INVESTIGATING THE LOCUS OF THE PHONOLOGICAL DEFICIT IN GREEK CHILDREN WITH DYSLEXIA AND DEVELOPMENTAL LANGUAGE DISORDER: DEGRADED PHONOLOGICAL REPRESENTATIONS OR DEFICIENT PHONOLOGICAL ACCESS?

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Abstract: The objective of the study was to investigate the locus of the phonological deficit in Greek children with dyslexia and Developmental Language Disorder (hereafter children with DDLD) by testing the Degraded Phonological Representations Hypothesis and the Deficient Phonological Access Hypothesis. Sixty-six children with DDLD aged 7-12 years and 63 typically developing (TD) children aged 7-12 years, all monolingual Greek speakers, were assessed with phoneme deletion, nonword repetition, rapid automatic naming, and spelling tasks, in addition to a range of language and reading tasks. The DDLD group performed significantly poorly on phoneme deletion tasks loading on phonological short-term memory capacity. Further, a qualitative analysis of spelling errors revealed that the majority of errors (96%) made by the DDLD group did not change the phonology of the spelled words, showing that mainly nonphonological difficulties account for poor spelling accuracy performance in Greek children with DDLD. The findings are consistent with the view that phonological representations of children with dyslexia and DLD are intact, but less accessible.

Key words: Developmental language disorder, Dyslexia, Phonological deficit, Spelling accuracy

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INTRODUCTION

Phonological difficulties in children with dyslexia and DLD

Dyslexia and Developmental Language Disorder[1], or DLD for short, are two neurodevelopmental disorders which affect, respectively, the typical development of literacy and oral language skills. It is well-established that children with dyslexia and DLD show poor performance on three main dimensions that rely on the efficient functioning of the phonological system, namely, on tasks assessing phonological awareness, phonological short-term memory and rapid automatic naming skills (see for dyslexia: Wagner & Torgesen, 1987; see for DLD: Ramus, Marshall, Rosen, & van der Lely, 2013). Phonological representations, referring to the abstracted way that speech sounds of a particular language are represented in the brain, are involved in the successful completion of all three tasks. Specifically, the three tasks require, respectively, the manipulation of phonological representations (such as deletion tasks), the retention of verbal material in short-term memory (such as nonword repetition tasks), and quick and efficient access to phonological representations (such as rapid automatic naming tasks) (e.g., Snowling, 2000). Phoneme deletion, nonword repetition and rapid automatic naming tasks have been reported to account for significant amounts of variance in reading and spelling performance across orthographies, as evidenced by large-scale cross-linguistic studies in typically developing (TD) children (Moll et al., 2014; Ziegler et al., 2010).

The language of examination in the present study is Greek. Greek has a shallow orthography, which means that it is characterized by consistent grapheme-to-phoneme mappings (Seymour, Aro, & Erskine, 2003), estimated to be 95% consistent for reading and 80% consistent for spelling (Protopapas & Vlahou, 2009). Considering this high level of orthographic consistency for reading, it is not surprising that reading difficulties are evident primarily in poor reading fluency rather than poor reading accuracy (Nikolopoulos, Goulandris, & Snowling, 2003). Having said that, reading accuracy difficulties are evident in children with dyslexia even in Grade 7 (Protopapas & Skaloumbakas, 2007; Protopapas, Skaloumbakas, & Bali, 2008; Protopapas, Simos, Sideridis, & Mouzaki, 2012). With respect to phonological difficulties, children with dyslexia and DLD have been reported to show phonological deficits in tasks measuring phonological awareness, phonological short-term memory

1. The term "Developmental Language Disorder", or DLD for short, has been proposed as a replacement for "Specific Language Impairment" (Bishop et al., 2017). The term DLD has been embraced by some researchers (Joye, 2019; Joye, Broc, Olive, & Dockrell, 2019; Mengisidou, 2019; Mengisidou & Marshall, 2019) since it was first proposed by Bishop et al. (2017).

and rapid automatic naming skills (e.g., Diamanti, Goulandris, Campbell, & Protopapas, 2018; Spanoudis, Papadopoulos, & Spyrou, 2019; Talli, Sprenger-Charolles, & Stavrakaki, 2016).

Phonological awareness deficits have been associated with reading difficulties in dyslexia and DLD (see for dyslexia: Boets et al., 2010; Gallagher, Frith, & Snowling, 2000; Lundberg, 2002; Lyytinen et al., 2004; Snowling, Gallagher, & Frith, 2003; see for DLD: Bird, Bishop, & Freeman, 1995; Briscoe, Bishop, & Norbury, 2001; Nathan, Stackhouse, Goulandris, & Snowling, 2004; van Alphen et al., 2004). Phonological short-term memory is considered as another skill called for by decoding skills in reading. Poor nonword repetition performance in children with DLD is established (Gathercole, Willis, Baddeley, & Emslie, 1994), being an excellent behavioural marker of DLD, as it can discriminate with high accuracy children who received a diagnosis of DLD from TD children (Conti-Ramsden, Botting, & Faragher, 2001; Hesketh & Conti-Ramsden, 2013; Kalnak, Peyrard-Janvid, Forssberg, & Sahlén, 2014). Effect sizes also reveal that the longer the nonwords, the bigger the gap between children with and without DLD. This is a very well-replicated finding (e.g., Barry, Yasin, & Bishop, 2007; Gathercole & Baddeley, 1996; Graf Estes, Evans, & Else-Quest, 2007; Loucas, Baird, Simonoff, & Slonims, 2016). Poor nonword repetition performance has also been consistently found in dyslexia (e.g., Catts, Adlof, Hogan, & Weismer, 2005; de Bree, Rispens, & Gerrits, 2007; Gathercole & Baddeley, 1990; Kamhi & Catts, 1986). In Georgiou and Parrila's (2013) review, it has been reported that there is an association between the speed with which people perform in rapid automatic naming tasks and their reading ability, and an association between a slow naming speed and reading difficulties, accounted for by lexical access impairments, serial processing and articulation (Georgiou, Ghazyani, & Parrila, 2018). With respect to DLD, Bishop, Macdonald, Bird, and Hayiou-Thomas (2009) reported that performance in the rapid automatic naming task at 9 years was the strongest predictor to divide the children with DLD into groups on the basis of literacy achievement. The researchers concluded that rapid automatic naming is related to reading ability, and good rapid automatic naming skills protect the child against reading difficulties, even when oral language skills are impaired (see also Brizzolara et al., 2006; Catts, 1993; Vandewalle, Boets, Ghesquiere, & Zink, 2010).

The leading view on dyslexia for many years has been that phonological representations are degraded (i.e., less robust and distinct), and that this primary representational deficit impacts upon higher-level phonological processing, and ultimately, upon reading development. This view is called the Degraded Phonological Representations Hypothesis (e.g., Goswami, 2000; Leong, Hämäläinen, Soltész, & Goswami, 2011; Ziegler & Goswami, 2005). The concept of degraded phonological representations implies that during the course of development, children with dyslexia have experienced difficulties in establishing representations of phonological units that are adequately robust and distinct for the recognition and production of words. This view has received substantial empirical support from a range of experimental studies (e.g., Grigorenko, 2001; Ramus et al., 2003; Saksida et al., 2016; Vellutino, Fletcher, Snowling, & Scanlon, 2004).

However, in an influential review of the dyslexia literature in adults, Ramus and Szenkovits (2008) argued that the phonological deficit is evident only under certain task demands, namely tasks requiring explicit manipulation of speech sounds, loading phonological short-term memory, or requiring speeded access to phonological representations. The researchers instead proposed the Deficient Phonological Access Hypothesis, arguing that phonological representations of people with dyslexia are intact, but hard to access because of the involvement of the aforementioned processes, which are required to explicitly access phonological representations, processes which are deficient in dyslexia. This hypothesis has since been supported by a number of empirical studies (e.g., Boets et al., 2013; Dickie, Ota, & Clark, 2013; Mengisidou & Marshall, 2019; Ramus et al., 2013; Soroli, Szenkovits, & Ramus, 2010; Szenkovits, Darma, Darcy, & Ramus, 2016). This hypothesis reflects a central distinction in the literature between explicit and implicit access to phonological representations: for the latter, processing demands are minimized, and it is only by using phonological tasks with minimal processing demands that the quality of phonological representations can themselves be assessed (Ramus et al., 2013).

The two phonological hypotheses of dyslexia presented also apply to DLD, given that many children with DLD have phonological difficulties linked to reading difficulties similar to those seen in children diagnosed with dyslexia (e.g., Bishop et al., 2009; Catts, 1993; Hulme & Snowling, 2009; Kamhi & Catts, 1986). From the review so far, it is evident that in the dyslexia literature, most of the studies supporting a phonological access deficit have been conducted in adults. Adopting a developmental perspective, however, allows researchers to test what is perhaps the most valid criticism of the Deficient Phonological Access Hypothesis: the possibility that adults with dyslexia have degraded phonological representations in childhood, but these representations have recovered by adulthood (e.g., Goswami, 2003). Recently, Mengisidou and Marshall (2019) tested the Degraded Phonological Representations Hypothesis and the Deficient Phonological Access Hypothesis in Greek children with dyslexia and DLD, combined in a single group, the DDLD group, aged 7-12 and in their TD peers aged 6-12 years using phonological fluency tasks ("Name as many words as possible beginning with the letter 'F' in 1 minute"). The explanatory variables were the number of words retrieved in a phonological category (e.g., the letter 'F') and the number of items belonging to a phonological cluster. For example, "flag-flower" is a phonological cluster since the two words share the initial two phonemes ("fl"). The researchers argued that phonological clustering provides a more implicit measure of the quality of children's phonological representations on the basis that phonological similarity in successive produced responses might aid lexical retrieval. In the example given above, the retrieval of "flag" might facilitate the retrieval of "flower" because in the two words phonological representations partly overlap. The results showed that the DDLD group retrieved significantly fewer words in phonological fluency tasks compared to the TD group, but that the two groups did not differ on average cluster size after controlling for age. Mengisidou and Marshall (2019) interpreted these results as evidence that deficient explicit access to phonological representations explains DDLD children's phonological fluency difficulties, as evidenced by the retrieval of fewer words belonging to phonological categories, while implicit access to phonological representations is intact, as evidenced by the number of items belonging to a phonological cluster.

Aside from classic phonological tasks and phonological fluency tasks, however, spelling tasks can also be used towards investigating the locus of DDLD children's phonological difficulties. Spelling accuracy performance in children with dyslexia and DLD is reviewed below in order to define the background in which this study should be placed.

Spelling accuracy performance in children with dyslexia and DLD

Accurate spelling requires several years of formal schooling. Children with dyslexia and DLD show difficulty, however, in achieving age-appropriate spelling skills (e.g., for dyslexia: Protopapas, Fakou, Drakopoulou, Skaloumbakas, & Mouzaki, 2013; for DLD: Joye et al., 2019). In the light of direct evidence that spelling accuracy is moderated by orthographic consistency (Marinelli, Romani, Burani, & Zoccolotti, 2015), the objective of the present study is to use a spelling task to examine what specific spelling errors in dictation are made by Greek children with DDLD and whether the same errors are made by their TD peers.

With respect to the types of spelling errors observed in Greek children with dyslexia, studies have revealed that despite a persistent spelling difficulty, the number of phonological errors is negligible (Nikolopoulos et al., 2003; Niolaki & Masterson, 2013; Porpodas, 1999; Protopapas et al., 2013). For example, Porpodas (1999) reported that the proportion of word spelling accuracy of first Graders suffering poor reading and spelling skills was 25% while the proportion of their nonword spelling phonological accuracy was 88%. However, despite the fact that Greek children with dyslexia make a negligible number of phonological errors, research has shown that they produce significantly more phonologically incorrect words than TD children, with their greater difficulty being observed in the level of the morphological and orthographic structure of words, as reported by Protopapas et al. (2013). Protopapas et al. (2013) followed a systematic, fine-grained, approach to error classification in Greek TD children and children with dyslexia, providing one of the most precise spelling analyses in the dyslexia literature to date. They assessed children of Grades 3-4 and 7 in a spelling-to-dictation task and in a passage spelling task. They reported that both groups made primarily grammatical errors followed by orthographic errors, while phonological errors were negligible. Group comparisons revealed that children with dyslexia produced significantly more phonological, grammatical, and orthographic errors than TD children. The researchers concluded that spelling errors of children with dyslexia indicate a persistent difficulty with internalizing regularities of the Greek orthographic lexicon, including derivational, inflectional and word families. Diamanti, Goulandris, Stuart, and Campbell (2014) also found weaknesses in how Greek children with dyslexia applied morphological knowledge to correctly spell word suffixes. With respect to the types of spelling errors produced by children with DLD, Critten, Connelly, Dockrell, and Walter (2014) reported that English children with DLD aged 9-10 years showed a lack of efficiency in phonological processes and in applying derivational morphological rules in their spelling compared to age- and language-matched children aged 6-8 years; however, no difference was found in accuracy and error patterns for inflectional morphemes. To date, however, there is no study investigating the types of spelling errors in Greek children with DLD.

Further, what predicts spelling accuracy in dyslexia and DLD is another area of exploration. The impact of phonological and reading skills on the spelling profiles of children with DLD has been confirmed in a recent meta-analytic study which included 984 children with DLD (Joye et al., 2019). In the absence, however, of substantial evidence investigating what processes underlie poor spelling accuracy in more consistent orthographies than English, with a richer morphology, researchers are not able to identify whether difficulties in nonphonological processing skills may also have an impact on spelling accuracy (Joye et al., 2019). The Greek orthography is ideal towards this investigation given that it is a more consistent and morphologically richer orthography than English.

The present study

From the review so far, it is evident that it is not yet clear whether the phonological deficit in dyslexia and DLD originates from degraded phonological representations themselves, or whether the phonological representations are intact but access to them is problematic whenever task demands are high. Moreover, research investigating what processes underlie poor spelling accuracy performance in children with dyslexia and/or DLD in the Greek consistent orthography is still lacking. In the present study, DDLD children's phonological skills were assessed using a range of classic phonological tasks and a spelling task in order to add to the theoretical debate on the contested locus of the phonological deficit in dyslexia and DLD. Specifically, the aim of the present study is to test the Degraded Phonological Representations Hypothesis and the Deficient Phonological Access Hypothesis using three phoneme deletion tasks with items varying in syllabic length and syllabic complexity. That is, a task of monosyllable items with a simple CVC (C: consonant; V: vowel) syllable structure, a task of monosyllable items with a complex CCV syllable structure, and a task of trisyllable items with a simple CVCVCV syllable structure, with the explanatory variables being the groups' accuracy performance in the three phoneme deletion tasks. To this same end of the present study, a nonword repetition task with items varying in syllabic length and a rapid automatic naming task are also used, with the explanatory variables of the two tasks being the following. The groups' nonword repetition accuracy performance, and the time spent on naming pictures and the number of phonological errors in the naming task.

Overall, the present study set out to answer the following research questions about phonological skills and spelling accuracy in Greek-speaking children with DDLD:

- Is poorer phonological accuracy performance in phoneme deletion tasks in children with DDLD better explained by degraded phonological representations themselves, or by deficient access to (intact) phonological representations?
- Is poorer spelling accuracy in children with DDLD better explained by phonological or nonphonological difficulties?

Using phoneme deletion tasks, the Degraded Phonological Representations Hypothesis predicts that the TD group will outperform the DDLD group in accuracy performance in all three phoneme deletion tasks. This is explained by impaired phonological representations in the DDLD group. In contrast, the Deficient Phonological Access Hypothesis predicts that accuracy performance in the phoneme deletion task of monosyllable items with a simple CVC syllable structure will be equivalent for the two groups. This is explained by the fact that short nonwords with a simple syllable structure do not load children's phonological short-term memory capacity. The Deficient Phonological Access Hypothesis also predicts that accuracy performance in the phoneme deletion task of trisyllable items with a simple CVCVCV syllable structure and in the phoneme deletion task of monosyllable items with a complex CCV syllable structure will be poorer for the DDLD group than the TD group. This is explained by the fact that longer nonwords, namely nonwords with three syllables, or nonwords with a complex syllable structure load children's phonological short-term memory capacity. It should be noted that in this study, phonological short-term capacity was not actually measured, however, a nonword repetition measure consisting of 3-, 4-, 5-, and 6-syllable nonwords was used to investigate whether the DDLD group shows phonological short-term memory deficits relative to the TD group.

Using the rapid automatic naming task, the Degraded Phonological Representations Hypothesis predicts that the DDLD group will make significantly more phonological errors in their picture naming than the TD group. Phonologically inaccurate performance is explained by inaccurate phonological representations. The Deficient Phonological Access Hypothesis, however, predicts that the DDLD group will name pictures significantly slower than the TD group but that the two groups will not differ on phonological accuracy performance. Slower picture naming performance is explained by the fact that the phonological access deficit in the DDLD group renders performance on tasks requiring speeded access to phonological representations particularly slow. Phonologically accurate performance is explained by intact access to phonological representations in the rapid automatic naming task not requiring metalinguistic manipulation.

As already mentioned, another objective of the present study was to investigate spelling error types in dictation in children with DDLD. In Greek, in order for a word to be processed successfully in dictation, requires not only phonological processing skills but also grammatical, and orthographic processing skills. A few studies have analysed spelling errors in Greek children with dyslexia, but no study has investigated spelling errors in Greek children with DLD. The present study aims to fill this gap by analysing spelling errors using a dictation task in a large sample of Greek children with dyslexia and/or DLD, combined in the DDLD group, and by examining whether the same errors can be found in TD children in group comparisons. Types of spelling errors will inform the researcher about processes which are problematic in Greek children with DDLD and processes which function in an age-appropriate level. In this context, phonological errors reflect knowledge of grapheme-to-phoneme mappings, grammatical errors reflect children's knowledge of inflectional morphology, and orthographic errors reflect children's knowledge of word stems. The ultimate objective, however, which is related to the two prominent phonological hypotheses considered, is to investigate whether the Degraded Phonological

Representations Hypothesis or the Deficient Phonological Access Hypothesis better characterises the locus of the phonological deficit in Greek children with dyslexia and/or DLD. It is predicted that if the Degraded Phonological Representations Hypothesis holds true, qualitative analysis of spelling errors will reveal that the DDLD group produces a significantly higher proportion of phonological spelling errors than the TD group. This is explained by inaccurate phonological representations in the DDLD group. However, if the Deficient Phonological Access Hypothesis holds true, qualitative analysis of spelling errors will reveal a similar proportion of phonological spelling errors in the DDLD group relative to the TD group. This is explained by accurate phonological representations but inappropriate orthographic encoding of words using grapheme-to-phoneme mappings in the DDLD group.

METHOD

Participants

Participants were 129 children, namely, 66 children with dyslexia and/or DLD (43 males), and 63 TD children (28 males), who were monolingual Greek speakers. The researcher recruited children with dyslexia and/or DLD based on previous clinical diagnoses: they were selected on the basis that they had received a diagnosis because of persistent and specific reading or language problems[2]. Thirty children with dyslexia and/or DLD had co-existing difficulties accompanying the diagnosis of persistent and

[2.] In Greece, the evaluation of reading or language problems is carried out by a five-member interdisciplinary team. The team consists of a teacher (of preschool, primary, or secondary education), a paediatric psychiatrist, or a paediatrician specialized in paediatric neurology, or a neurologist specialized in paediatric psychology, a social worker, a psychologist, and a speech and language therapist. The interdisciplinary team may also include an occupational therapist,or a member of the specialized special education personnel. Initially, parents give an interview to the social worker, offering detailed information on the child's socio-developmental history. At the same time, the child is given a psychologist's mental ability test and the child's learning is evaluated by a teacher in order to initially determine the child's level of intelligence and the type and intensity of their difficulties, respectively. The report, which is a confidential document, is delivered to the school, after the parents are first informed of the child's difficulties. Further, given that in Greece, clinicians use different types of diagnostic assessments, the researche is not aware which of the assessments were used for each of the selected children. The researcher is not therefore in a position to provide more details to better characterize the profiles of the selected children with dyslexia and/or DLD in the sample on the basis of the diagnostic procedure followed by clinicians. Despite that limitation of the design of the present study, however, the language, literacy, and phonological profile of the group of children with DDLD compared to the group of children with TD is presented in the Methods section as assessed with a range of tasks for the purpose of the present study (see Table 1).

specific reading or language problems, such as attention-deficit/hyperactivity disorder, developmental disorder of motor skills, articulation disorder, specific disorder in speech fluency, or dysgraphia. In line with the CATALISE consortium (Bishop et al., 2017), children with additional disorders were not excluded from the study given that additional disorders are considered as descriptors of a child's profile[3]. Furthermore, the nonverbal IQ inclusion criterion for both the DDLD and TD groups was a score of 70 or above, following the CATALISE consortium (Bishop et al., 2017) and Norbury et al.'s (2016) population study which reported that children with a lower nonverbal ability (i.e., a standard score between 70 and 85) did not differ significantly in their language profile from children with an average nonverbal ability (i.e., a standard score > 85). In the present study, five children with DDLD had lower nonverbal ability (all of whom had a standard score of 75).

When recruiting children for the TD group, we excluded those who achieved a percentile score of 10 or lower on a standard text-reading fluency measure, or substantial difficulties with the language and literacy tasks (e.g., children who had substantial difficulty understanding instructions and/or whose response times were extremely slow). Nine children who had a percentile score of 10 or lower on a text-reading fluency measure, and another child who also had substantial difficulties with the language and literacy tasks, were therefore excluded from the study. None of the TD children included in the study had a current or prior history of hearing or visual deficit, neurological disease, or medication for any neurological, psychiatric, or behavioural disorder. Although our inclusion criteria permitted TD children who had a nonverbal IQ score as low as 70, none actually scored lower than 80.

Traditionally, dyslexia and DLD are viewed as separate disorders. In the present study, however, the children with dyslexia and DLD were combined in one group, the DDLD group, as proposed for this same group of participants by Mengisidou and Marshall (2019). In fact, literacy difficulties are very common in children with DLD (e.g., Conti-Ramsden et al., 2001), and it is the case that approximately 50% of children who fit the criteria for dyslexia also fit the criteria for DLD, and vice versa (e.g., Messaoud-Galusi & Marshall, 2010; Spanoudis et al., 2019). In addition, there are currently no gold-standard assessments of diagnosing dyslexia and DLD with adequate psychometric properties, namely, valid and reliable assessments with

[3] Bishop (2017) argues that it is misleading to assume that co-occurring conditions are causes of language disorder, but that DLD should be distinguished from cases of language disorder associated with 'differentiating conditions' that have a known or likely biomedical origin, including brain injury, sensorineural hearing loss, genetic syndromes, intellectual disability and autism spectrum disorder. None of the children recruited to the present study had any of these conditions. Considering this conceptualization of DLD, it was not considered appropriate to control for co-occurring conditions in the analyses.

diagnostic or prognostic value. In this context, Dockrell and Marshall (2015) argue that screening measures to date do not meet psychometric properties to identify language problems, and, also, that the interpretation of language assessments is challenged by a range of factors, including socioeconomic status, multilingualism, hearing impairment, and even the characteristics of the assessment. The last of these factors is particularly relevant to the present study.

In Greece, while there has been some progress in the development of psychometric materials over recent years (e.g., Sideridis, Mouzaki, Protopapas, & Simos, 2008; Βογινδρούκας, Πρωτόπαπας, & Σταυρακάκη, 2009), standardised clinical tools for the diagnosis of dyslexia and DLD for preschool- and school-aged children are still lacking. Dyslexia is therefore often diagnosed on the basis of non-standardized measures of reading and spelling ability (Anastasiou & Polychronopoulou, 2009), and the same is also the case for DLD. This raises the issue of how accurately children with dyslexia, children with DLD, and children with dyslexia plus DLD can be differentiated; this might not be as easy as in studies of English-speaking children (e.g., Catts et al., 2005; Ramus et al., 2013). Further, previous research in Greek that explored the overlap between dyslexia and DLD, reported that dyslexia and DLD show common deficits on tasks measuring reading skills and reading-related phonological skills (Spanoudis et al., 2019; Talli et al., 2016), even though they do not completely overlap (see also the Principal Component Analysis with oblique rotation that was carried out on language and literacy scores within just the children with dyslexia and/or DLD in the Results section).

This DDLD group had a mean age of 9.51 (*SD* = 1.46; range = 7.04 - 12.02) years and the TD group had a mean age of 8.97 (*SD* = 1.60; range = 7.00 - 12.04) years. The DDLD group was significantly older than the TD group, $t(127) = -2.01$, $p = .046$. On the Greek standardization of the nonverbal IQ task (Σιδερίδης, Αντωνίου, Μουζάκη, & Σίμος, 2015) of the Raven's Coloured Progressive Matrices (CPM; Raven, 2008), the mean standard score of the DDLD group was 96.74 (*SD* = 15.12) and of the TD group was 106.42 (12.77), with the Greek standardization of the CPM having good internal consistency (Cronbach's $\alpha = .86$), as reported by Σιδερίδης et al. (2015). The TD group significantly outperformed the DDLD group, $t(127) = 3.92$, $p < .001$, Cohen's $d = .69$, as has been found in previous studies of children with literacy and language disorders (e.g., Ramus et al., 2013).

Statistical analyses

First, analyses of covariance were carried out, with the score of each task as a dependent variable, group as a fixed factor, and age in months as a covariate variable, in order to better appreciate the DDLD group's overall performance on language, literacy, and phonological tasks. Second, a PCA within the DDLD group was carried out in order to justify keeping children with dyslexia and children with DLD in the same group. Third, group differences on phoneme deletion variables were analysed using multivariate analysis of variance. Specifically, a 3 (Phoneme deletion of CVCVCV, CVC, and CCV items) by 2 (Group) multivariate analysis of variance for accuracy performance was conducted based on *z* scores computed for the phoneme deletion tasks as there was not an equal number of nonwords in all three tasks. This analysis was performed in order to investigate phonological accuracy performance in phoneme deletion tasks in children with DDLD, and specifically, to examine how syllabic length and syllabic complexity affect DDLD children's accuracy performance on phoneme deletion tasks compared to their TD peers' accuracy performance. Fourth, for the nonword repetition data, a 4 (3-, 4-, 5-, and 6-syllable nonwords) by 2 (Group) univariate analysis of variance was performed. This analysis was performed in order to investigate deficits in phonological short-term memory capacity in children with DDLD. Fifth, with respect to the rapid automatic naming task, given that the distributions of the number of phonological errors, semantic errors, and omissions in the rapid automatic naming task were strongly skewed to the right, a non-parametric test, two independent samples Mann-Whitney *U* test, was used to compare statistically the two groups on these three numbers. This analysis was performed in order to investigate whether children with DDLD make more phonological errors in their picture naming than TD children, and whether children with DDLD name items significantly slower than TD children. Sixth, a qualitative analysis of spelling errors was carried out to examine what specific spelling errors in dictation are made by Greek children with DDLD and whether the same errors are made by their TD peers. This allowed the researcher to reveal what processes underlie poor spelling accuracy performance, namely, phonological or nonphonological difficulties, in more consistent orthographies than English, such as Greek. With respect to the analyses of the spelling task, the distributions of the proportional numbers of phonological and grammatical errors were strongly skewed to the right. This was because there were children who did not produce any phonological or grammatical errors. Thus, a non-parametric test, two independent samples Mann-Whitney *U* test, was used to compare the groups on the proportional numbers of phonological and grammatical errors since the explanatory variables of interest were continuous but not normally distributed. However, a parametric test, an independent samples *t*-test, was used to compare the two groups on the proportional number of orthographic errors since the distribution of the proportional number of orthographic errors was normal. Conventions for interpreting partial eta squared originating from analyses of group differences on performance in each variable, as proposed by Cohen (1988) were used in the present study. Nonverbal IQ was not statistically controlled in the statistical analyses, following Dennis et al. (2009) who argued that using IQ scores as a covariate is misguided and unjustified in cognitive studies with children with neurodevelopmental disorders.

Tasks

Language, literacy, and phonological skills were assessed using a wide range of tasks in order to profile the DDLD group's language, literacy, and phonological difficulties. This paragraph explains the researcher's strategy for task selection. In the overall sample ($N = 129$), language skills were assessed with a widely used task of receptive vocabulary, in addition to tasks drawing upon a range of language processing skills, namely verbal comprehension, syntax comprehension, and sentence repetition. Literacy skills were assessed with reading accuracy, text-reading fluency and spelling tasks. Reading accuracy and reading fluency are sensitive measures and can reveal reading difficulties in children who are reading in the Greek consistent orthography (Diamanti et al., 2018). Spelling accuracy is another sensitive index of reading difficulty in Greek (Porpodas, 1999; Protopapas & Skaloumbakas, 2007). Two literacy tasks were used in the overall sample, namely text-reading fluency, as measured by Alouette, and spelling. However, given that there were no Greek standardised reading accuracy tasks designed for the age range of the study, second Graders ($N = 27$) were assessed with syllable and nonword reading tasks, and third to sixth Graders ($N = 102$) were assessed with reading accuracy and text-reading fluency tasks. In the overall sample, phonological skills were assessed with widely-used tasks assessing reading-related phonological skills, namely phoneme deletion, nonword repetition and rapid automatic naming tasks, which reveal the typical phonological deficit in children with dyslexia and DLD (e.g., Ramus et al., 2013).

Language Skills

Verbal Comprehension. Children's verbal comprehension was assessed with the Similarities and Vocabulary subtasks of the Greek standardization (Γεώργας, Παρασκεύοπουλος, Μπεζεβέγκης, & Γιαννίτσας, 1997) of the Wechsler Intelligence Scale for Children (WISC-III; Wechsler, 1991). The third version of the WISC was used because the researcher had access to that version and not to most recent ones. For the Similarities subtask, children had to identify how two words are alike (maximum score = 33). Internal consistency for the WISC-III Similarities subtask was computed using Cronbach's α; for 6- and 7-year-old children: $\alpha = .65$, for 8-year-olds: α = .59, for 9-year-olds: α = .62, for 10-year-olds: α = .78, for 11-year-olds: α = .76, for 12-year-olds: α = .81. This subtask is also a good measure of general verbal ability, as it is highly correlated with the total scale (factor loadings: .74 for children aged 6 to 7, and .77 for those aged 8 to 10; Wechsler, 1991).

For the Vocabulary subtask, children were asked to define words (maximum score = 60). Internal consistency for the WISC-III Vocabulary subtask was computed using Cronbach's α; for 6-year-old children: α = .62, for 7-year-old children: α = .68, for 8-year-olds: α = .76, for 9-year-olds: α = .81, for 10-year-olds: α = .84, for 11-year-olds: α = .83, for 12-year-olds: α = .81. In both subtasks, responses scored two, one, or zero points, with the difference in scores reflecting the quality (accuracy and detail) of the response given.

Syntax Comprehension and Sentence Repetition. Two subtasks of the Diagnostic Verbal Intelligence (DVIQ) Test (Σταυρακάκη & Τσιμπλή, 2000) were used, namely syntax comprehension and sentence repetition. For syntax comprehension, children were required to listen carefully to a sentence and to select the picture that best depicted the meaning of the sentence. The child's score was the number of correctly-selected pictures (maximum = 17). For sentence repetition, children heard a sentence and were asked to repeat it as accurately as possible. The maximum possible score was 30.

Peabody Picture Vocabulary Test-Revised (PPVT-R). The Greek non-standardised version (Simos, Sideridis, Protopapas, & Mouzaki, 2011) of the PPVT-R (Dunn & Dunn, 1981) was used to assess children's receptive vocabulary. Children were provided orally with a word and were instructed to decide which of the pictures provided best represented its meaning. The child's score was the number of correctly selected pictures (maximum = 173). The task has good internal consistency (Cronbach's α = .92-.98) and test-retest reliability (6 months; Pearson's *r* = .65-.86), as reported by Simos et al. (2011).

Literacy Skills

Alouette. In the overall sample, text-reading fluency was assessed with the Alouette task (Lefavrais, 1967), which has been adapted into Greek by Talli et al. (2016). Children were required to read as accurately and fast as possible a 271-word text bearing no meaning. The number of words read correctly within 3 min was recorded for each child.

Reading Accuracy and Text-Reading Fluency. The reading accuracy and text-reading fluency subtasks of the Reading Test Alpha (Τεστ Ανάγνωσης Άλφα; Παντελιάδου & Αντωνίου, 2007) were used to assess, respectively, reading accuracy and reading fluency in children from Grade 3 to 6. In the reading accuracy subtasks, children were asked to read as accurately as possible the presented words and nonwords, and to report aloud only the real words of the lexical decision subtask. The reading accuracy score was the number of words and nonwords read correctly (maximum = 77), alongside the number of words and nonwords identified as such in the lexical decision subtask (maximum = 36). Test-retest reliability for all three subtasks ranges between Pearson's r = .74 and .87, as reported by Παντελιάδου και Αντωνίου (2007). In the text-reading fluency subtask, children were required to read as accurately and fast as possible a text of 279 words for 60 seconds. The reading fluency score was the number of words read correctly within the time limit. The task has good test-retest reliability (Pearson's r = .74-.87), as reported by Παντελιάδου και Αντωνίου (2007).

Syllable and Nonword Reading. The syllable and the nonword reading subtasks of the Test of Detection and Investigation of Reading Difficulties (Πόρποδας, 2007) contained 24 syllables and 24 nonwords, respectively. A child's score for each subtask was the number of syllables and nonwords read correctly (maximum = 24, for each subtask).

Spelling-to-Dictation. The spelling-to-dictation task (Sideridis et al., 2008) was another literacy task which was administered in the overall sample. The task consisted of 60 words presented orally in the context of a short sentence. First, the word is read aloud, then the sentence including the target word, and then the word is read aloud again. Any word with correct spelling scored one point and the task was discontinued after six consecutive spelling errors. The task has very good psychometric characteristics (internal consistency in the overall sample: Cronbach's α = .95; test-retest reliability one year later: Pearson's r = .91; internal consistency for Grade 2 onwards: respectively, α = .89, α = .93, α = .94, α = .95, and α = .94), as reported by Sideridis et al. (2008).

Phonological Skills

Phoneme Deletion. Children's phonological awareness skills were assessed with three phoneme deletion tasks of the computerised battery Evaluation de la Lecture (EVALEC; Sprenger-Charolles, Cole, Bechennec, & Kipffer-Piquard, 2005), which has been adapted into Greek by Talli et al. (2016). The first two tasks contained 12 monosyllabic items each of CVC or CCV syllable structure, respectively, and the third task contained 10 trisyllabic items of CVCVCV syllable structure. Children had to produce the nonword without the initial consonant or consonant cluster. Three nonwords were given as practice trials for each task and children asked to produce them without their first sound. A child's score was the total number of correct responses in each task.

Nonword Repetition. The EVALEC's nonword repetition task has been adapted from Sprenger-Charolles et al. (2005; see Talli et al., 2016) and required children to repeat 24 nonwords. Nonwords increased in length from three to six syllables. Three nonwords were given as practice trials and children asked to repeat them. The number of nonwords repeated correctly was the child's score.

Rapid Automatic Naming. Rapid automatic naming was assessed with the picture naming subtask of the Phonological Assessment Battery (PhAB; Frederickson, Frith, & Reason, 1997). The measure contains two cards of five pictures repeated ten times on each card. Prior to testing, the experimenter named the pictures to familiarize children with the task. Children were required to name the pictures as fast as possible while trying not to make any mistakes. Children's score was the average naming time (in seconds) taken for the two cards.

Categorization of Spelling Errors

Following the classification system of errors proposed by Protopapas et al. (2013), errors were classified into three broad categories: phonological, grammatical, and orthographic errors, presented in detail below. Stress omissions were not counted because of their large number, as previously reported (Anastasiou & Protopapas, 2015; Protopapas et al., 2013). Unclassifiable errors, such as mirrored letters (e.g., 'έτσι' /etsi/ spelled '3τσι'), were also not considered as they were very rare in this sample.

Phonological Errors. Phonological errors alter the word's phonological form, so that the written word is pronounced differently from the one intended as each sound can be written in one or more specific ways. In this category, phonological errors could concern a substitution of syllables or phonemes, an insertion of syllables or phonemes, an omission of syllables or phonemes, or an inversion of syllables or phonemes.

Grammatical Errors. Grammatical errors concern phonologically equivalent (i.e., they maintain the word's correct pronunciation) spellings of inflectional suffixes. Grammatical errors are considered those errors where the written word does not depict correctly its grammatical type (part of speech and inflection). In the grammatical category, errors could be found in an inflected suffix[4] of a noun, an adjective, a verb, or in an uninflected suffix[5].

Orthographic Errors. Orthographic errors concern phonologically equivalent (i.e., they maintain the word's correct pronunciation) spellings of word stems, including roots and any derivational morphemes preceding the obligatory inflectional suffix. In this category, orthographic errors could be identified in a thematic rule[6], in a thematic exception[7], in an etymological vowel[8], or in an etymological consonant[9].

Procedure

Ethical approval for the study was obtained from the Departmental Research Ethics Committee of UCL Institute of Education, University College London in November 2014, and from the Hellenic Ministry of Education, Research and Religious Affairs in October 2015. Parents gave informed written consent on behalf of the participating children. Data were collected between October 2015 and July 2016. Children were individually tested in one session of approximately 90 min in their schools, or in the referral centre where they were receiving speech and language therapy. The researcher, a native Greek speaker, assessed all the children. Responses were recorded when needed, using Audacity for Windows 7 and a microphone for later transcription.

RESULTS AND DISCUSSION

Statistical analyses were carried out using statistical package SPSS 24. The first part of the Results presents the groups' performance and group differences on language, literacy, and phonological tasks. The second part presents the PCA within the DDLD

4. An error of an inflected suffix concerns spellings in inflected parts of speech (e.g., articles, verbs, nouns, and adjectives).
5. An error of an uninflected suffix concerns spellings in uninflected parts of speech (e.g., adverbs, and gerunds).
6. An error in a thematic rule refers to spellings in derivational morphemes taught in school as rules.
7. An error in a thematic exception refers to spellings in derivational morphemes violating school rules, or taught exceptions.
8. An error of an etymological vowel refers to spellings in a root vowel grapheme.
9. An error of an etymological consonant refers to spellings in a consonant letter, or in double consonant letters.

group. The third part considers the groups' performance and group differences on phoneme deletion, nonword repetition, and rapid automatic naming tasks. The fourth part investigates types of spelling errors in the dictated word list in the two groups.

Groups' performance and group differences on language, literacy, and phonological tasks

Table 1 shows that the TD group significantly outperformed the DDLD group in all language tasks, in all literacy tasks, and in all phonological tasks except for the phoneme deletion task of CVC items.

Table 1. Groups' performance and group differences on language, literacy, and phonological tasks

	DDLD group		TD group					
Tasks	*M*	*SD*	*M*	*SD*	*N*	*F*	*p*	η_p^2
Verbal Comprehension: WISC-III Similarities	9.33	3.77	11.66	4.70	129	9.70	.002	.07
Verbal Comprehension: WISC-III Vocabulary	17.00	6.02	22.36	7.80	129	19.20	< .001	.13
Syntax Comprehension: DVIQ Test	13.22	2.25	14.17	2.11	129	6.05	.015	.04
Sentence Repetition: DVIQ Test	23.84	4.79	27.46	2.74	129	27.18	< .001	.17
Receptive Vocabulary: PPVT-R	113.93	18.24	123.55	17.06	129	9.54	.002	.07
Text-Reading Fluency: Alouette	124.92	51.12	190.17	62.10	129	42.61	< .001	.25
Text-Reading Fluency: Reading Test Alpha	63.16	26.14	91.86	24.73	102	31.96	< .001	.24
Reading Accuracy: Reading Test Alpha	95.12	12.00	105.00	7.36	102	23.73	< .001	.19
Syllable Reading: Test of DIRD	20.50	4.45	23.35	1.22	27	6.33	.019	.20
Nonword Reading: Test of DIRD	17.50	6.02	22.23	1.67	27	9.49	.005	.27
Spelling Ability: Spelling-to-Dictation	18.31	6.64	30.26	13.18	129	42.85	< .001	.25
Phoneme Deletion of CVCVCV Items: EVALEC	6.84	2.45	8.58	1.37	129	22.72	< .001	.15
Phoneme Deletion of CVC Items: EVALEC	11.01	1.28	11.17	1.26	129	0.30	.579	.00
Phoneme Deletion of CCV Items: EVALEC	9.13	2.78	10.85	1.51	129	18.49	< .001	.13
Nonword Repetition: EVALEC	14.23	3.95	18.53	3.82	129	38.50	< .001	.23
Rapid Automatic Naming: PhAB	140.50	43.76	103.14	26.46	129	34.01	< .001	.21

Note: WISC-III, Wechsler Intelligence Scale for Children; DVIQ, Diagnostic Verbal Intelligence Test; PPVT-R, Peabody Picture Vocabulary Test-Revised; Test of DIRD, Test of Detection and Investigation of Reading Difficulties; EVALEC, Evaluation de la Lecture; PhAB, Phonological Assessment Battery; $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$; η_p^2, partial eta squared, respectively, .01, .06, and .14 small, medium, and large effect size.

Principal Component Analysis (PCA) within the DDLD group

The dataset was suitable for the PCA: Kaiser-Meyer-Olkin Measure of Sampling Adequacy value was .78, meeting Kaiser's (1974) criterion for this value, Bartlett's Test of Sphericity value was significant ($p < .001$; Bartlett, 1954), and most of the intercorrelations observed among all seven tasks of interest had a value of .30 and above. The PCA revealed that five language tasks (WISC-III Similarities, WISC-III Vocabulary, syntax comprehension, sentence repetition, and receptive vocabulary) and two literacy tasks (Alouette and spelling-to-dictation) used in the overall sample to profile children with dyslexia and/or DLD loaded onto Component 1. Table 2 presents each task's contribution to Components 1 and 2, which is expressed by its loading value. WISC-III Vocabulary, WISC-III Similarities and receptive vocabulary had the highest loadings onto the first component, while Alouette and sentence repetition had the lowest loadings onto this component.

Components 1 and 2 had an eigenvalue larger than 1, meeting Kaiser's (1974) criterion. The first component had, however, by far the largest eigenvalue of all seven components generated by the PCA. The second component had an eigenvalue of 1.2 and accounted for 18% of the variance in all seven tasks, while the remaining components had an eigenvalue lower than 1, and as such, they were not considered further. Even though Components 1 and 2 had an eigenvalue larger than 1, a one-factor solution was selected. This selection was based on the scree plot generated by the PCA illustrating a clear split between Component 1 and the remaining components. The PCA was therefore repeated, and a one-factor solution was selected. This analysis revealed that Component 1 had an eigenvalue of 3.4 and explained 49.68% of the variance in all seven tasks. The result of the PCA suggests that it is appropriate to combine the children with dyslexia and/or DLD into a combined DDLD group.

Table 2. The loadings onto Components 1 and 2 for each task generated by the Principal Component Analysis (PCA) with oblique rotation in the DDLD group

Tasks	Component 1	Component 2
WISC-III Vocabulary	.83	.10
WISC-III Similarities	.80	-.02
Receptive Vocabulary	.78	.13
Spelling-to-Dictation	.70	-.52
Syntax Comprehension	.68	.48
Alouette	.60	-.62
Sentence Repetition	.41	.57

Groups' performance and group differences on phonological tasks

Phoneme deletion tasks

Analysis for accuracy revealed a significant effect of task, Wilks' Lambda = .93, $F(3, 124) = 2.98$, $p = .030$, multivariate $\eta_p^2 = .06$, and a significant effect of group, Wilks' Lambda = .80, $F(3, 124) = 10.25$, $p < .001$, multivariate $\eta_p^2 = .19$. Children with DDLD performed significantly less accurately on deleting the initial phoneme of items with CVCVCV syllable structure, $F(1, 126) = 24.35$, $p < .001$, $\eta_p^2 = .16$, and on deleting the initial phoneme of items with CCV syllable structure, $F(1, 126) = 18.39$, $p < .001$, $\eta_p^2 = .12$, but the two groups did not differ on how accurately they deleted the initial phoneme of items with CVC syllable structure, $F(1, 126) = 0.49$, $p = .480$, $\eta_p^2 = .00$. In sum, children with DDLD performed just as accurately as TD children on phoneme deletion tasks with monosyllable CVC stimuli, but were significantly less accurate on longer stimuli (CVCVCV) and stimuli with a more complex syllable structure (CCV). The results are consistent with the Deficient Phonological Access Hypothesis in that equivalent accurate performance in the two groups in the phoneme deletion task of monosyllable items with a simple CVC syllable structure indicates intact explicit access to phonological representations in a phoneme deletion task requiring metacognitive access to phonological representations without loading on phonological short-term memory capacity since nonwords were short and structurally simple. The Deficient Phonological Access Hypothesis is also supported by the significantly poorer accuracy performance in the DDLD group compared to the TD group in the Phoneme Deletion task of trisyllable items with a simple CVCVCV syllable structure and in the Phoneme Deletion task of monosyllable items with a complex CCV syllable structure, with both tasks requiring access to phonological representations whilst loading on phonological short-term memory capacity since nonwords were long or had a complex syllable structure.

Nonword repetition task

The nonword repetition data in Table 3 represents the number of correctly repeated nonwords in terms of nonword length in the DDLD and TD groups. As presented in Table 3, the two groups differed significantly on the number of 3-, 4-, 5-, and 6-syllable nonwords repeated correctly, with the TD group outperforming the DDLD group.

Further, as Table 3 shows, a medium effect of group was found for accuracy scores on 3-syllable nonwords, and large effects of group were found for accuracy scores on 4-, 5-, and 6-syllable nonwords, with the effect size increasing as nonword length increases. The results demonstrate that the longer the nonword is, the bigger the gap

Table 3. Mean (SD) numbers of correctly repeated nonwords in terms of the number of syllables in the DDLD and TD groups

	DDLD group		TD group				
Number of Syllables	*M*	*SD*	*M*	*SD*	*F*	*p*	η_p^2
3	5.14	1.49	5.74	0.59	8.80	.004	.06
4	4.16	1.59	5.26	0.91	22.84	< .001	.15
5	3.17	1.64	4.57	1.52	24.12	< .001	.16
6	1.20	1.55	2.95	1.97	29.84	< .001	.19

Note: $^{**}p < .01$, $^{***}p < .001$; η_p^2, partial eta squared, respectively, .01, .06, and .14 small, medium, and large effect size.

between the two groups, with the DDLD group's performance falling more sharply than the TD group's performance as nonword length increases.

Rapid automatic naming task

Children with DDLD took on average 140.50 seconds (*SD* = 43.76) to name all the pictures in the Rapid Automatic Naming task and TD children took on average 103.14 seconds (*SD* = 26.46), with the difference being significant, $F(1, 127) = 34.01$, $p < .001$, $\eta_p^2 = .21$. The numbers of phonological errors, semantic errors, and omissions were negligible in both groups. As Table 4 shows, significantly more semantic errors were found in the DDLD group relative to the TD group, but the two groups did not differ on the number of phonological errors and the number of omissions in the picture naming task. The results are consistent with the Deficient Phonological Access Hypothesis, showing accurate phonological representations in children with DDLD, as exemplified by phonologically accurate performance in naming pictures in a task not requiring manipulation of phonemes. The phonological access deficit in the DDLD group, however, renders performance on a task requiring speeded access to phonological representations particularly slow.

Table 4. Means (SD) of naming error types in the DDLD and TD groups

	DDLD group		TD group				
Naming Error Types	*M*	*SD*	*M*	*SD*	*U*	*Z*	*p*
Phonological Errors	0.06	0.38	0.04	0.43	2050.00	-0.52	.601
Semantic Errors	1.27	1.61	0.62	1.08	1616.50	-2.40	.016
Omissions	0.42	1.39	0.13	0.53	1856.00	-1.78	.074

Spelling errors in the DDLD and TD groups

In order to compare statistically the two groups, proportions of phonological, grammatical, and orthographic errors were computed based on the composite scores of all three categories of errors divided by the number of total words spelled. Table 5 presents proportions of phonological, grammatical, and orthographic errors in the DDLD group and the TD group and group comparisons. Group comparisons revealed that the DDLD group produced significantly more phonological, grammatical, and orthographic errors compared to the TD group. Importantly, however, although the DDLD group produced significantly more phonological errors than the TD group, most of the errors made by the DDLD group, namely 96% of errors were nonphonological errors, supporting the Deficient Phonological Access Hypothesis.

Table 5. Mean (SD) proportional numbers of phonological, grammatical, and orthographic errors in the DDLD and TD groups

	DDLD group		TD group				
Spelling Error Types	*M*	*SD*	*M*	*SD*	*U*	*Z*	*p*
Phonological Errors	3.61	5.20	1.22	2.24	1408.50	-3.43	< .01
Grammatical Errors	15.30	8.74	7.51	8.31	940.00	-5.37	< .001
					t	*p*	η_p^2
Orthographic Errors	41.24	9.92	36.07	12.64	-2.58	.011	.03

Note: $^{**}p < .01$, $^{***}p < .001$; η_p^2, partial eta squared, respectively, .01, .06, and .14 small, medium, and large effect size.

Group comparisons based on proportional scores should be treated with caution, however. Considering that not all the children attempted to spell all the words in the list, an issue was that children who stopped earlier, attempted to spell only the easier words since the word list begins with easier words and continues with more difficult words (see Mouzaki, Sideridis, Protopapas, & Simos, 2007, for a Rasch model analysis confirmed that the order of words on the basis of their difficulty strongly correlated with the order the words are administered). Concomitantly, with respect to the qualitative analysis of spelling errors, this implies that children who attempted to spell more, and therefore more difficult words in the list, were also more likely to produce more phonological, grammatical, and orthographic errors.

GENERAL DISCUSSION

The objective of the study was to investigate the contested locus of the phonological deficit in Greek children with DDLD using classic phonological tasks and a spelling-to-dictation task by testing two prominent phonological hypotheses of dyslexia and DLD. One which considers that the phonological deficit in dyslexia and DLD lies in children's impaired phonological representations (the Degraded Phonological Representations Hypothesis), and another which considers that the phonological deficit in dyslexia and DLD lies in children's difficulty to access (intact) phonological representations (the Deficient Phonological Access Hypothesis).

Children with DDLD showed the typical phonological deficit as exemplified in poor performance on tasks measuring phonological awareness, phonological short-term memory and rapid automatic naming skills relative to TD children. This finding is consistent with previous studies in Greek-speaking children with dyslexia and DLD (e.g., Diamanti et al., 2018; Spanoudis et al., 2019; Talli et al., 2016). Three phoneme deletion tasks, a nonword repetition task, a rapid automatic naming task, and a spelling-to-dictation task were used to test the two prominent hypotheses of dyslexia and DLD. With respect to phoneme deletion tasks, analyses showed that the TD group significantly outperformed the DDLD group in accuracy in phoneme deletion of CCV and CVCVCV items, but the two groups did not differ in accuracy performance in phoneme deletion of the simpler CVC items. It was predicted that if the Degraded Phonological Representations Hypothesis holds true, the TD group would outperform the DDLD group in accuracy performance in all three phoneme deletion tasks. In contrast, if the Deficient Phonological Access Hypothesis holds true, accuracy performance in the phoneme deletion task of monosyllable items with a simple CVC syllable structure would be equivalent for the two groups; however, the two groups would differ on accuracy performance in the phoneme deletion task of trisyllable items with a simple CVCVCV syllable structure and in the phoneme deletion task of monosyllable items with a complex CCV syllable structure. For the former hypothesis, the phonological deficit in dyslexia and DLD makes itself manifest in significantly poorer performance in every phoneme deletion task due to impaired phonological representations, irrespective of the load of additional cognitive processes involved in the tasks. For the latter hypothesis, the phonological deficit in dyslexia and DLD makes itself manifest in significantly poorer performance in phoneme deletion tasks loading on additional cognitive processes but in equivalent performance in phoneme deletion tasks not loading on additional cognitive processes. The findings are consistent with the Deficient Phonological Access Hypothesis given that the two groups did not differ in accuracy performance in the phoneme deletion task of monosyllable items with a simple CVC syllable structure but did differ significantly in accuracy performance when items had trisyllabic CVCVCV or monosyllabic CCV structure.

With respect to the rapid automatic naming task, analyses showed that the DDLD group named the pictures in the two cards significantly slower than the TD group, and produced significantly more semantic errors, but that the two groups did not differ in their number of phonological errors and omissions. It was predicted that if the Degraded Phonological Representations Hypothesis holds true, the DDLD group would make phonological errors when naming pictures. If the Deficient Phonological Access Hypothesis holds true, however, the DDLD group would name pictures significantly slower than the TD group but the two groups would show no difference on phonological accuracy. The former hypothesis attributes phonologically inaccurate performance to inaccurate phonological representations. The latter hypothesis attributes slower naming performance to a phonological access deficit in the DDLD group which renders performance on tasks requiring speeded access to phonological representations particularly slow. Phonologically accurate performance is explained by intact access to phonological representations in a task not requiring metalinguistic manipulation. The findings are consistent with the Deficient Phonological Access Hypothesis given that the DDLD group showed a significantly slower naming performance than the TD group, but the two groups did not differ on the number of phonological errors produced. Overall, the findings suggested that in children with DDLD phonological representations were as robust and distinct as those of TD children. This is consistent with the Deficient Phonological Access Hypothesis, as initially proposed by Ramus and Szenkovits (2008), and recently tested in Greek-speaking children with DDLD by Mengisidou and Marshall (2019) using phonological fluency tasks.

A second objective of the study was to investigate the types of spelling errors in Greek children with dyslexia and/or DLD in Grades 2-6, and also in their TD peers in Grades 2-6 in order to specify what underlies poor spelling accuracy in Greek children with DDLD. The researcher analysed DDLD children's spelling ability in comparison to TD children by using a spelling-to-dictation task. Children with DDLD spelled correctly fewer words than TD children, with a large effect size being found. This finding was expected (e.g., Joye et al., 2019; Protopapas et al., 2013). However, the objective of the study was to understand why Greek children with DDLD showed this poor spelling accuracy relative to their TD peers. Spelling errors were classified into each of the three categories of errors, namely phonological, grammatical, and orthographic errors. Classification of errors into categories allowed the researcher to identify DDLD children's impaired processes which reflect on the specific error types.

For the phonological error category, DDLD and TD children's substitution, insertion, omission, and inversion errors were analysed. Phonological errors were negligible both in TD children and children with DDLD (respectively, 1.22 versus 3.61%). Phonologically correct spelling implies that poor phonological processes cannot be considered as an explanation for poor spelling accuracy in Greek children with DDLD. This is despite the DDLD group having poorer phonological skills as measured by tasks of phonological awareness, phonological short-term memory and rapid automatic naming. The finding that phonologically correct spelling is not challenging for Greek children with DDLD is consistent with other studies in the Greek orthography which found that the majority of spelling errors were phonologically correct in children with dyslexia (Niolaki & Masterson, 2013; Porpodas, 1999; Protopapas et al., 2013). This finding is not consistent with other studies in the Greek orthography, however, which revealed that children with dyslexia produced a substantial amount of phonological errors (Niolaki, Masterson, & Terzopoulos, 2014). Niolaki et al. (2014) in their case study, reported a rate around 88% of phonologically appropriate errors (i.e., errors which did not change the phonology of the spelled word) in Greek children with very poor nonword reading and spelling skills.

It was predicted that if the Degraded Phonological Representations Hypothesis holds true, qualitative analysis of spelling errors would reveal that the DDLD group would display a significantly higher proportion of phonological spelling errors than the TD group. In contrast, if the Deficient Phonological Access Hypothesis holds true, qualitative analysis of spelling errors would reveal that the majority of spelling errors in the DDLD group would be phonologically correct. The former hypothesis attributes phonological spelling errors to children's inaccurate phonological representations, and the latter hypothesis attributes phonological spelling errors to accurate phonological representations but inappropriate orthographic encoding of words using phoneme-to-grapheme mappings that are inappropriate for a particular context in the DDLD group. The findings are consistent with the Deficient Phonological Access Hypothesis in that the majority of spelling errors found (96%) were nonphonological errors.

However, the finding that phonologically correct spelling is not a challenging task among Greek children with DDLD does not imply that phonological processes are not crucial for spelling ability, and that interventions focused on improving children's phonological skills do not have a positive effect on their spelling ability. In fact, it has been reported that children rely heavily on phonological skills to spell words in dictation, independently of age and orthographic consistency (e.g., Joye et al., 2019). Having said that, as proposed by Daigle, Costerg, Plisson, Ruberto, and Varin (2016), emphasis should be put on features which are not processed phonologically by children, features which can be learned, stored in memory and retrieved during spelling production, such as multigraphemic phonemes, silent letters, homophones, lexical frontiers. Daigle et al. (2016) reported that French children with dyslexia aged 11 ½ years had difficulty with phonological properties of words, however, most of the errors produced were nonphonological, indicating nonphonological processing difficulties. In the present study, proportionally to the number of total words spelled, children with DDLD produced significantly more grammatical errors than TD children (respectively, 15.30 versus 7.51%) and more orthographic errors (respectively, 41.24 versus 36.07%). Therefore, indirectly, the study also proposes the importance of morphological awareness in spelling ability in a consistent orthography. This has been previously reported in Greek (e.g., Desrochers, Manolitsis, Gaudreau, & Georgiou, 2017; Diamanti et al., 2017, 2018; Pittas & Nunes, 2014), and in languages using less consistent grapheme-to-phoneme mappings than those of Greek (e.g., Caravolas et al., 2012; Ziegler et al., 2010).

The importance of morphological awareness in spelling ability has been also investigated in older children with dyslexia since it is evident that morphological rather than phonological awareness is more critical for spelling ability in older rather than younger ages. Tsesmeli and Seymour (2006), for example, showed that poorer morphological knowledge (and not poorer vocabulary knowledge) in Greek children with dyslexia over 13 years of age resulted in poorer spelling accuracy performance in comparison to their TD peers. Corroborating evidence originates from an intervention study in the Greek language showing that an intervention based on derivational parts of words improved spelling accuracy performance in a group of children with dyslexia over 13 years of age (Τσεσμελή & Seymour, 2007). In TD children, it has also been reported the important role of morphological awareness in children's spelling ability. Pittas and Nunes (2014) examined the contribution of morphological awareness to the prediction of spelling in Greek in a large group (***N*** = 404) of children aged 6-9 years. They showed that morphological awareness made a unique contribution to the prediction of spelling in Greek. Hence, in educational settings, interventions should focus on analyzing the morphological structure of words in order for spelling ability to be improved (Bryant, Nunes, & Bindman, 1999; Elbro & Arnbak, 1996).

With respect to the spelling task used, a strength is that a dictated word list was used to shed light on the types of knowledge children with DDLD have difficulty with. In a spelling-to-dictation task, spellers are asked to spell fixed words, not words that they might know better as in narrative productions, with this implying that a dictation task can reveal better than a narrative production task the strategies used by children to spell words (Daigle et al., 2016). One methodological limitation is that in the case there were parts in a word that were more difficult than other parts, this could not be ruled out in the analyses. Diamanti et al. (2014), for example, found that in Greek, misspelled inflections in verbs are more frequent than misspelled inflections in nouns as the former inflections are less consistent than the latter since verb inflections are more complex than noun inflections. In the word list used, there were several vowel phonemes in a stem in a word that could be misspelled but only one vowel phoneme in the inflectional suffix that could be misspelled. This indicates that using the word list, there were more opportunities for orthographic than grammatical errors, and therefore it would not be surprising to find more orthographic than grammatical errors. Having said that, according to Diamanti et al. (2014), derivational spellings are more difficult than inflectional spellings because since inflections are more common than derivations, children are more familiar with the former than the latter. Another methodological limitation is that words later in the task can be more difficult since they can be less frequent, multisyllable and/or with a complex syllable structure. This issue raises a question which concerns children's phonological processing skills and the experimenter's ability to interpret correctly children's phonological processing skills based on a spelling task like the one used in this study. The use of a spelling task with a discontinue rule means that the words attempted by the DLDD group were the easier ones since they were at the start of the graded test, and phonological errors may be more apparent when the children are spelling less familiar and more complex words. Ultimately, it might be that children with different profiles produce different types of spelling errors. For example, two types of dyslexia described in the literature, *surface* and *phonological* dyslexia (Castles & Coltheart, 1993). Douklias, Masterson, and Hanley (2010) found, for example, that children who match a surface-dyslexia reading profile made a lot of orthographic spelling errors in irregular words whereas those who match a phonological-dyslexia reading profile made phonological spelling errors in nonwords.

Overall, an important strength of the study is its inclusion of a large overall sample, which covers a wide range of scores, and large numbers of children in each participating group to study the relationship between measures of interest. This allows the researcher to investigate the associations between measures of interest without over-estimating the size of any association and avoids results of low statistical power which yield many false positive results (West, Vadillo, Shanks, & Hulme, 2018).

A limitation is that the concept of access to representations is underspecified in the literature. As Mirman and Britt (2014) argue in the context of semantic access deficits in adults, it is not clear precisely what researchers mean when they refer to 'access', nor what the nature of the 'access deficit' is. Further investigation, using different research methods, is needed to shed light on the origin of access deficits in dyslexia and DLD. To this end, Boets et al. (2013) reported that in adults with dyslexia less coordination was found between brain regions in the bilateral auditory cortex that process basic phonemes and Broca's region, a region in the brain's frontal lobe known to be involved in higher-level language processing. The researchers interpreted this evidence as suggesting that deficient access to (intact) phonological representations originates from the above-mentioned disconnection between cortical regions and Broca's region in adults with dyslexia. It remains to be investigated though whether this finding can be replicated in a sample of children with dyslexia and DLD.

Another limitation of the design of the study is that the researcher recruited children with DDLD based on previous clinical diagnoses. The researcher, however, did not have access to the full record of the types of assessments used for each child, along with their scores, and as such she was not in a position to distinguish children with dyslexia from those with DLD. That limitation led her to combine children with different diagnoses together in a single group, as justified in the Participants section. However, careful selection of children who fall into more distinct groups (e.g., Ramus et al., 2013) – assuming that adequate assessments of language and literacy skills exist in the language to differentiate these groups – might reveal that children with different profiles of literacy and language impairments have different loci for their phonological difficulties.

To conclude, this study investigated the locus of the phonological deficit in a sample of Greek children with DDLD by investigating phonological skills in a range of classic phonological tasks, and also types of spelling errors in dictation. To this end, two prominent phonological hypotheses of dyslexia and DLD were considered. That is, the Degraded Phonological Representations Hypothesis arguing that the phonological deficit in dyslexia and DLD lies in children's phonological representations, and the Deficient Phonological Access Hypothesis arguing that the phonological deficit in dyslexia and DLD lies in children's ability to explicitly access (intact) phonological representations. The children with DDLD deleted significantly less accurately phonemes in phonological tasks that loaded their phonological short-term memory capacity relative to TD children. However, the two groups did not differ in the phoneme deletion task of monosyllable items, in the number of phonological errors in the picture naming task, and in the proportional number of phonological errors in the spelling task, with all three considering to be implicit phonological measures of the quality of phonological representations. These findings suggest that in children with DDLD phonological representations are as robust and distinct as those of TD children. These findings in turn are consistent with the Deficient Phonological Access Hypothesis. Further investigation is needed to shed light on the underlying cause(s) of deficient explicit access to phonological representations in children with dyslexia and DLD.

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