($F(7, 91) = 28.522$, $p < .001$) and explained 68% of the variance (adjusted $R^2 = .679$), see Table 6. Timed word reading and RAN were the only unique significant contributors; the language measures were not. This remained the case when only one of the language measures was included, meaning that this finding cannot be due to collinearity of language measures. An exploratory analysis was conducted to investigate the relationship between oral language

Table 4: Mean Outcomes and Correlations between the Independent Variables

	Mean (SD)	RAN	Vocab	SRep	Morph	SA	VSTM	VWM	VisSTM	VisWM	NV-IQ
Word reading	43.1 (19.7)	-.645**	.278**	.365**	.461**	.219*	.447**	.232*	.235*	.276**	.146
RAN letters	33.8 (10.3)	1	-.177*	.-180*	-.209*	.249**	-.316**	-.175*	-.359**	-.229*	-.056
Vocabulary	110.8 (11.2)		1	.691**	.676**	.199*	.299**	.308**	.352**	.221*	.210*
Sentence Rep	48.6 (16.8)			1	.734**	.126	.539**	.451**	.311**	.258*	.274*
Morphology	25.5 (3.7)				1	.222*	.411**	.350**	.224*	.191*	.162
Sustained att	7.18 (2.3)					1	.178*	.115	.166	.337**	.154
VSTM	7.5 (1.8)						1	.371**	.162	.215*	.145
VWM	3.9 (1.3)							1	.254**	.211*	.312**
Visspat STM	23.9 (4.8)								1	.539**	.338**
Visspat WM	22.2 (5.1)									1	.420**
NV-IQ	36.2 (6.5)										1

Note. ** $p < .01$ * $p < .05$

Table 5: Correlations between the Raw Spelling Score and the Independent Variables (Raw Scores)

	Spelling
Word reading	.803**
RAN	-.413**
Vocabulary	.294**
Morphology	.414**
Sentence repetition	.483**
Sustained attention	.050
Verbal STM	.503**
Verbal WM	.289**
Visuospatial STM	.152
Visuospatial WM	.183
Non-verbal IQ	.087

Note. ** $p < .001$.

ability and spelling. When the regression analysis was conducted with the variables excepting word reading, morphology ($B = .369$, $t = 2.800$, $p = .006$) as well as VSTM ($B = .297$, $t = 2.825$, $p = .006$) did provide unique contributions to the spelling outcomes in a significant regression model ($F(6, 91) = 9.670$, $p < .001$), although the explained variance was lower than in the model that did contain word reading (adjusted $R^2 = .364$).

The pattern of findings was similar when the total number of errors was the dependent variable.

Table 6: Standardized Beta Coefficients of Independent Variables Predicting Spelling Outcomes

	Spelling raw score (max 30)	
All raw scores	Standardized coefficients Beta	*t*
Timed word reading	.811	9.197***
RAN letters	.177	2.247**
Vocabulary	-.013	-.146
Sentence repetition	-.003	-.025
Morphology	.076	.770
VSTM	.151	1.983
VWM	.052	.776

Note. *** $p < .001$. ** $p < .01$.

Discussion

The goal of this study was to gain insight into the similarities and differences of the spelling of children with dyslexia and DLD and the role that literacy and language abilities play in their spelling outcomes. We targeted three questions to address this issue, namely 1) whether children with DLD, dyslexia, and typically developing children show differences in spelling dictation outcomes, 2) whether the pattern of errors differs between the dyslexia and DLD groups (and the subgroups of DLD-only and DLD+reading difficulties (RD), and 3) whether spelling outcomes are predicted by both literacy(-related) abilities as well as language abilities.

Spelling outcomes

The three mean spelling outcomes (percentile scores, raw correct score and total error score) indicated that the TD group outperformed the Dyslexia and DLD groups on spelling and that the latter two groups show low spelling outcomes. Within the DLD-group, this was most clearly the case for the children with DLD+ RD.

The spelling difficulties for the group of children with dyslexia were anticipated, as reading, a core deficit in any definition of dyslexia, is related to spelling (Georgiou et al., 2020), and as poor spelling can be part of the dyslexia diagnosis (in the Netherlands). Children with DLD also showed poorer spelling outcomes than their age-matched peers, in line with previous findings (meta-analyses by Joye et al., 2019; Graham et al., 2020).

The finding that for the DLD group the spelling difficulties were most clearly present for the subgroup of children with DLD+RD is similar to previous findings (Bishop et al., 2009; McCarthy et al., 2012; Snowling et al., 2019; Vandewalle et al., 2012). In our study, the spelling percentile score of the DLD+RD group was extremely low (4th percentile). Also, the mean

raw spelling score and total number of errors were even lower than that of the dyslexia-only group. These children thus have severe spelling difficulties. The division between the children with DLD-only and children with DLD+RD speaks to the literature, which has shown that DLD and severe word reading difficulties can be co-occurring and comorbid disorders, but that DLD as such does not automatically entail a literacy disorder (e.g., Adlof & Hogan, 2018; Catts et al., 2005; Rakhlin et al., 2013; Snowling et al., 2019).

Error types

With respect to the types of errors, we found that the control group made fewer errors in all error categories than the dyslexia and DLD groups. These categories were 1) transparent phoneme-grapheme associations, 2) less transparent phoneme-grapheme associations, 3) phonology, orthography, morphology, 4) spelling rules, and 5) orthographic knowledge. We found no evidence that the children with dyslexia and children with DLD groups differed from each other, except for the errors in transparent phoneme grapheme mappings, where the group of children with DLD made more errors than the group of children with dyslexia.

The error comparison between the four groups did not provide evidence for or against a difference between the three clinical groups (Dyslexia, DLD-only and DLD+RD) as they made a similar number of errors on three of the five categories (less transparent phoneme-grapheme mappings and phonology-orthography-morphology associations, spelling rules). The errors made in these categories furthermore suggest that all three clinical groups make errors when spelling is not straightforward and requires more complex associations or rules. Furthermore, the DLD+RD and Dyslexia groups made more errors than the control group on straightforward phoneme-grapheme mappings, indicating that for these groups, the basis phoneme-grapheme associations are challenging. Finally, these groups also made more errors than the control group regarding orthographic knowledge.

The findings thus indicate that children with dyslexia make errors when connections between phonology-orthography and phonology-orthography-morphology (including spelling rules) need to be made. This is in line with the literature (Angelelli et al., 2004; Landerl & Wimmer, 2000; Protopapas et al., 2013), and points to the need of systematic spelling instruction and treatment for these children, even at the most basic phoneme-grapheme associations. The errors made by the children with DLD align with studies that point to phonological errors (e.g., Broc et al., 2013; Joye et al., 2020; Larkin & Snowling, 2008; McCarthy et al., 2012), as well as those that have reported orthographic and morphological errors in this group (Deacon et al., 2014; Joye et al., 2020; McCarthy et al., 2012; Silliman et al., 2006; Windsor et al., 2000; Wolter & Apel, 2010), especially in more transparent orthographies (see also Broc et al., 2021). They indicate that children with DLD also have a need for systematic and intensive spelling instruction. As the DLD group showed most difficulties with straightforward phoneme-grapheme mappings, it is clear that they require intensive spelling instruction from the outset of literacy instruction. Across-the-board spelling difficulties were present mainly for the DLD+RD group: this group requires the greatest amount of support, as spelling performance was extremely low and spelling errors were evident in all error categories. Basic letter-sound associations need to be strengthened for these children,

as do orthographic representations of specific words, as well as integrations of orthography and linguistic rules.

In order to understand the mechanisms of spelling errors more clearly, it could be investigated which specific sources of information children use during spelling specifically selected target types and orthographic rules/patterns. This could be done by assessing dictation of words that require specific morphological, lexical, phonological and orthographic sources of knowledge (e.g., de Bree et al., 2017; Kim et al., 2016). In this approach, words are selected that require specific phonological, morphological and orthographic operations (i.e., spelling plurals such as taken for singular taak [task] and takken for singular tak [branch], or past tense leefde for infinitive leven [live]). These words also differ in their lexical frequency and age of acquisition. Such a comparison can indicate whether specific measures of language, orthography and frequency contribute similarly to the spelling outcomes for the different groups. Gaining insight in the types of errors across specific targets can determine most clearly which instruction is most suitable.

Language and literacy as predictors of spelling

With respect to the third research question, whether literacy and language abilities predicted spelling outcomes, it was found that word reading was the dominant contributor to spelling outcomes. RAN was an additional significant unique predictor, whereas we found no evidence that language abilities and general cognitive abilities predict (or do not predict) spelling outcomes. However, if word reading was left out of the analyses, morphology and VSTM became unique significant contributors. Note that this coincided with a decreased amount of explained variance. If only the language measure morphology was included (and leaving out vocabulary and sentence repetition), then morphology did contribute to the model of total errors. There are thus subtle indications of contributions of language measures to spelling. Nevertheless, the regression analyses generally pointed to the importance of reading measures for spelling (Georgiou et al., 2020; Werfel et al., 2021).

These findings match other studies that report a contribution of language to spelling (Joye et al., 2019) but especially or only if reading is not included in the analyses (Joye et al., 2019; Kim et al., 2013; Larkin et al., 2013; McCarthy et al., 2012). Word reading might subsume effects of language variables. This was also visible in the correlations between word reading and the language measures in our sample. Reading ability requires linguistic knowledge, as decoding and sight word reading is facilitated by vocabulary and morphology. The findings also speak to those of van Weerdenburg et al. (2011), who found that verbal-sequential processing had the highest predictive value of spelling of all language measures included. This factor contained RAN, which was found to be a strong contributor to spelling in our sample.

With respect to RAN, we had not necessarily anticipated a contribution of this measure to spelling above and beyond word reading. RAN can be taken to be a microcosmos of reading (Norton & Wolf, 2012), as it requires conversion of visual information to an auditory response as fluently as possible. Furthermore, RAN is a measure determined by speed, whereas spelling is not a timed measure. This continued contribution of RAN to spelling

might indicate that RAN taps the efficiency of the alphabetic principle (Moll et al., 2009), which is thus poorer in children with dyslexia and children with DLD than their age-matched peers.

Limitations

This study is qualified by some important limitations. First, the sample size is limited, most prominently for the subgroups DLD-only (n = 12) and DLD+RD (n = 18). The findings can therefore not be taken to generalize to the populations of DLD, dyslexia and typically developing children at large, even though the pattern of findings largely resembles previous findings related to spelling performance in DLD and dyslexia, spelling errors in dyslexia, and contributors to spelling performance.

Related, the comparison now only consists of the spelling of monolingual children or children with a Dutch-dominant background. As bilingualism is becoming increasingly frequent, future research should also include bilingual speakers in the assessment of spelling and contributions of language and word reading (e.g. de Bree et al., 2022).

Furthermore, the contribution of language and literacy to spelling outcomes is determined on the basis of concurrent rather than longitudinal data. Longitudinal studies are necessary to evaluate whether earlier language abilities contribute more clearly to later spelling outcomes in children with (a risk of) literacy and language abilities than those measured concurrently, or whether mediating effects can be attested (Georgiou et al., 2020; Lervåg & Hulme, 2010; van Weerdenburg et al., 2011; Werfel et al., 2021).

Fourth, the dictation presented to the children was based on the grade they were attending. As the children did not all attend the same grade, the targets differed somewhat. This means that the errors that were made might also have differed due to some of the targets differing between the children. Thus, although all children attended grades in which spelling rules and associations between phonology-orthography and morphology are part of the spelling curriculum, a more controlled assessment of spelling is needed to further inform our understanding of the spelling acquisition of the different groups of children. A study with this approach is being conducted for spelling of children with DLD (Bliekendaal et al., in preparation). It can inform us more about the areas of spelling difficulty these children have, and also which instruction and which interventions might be helpful.

Fifth, we have not taken into account the spelling instruction the children have received. Spelling instruction is essential for spelling development (Graham & Santangelo, 2014), but schools can differ in the quality of spelling instruction as well as in the mean spelling outcomes obtained by their students (e.g., Cordewener et al., 2012). Furthermore, we know that specific spelling interventions for poor spellers/readers lead to improvement (Galuschka et al., 2014, 2020). Therefore, the amount and type of instruction could have impacted on the outcomes. Children with diagnosed dyslexia will have received or have been receiving specialized and intensive literacy interventions both at special dyslexia centres as well as at school. The fact that they still show poor performance on spelling points to the severity of their literacy deficit and that continued support is required. It is also expected that children with DLD in general will have had more intensified spelling instruction at school, as it is

common practice to provide these children with additional literacy instruction, given their increased risk of difficulties in this area. However, it is not clear whether the amount and type of instruction was the same for all children. For the subgroup of children with both DLD and (a suspicion of) dyslexia, more intensified instruction at school and specialist dyslexia treatment will have commenced. However, little is known about the treatment outcomes of children with comorbid disorders, such as dyslexia and DLD. It is evident that the absence of the information on the amount and type of spelling instruction and treatment limits the interpretations of the current study and requires further study. Future studies should thus connect spelling outcomes both to item characteristics (which targets assessed, frequencies, age of acquisition), child characteristics (language, word reading), as well as to school and treatment characteristics (e.g., methods used, quality of instruction, additional intervention received). Such a project is currently being conducted in regular school settings (Drijver et al., in preparation).

A final limitation is that we only compared spelling of the clinical groups to age-matched peers, not younger language-or literacy-matched control groups. This was not the aim of our study but might have provided insight in the amount of delay as well as potential similarities between the younger peers in spelling errors of the clinical groups.

Conclusions

Our findings indicate that children with dyslexia and children with DLD show spelling difficulties, and children with DLD and additional reading difficulties do so most prominently. The spelling errors show that errors arise when phonology-orthography and morphology need to be associated and rules have to be applied. For children with dyslexia and DLD+RD, errors are also more prominent in more basic phoneme-grapheme associations. These findings warrant (continued) intensive and systematic spelling intervention. The finding that there is a strong influence of reading ability on spelling outcomes and a less pronounced direct role of oral language underscores the importance of literacy instruction for spelling development and calls for the support of literacy skills as well as oral language in children at-risk of spelling difficulties.

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Supplemental figures

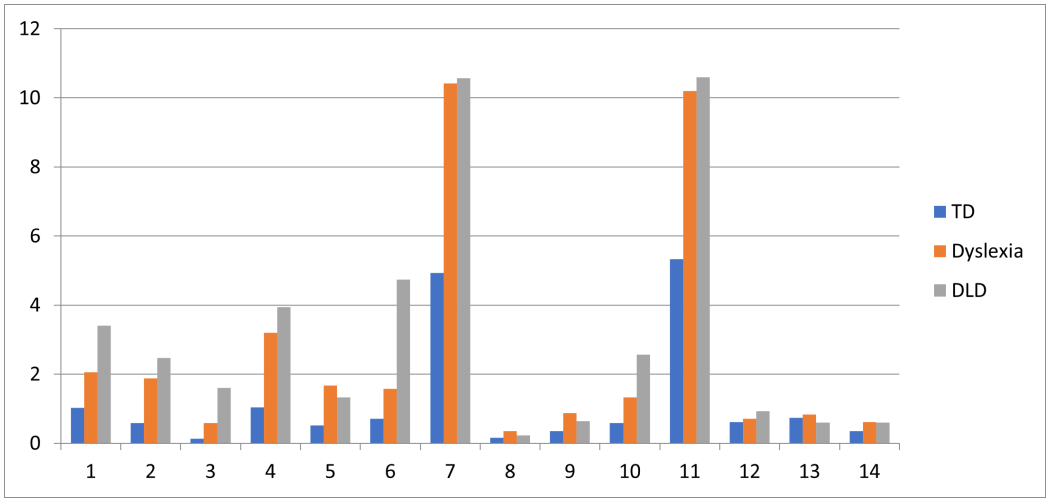

Figure 3: Number of Errors by SVS Spelling Category (de Vos & Braams, 2015, see Table 2) for Three Groups

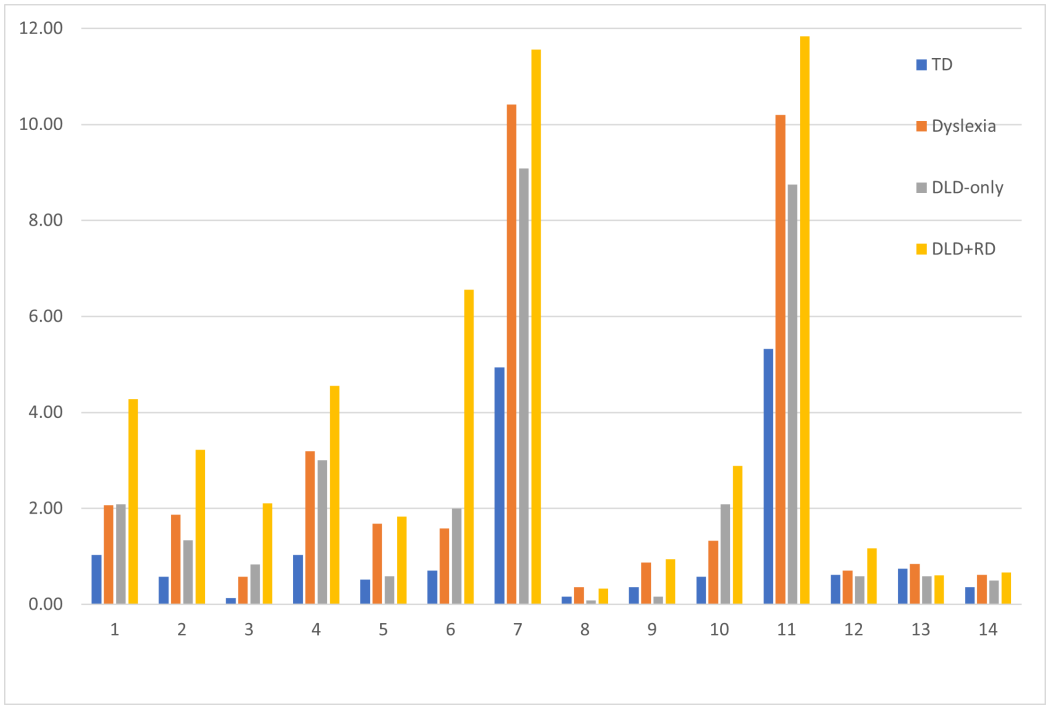

Figure 4: Number of Errors by SVS Spelling Category (de Vos & Braams, 2015, see Table 2) for Four Groups