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Written text production in Greek-speaking children with Developmental Language Disorder and typically developing peers, in relation to their oral language, cognitive, visual-motor coordination, and handwriting skills

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Abstract

Written text production remains a relatively under-explored area in the child development literature, not only for typically developing (TD) children, but also for children with Developmental Language Disorder (DLD), despite its important role for academic performance and life success. The present study attempts the combined investigation of written text production (productivity, accuracy, and complexity) in relation to oral language, cognitive, visual-motor coordination, and handwriting skills, among 60 Greek-speaking school-age children with and without DLD (N = 30 in each group). Participants were given a battery of tasks measuring oral language (phonological awareness, receptive and expressive grammar), cognitive (rapid automatized naming, verbal working memory, visual memory—immediate and delayed), visual-motor coordination, and handwriting skills (alphabet writing fluency and copying shapes). They were also asked to write a story, given a prompt, with their productions evaluated according to productivity, accuracy and complexity. As expected, children with DLD were outperformed by TD children across all oral language measures, in most cognitive measures, on visual-motor coordination and handwriting, as well as in written text production. Results also demonstrated the contribution of oral language skills to the prediction of writing productivity and complexity among TD children, as well as that of rapid automatized naming, visual-motor coordination and alphabet writing fluency in the case of spelling accuracy among peers with DLD. Particularly, the present study highlights the importance of oral language skills, not explicitly incorporated in relevant developmental models, along with other underexplored factors, such as rapid automatized naming ability and visual motor coordination. The results are discussed in relation to research evidence emphasizing the need for comprehensive assessments of written text production determinants in languages other than English.

Keywords Developmental Language Disorder · Written text production · Oral language · Working memory · Visual memory · Rapid automatized naming · Visual-motor coordination · Handwriting

Introduction

Written text production is considered essential for succeeding in both the academic and daily life contexts. For example, Greek students have been found to use writing skills to complete 30–60% of school tasks (Spantidakis, 2011). Despite the important role of written text production across school grades, however, research has so far mostly focused on reading among literacy skills (Hooper, 2002; Puranik et al., 2007). Written text production remains relative under-explored, both in typically developing (TD) school-age children, as well as in children with Developmental Language Disorder (DLD; see Dockrell, 2009), for which evidence with Greek-speaking primary school children remains scarce more generally.

Developmental Language Disorder (previously known as Specific Language Impairment—SLI; see Bishop, 2017) refers to children whose language abilities are substantially below those expected for their age, resulting in limitations in effective communication, social participation or academic achievement (American Psychiatric Association, 2013). More specifically, children with DLD have poor vocabulary skills (Hick et al., 2005b), phonological deficits (Leonard, 2014), and produce simple sentences, with many grammatical errors (Botting & Conti-Ramsden, 2004; Robertson et al., 2012). These difficulties are not due to hearing or other sensory impairment, motor dysfunction, and/or other medical or neurological condition and they are not better explained by intellectual disability. Although several studies have explored the difficulties that children with DLD face in oral language production, very few have been carried out so far to thoroughly evaluate their written texts (Puranik et al., 2007). That is especially the case for the first years of primary school, despite the importance of the latter for literacy development (Connelly et al., 2012; Dockrell & Connelly, 2009; Mackie et al., 2013; Puranik et al., 2007). To our knowledge, such an investigation has not yet been attempted in the Greek context, nor have the oral language, cognitive, visual-motor coordination and handwriting skills that might underpin written text production in school-age children with DLD and TD peers been examined so far in combination. The present study aims to offer relevant insight.

Written text production in children with Developmental Language Disorder

Previous studies have shown that English-speaking children with DLD face several difficulties with written text production. In kindergarten, children's difficulties concern limited alphabet (Boudreau & Hedberg, 1999; Cabell et al., 2009) and print knowledge (McGinty & Justice, 2009; Puranik et al., 2014). Also, it has been reported that kindergarteners with DLD perform worse on spelling and text production relative to TD peers. In other studies, English-speaking children with DLD in the first primary school grades (6–7 years of age) tended to produce shorter texts, with fewer ideas and more spelling and punctuation errors than TD peers, when asked to write down the story depicted in pictures (Bishop & Clarkson, 2003; Fey et al.). In line, Kim et al. (2015) has found that first grade English-speaking children with DLD were outperformed by TD peers in assessments of the quality and productivity of their writings.

So far, it is the written texts of English-speaking children with DLD that have mostly attracted research interest, especially those of children in senior primary school grades. In the study of Mackie et al. (2013), for example, 10-year-old children with and without DLD were asked to write a story based on six pictures depicting a sequence of events. The participants with DLD produced fewer words, fewer and less complex sentences, and made more spelling and grammatical errors. Consistently, in other studies, 10-year-old English-speaking children with DLD performed poorly on standardized writing measures and produced shorter texts, with poorer sentence structure and organization, fewer ideas, and more grammar, punctuation and lowercase/capital letters errors (Dockrell & Connelly, 2009; Dockrell et al., 2007). In line, Dockrell and Connelly (2015) investigated written text production using a standardized writing measure (WOLD: writing expression) and found that 10-year-old English speaking children with DLD produced texts with fewer words, not many word roots and many spelling errors relative to TD peers. Yet, our knowledge of how oral language difficulties in children with DLD predict their writing quality remains limited (Mackie et al., 2013). Furthermore, few studies have so far examined the degree to which rapid automatized naming ability, working memory capacity, as well as handwriting skills, relate to the difficulties that children with DLD face in written text production.

The *not so simple view of writing* model

Writing is a complex task and the written product reflects the efficiency of different underlying processes (Berninger, 2000; Berninger & Winn, 2006). According to "he Not So Simple View of Writing" (Berninger & Amtmann, 2003), a developmental model with significant empirical support so far, writing is based on ideation/text generation, transcription, as well as on executive function and self-regulatory processes (e.g., attention, goal setting, reviewing). Working memory is also given a central role in the model, as it can allow access to long term memory traces, during planning and composing processes, and to short term memory, during review of the written product (Berninger, 2000; Berninger & Amtmann, 2003; Berninger & Winn, 2006; Berninger et al., 2002; Juel et al., 1986). Although highly informative, this model does not specify the relative contribution of the underlying skills to writing, whereas oral language skills are not explicit components of the model. In the present study we set a relevant aim shifting the focus to the predictive roles of oral language, cognitive, visual-motor coordination, and handwriting skills for written text production in children with and without DLD. The latter was assessed with a comprehensive set of criteria: productivity, accuracy, and complexity (Mackie et al., 2013; Puranik et al., 2008; Wagner et al., 2011). It is important that these three dimensions are demonstrated in the written texts of not only children with DLD, but of TD children more generally (Mackie et al., 2013). This line of research could further inform developmental models of writing as well as the design of evidence-based interventions regarding written text production, that are tailored to the strengths as well difficulties faced by children as a function of their developmental profile (Fey et al., 2004; Graham, 2006).

Oral language skills and written text production

A group of studies have explored the relationships between oral language skills and written text production in TD children (see Shanahan, 2006, for a review), concluding that oral language skills are correlated with advanced written language skills (Silverman et al., 2015; Wagner et al., 2011), and that spoken vocabulary, more specifically, provides a critical building block for written language development (Green et al., 2003). For example, oral language has been shown to be uniquely related to written text production for TD English-speaking children in the kindergarten (Kim et al., 2011), as well as in the first (Kim et al., 2014) and the third grade of primary school (Berninger & Abbott, 2010; Olinghouse, 2008).

Thus, it seems logical to assume that the oral language deficits of children with DLD could impact on their written text production. Oral language and written text actually share several components, such as lexical retrieval and sentence construction. Moreover, for children with DLD, in terms of writing productivity, poor vocabulary knowledge can lead to smaller written texts (Dockrell & Connelly, 2009; Dockrell et al., 2007). In parallel, greater use of adjectives and adverbs in oral language has been associated with more advanced written text production (Beard, 2000; Perera, 1984). Thus, good vocabulary knowledge can enrich written text productions (Mackie et al., 2013). On the other hand, children's syntactic skills may also influence the complexity of sentences in written text productions (van der Lely & Christian, 2000). English-speaking children with DLD, given the difficulties they face in the use of appropriate inflectional morphemes, to represent tense and agreement (Rice & Oetting, 1993), tend to produce written texts that contain fewer morphological structures in their sentences. Furthermore, the syntactic difficulties of children with DLD may impact on their writing accuracy, as this might be reflected in the omission of inflectional morphemes (e.g. Mackie & Dockrell, 2004; Windsor et al., 2000) and words containing syntactic structures, such as verbs (Windsor et al., 2000). Also, difficulties to verbally formulate a syntactically and semantically correct sentence along with poor receptive grammar, characterizing children with DLD, have been found to affect the quality of their written texts (Connelly et al., 2012; Dockrell et al., 2014). Finally, a large proportion of children with DLD also experience phonological difficulties, which may directly contribute to an increased number of spelling errors in the context of written text production (Bishop & Clarkson, 2003; Dockrell & Connelly, 2015; Zourou et al., 2010).

However, the ways in which different aspects of oral language impact on writing products are underspecified (Shanahan, 2006), and are likely to differ as a function of written text production evaluation methods (Dockrell & Connelly, 2015). Also, models of writing do not identify oral language as central to the writing process (Mackie et al., 2013). So, further clarity is needed on the precise relationships between aspects of oral language and components of text production (Dockrell et al., 2014), to shed light into the mechanisms underlying written text production.

Furthermore, while a number of studies have recognized the importance of children's oral language skills for written text production in English (Kim et al., 2014; Puranik & Lonigan, 2012), to our knowledge, there is no such evidence regarding the Greek language.

Cognitive skills and written text production

Working memory

Besides other researchers (Berninger & Amtmann, 2003; Hayes, 1996), Berninger and Winn (2006), in the "Not–So–Simple View of Writing model", have also recognized the contribution of working memory in writing, proposing that it regulates the writing process by activating long-term and short-term memory representations. Working memory is a domain in which school-age children with DLD present many deficits (Archibald & Gathercole, 2006; Henry & Botting, 2016). In line, working memory has been found to correlate with written text production in 10–11 years-old children with DLD (Connelly et al., 2012; Dockrell et al., 2014), whereas, poor verbal working memory has been associated with slower language development more generally, in TD children (Gathercole, 2006; Henry & Botting, 2016; Stokes & Klee, 2009). Yet, to our knowledge, evidence regarding working memory and written text production in young primary school-age children with DLD remains scarce.

Visual memory

Berninger et al. (1991) have recognized that retrieval of letter symbols from visual memory might influence the automatic production of letters in the early stages of writing, possibly resulting to relevant difficulties as well. However, recent literature on the role of visual memory skills of children with DLD remains inconclusive (Leclercq et al., 2012; Vugs et al., 2013, 2014). Some studies have found that 3- to 4-years-old children with DLD face greater difficulties in visual memory tasks than TD children (Hick et al., 2005a, b). In line, Marton (2008) reported that 5- to 6-years-old children with DLD performed more poorly in all visuo-spatial memory tasks, while Bavin et al. (2005) found that participants with the specific developmental disorder (mean age 4, 5 years) were significantly slower in recalling patterns relative to TD peers. On the other hand, there are studies that failed to replicate significant differences between groups of children (6–16-year-olds) with and without DLD (Archibald & Gathercole, 2006; Baird et al., 2010). Further investigation is thus deemed necessary.

Rapid automatized naming

A widely used measure in the reading development literature, is rapid automatized naming (RAN). It has actually been identified as a significant concurrent and longitudinal predictor of reading skill (e.g., Altani et al., 2017; Kirby et al., 2010). This task taps lexical access, namely children's ability to name as quickly as possible familiar sets of visual stimuli, such as letters, digits, objects and colors. There are studies that have shown relevant difficulties in children with DLD, though, evidence has not been consistent in all cases. For example, Miller et al. (2001) found that rapid automatized naming was generally slower in children with DLD, though there were children in the specific group that did not appear to show such deficits. Other studies have shown, however, that children with DLD need more time to name all stimuli and make more mistakes in the specific task (Katz et al., 1992; Wiig et al., 2000).

It should be noted that rapid automatized naming has constituted a predictor of reading in studies with English-speaking TD children (kindergarten and elementary) (Pham et al., 2011; Savage & Frederickson, 2005; Wagner et al., 1997), as well as children with DLD, especially at the age of 8 (Katz et al., 1992). Regarding writing, rapid automatized naming for objects and colors has constituted a predictor of later spelling skills for 5- to 6-year-old English, Spanish, Czech, and Slovak children (Caravolas et al., 2012). Studies with TD French-speaking children in the first and second grade of primary school have also shown significant contribution of performance in the rapid automatized naming (pictures, digits and letters) to the prediction of spelling (Plaza, 2003; Plaza & Cohen, 2003), in line with the findings of Stainthorp et al. (2013) with English-speaking third and fourth graders. However, contribution of rapid automatized naming to the different aspects of written text production remains relatively underexplored.

Visual-motor coordination and written text production

Visual-motor coordination (along with fine motor skills, visual perception, attention etc.) constitutes a basic determinant of writing (Cornhill & Case-Smith, 1996, as cited in Feder & Majnemer, 2007), with its role is highlighted in developmental models of writing (Berninger et al., 1991), as well as in studies with TD children (Berninger et al., 1992; Carlson et al., 2013; Daly et al., 2003; Hurschler Lichtsteiner et al., 2018; Kaiser et al., 2009; Kulp, 1999; Weil & Cunningham Amundson, 1994), especially in the beginning stages of writing (Berninger et al., 1992). Also, according to Kulp (1999), visual-motor coordination was found to positively relate to teachers' ratings of children's writing and spelling abilities. Yet, to our knowledge, there is a lack of studies examining its role in the production of a written text by school-age children with DLD.

Handwriting skills and written text production

Handwriting skills are also proposed to underlie written text production (Berninger et al., 1992; Graham et al., 1997; Puranik & Al Otaiba, 2012; Puranik et al., 2017). If these skills are not automatized, children need to devote most or all of their cognitive effort to them, leaving few resources available for other processes supporting writing. This limits substantially the amount and quality of the texts generated (Berninger & Swanson, 1994; Juel et al., 1986; Limpo & Alves, 2013), also constraining their ability to translate ideas into written text (Dockrell & Connelly, 2015).

In line, performance in alphabet writing fluency tasks, has been identified as a significant predictor of writing in the context of the "Not-So-Simple View of Writing" model (Berninger & Winn, 2006). Evidence also supports the importance of handwriting skills for written text production in TD children in the kindergarten (Kim et al., 2011; Puranik & Al Otaiba, 2012), the first grade (Graham et al., 1997; Kim et al., 2014; Wagner et al., 2011), as well as in high school (Graham et al., 1997). While the constraining role of handwriting on written text production has been highlighted in studies with TD populations (e.g., Graham et al., 1997; Juel et al., 1986; Lerkkanen et al., 2004), evidence regarding school-age children with DLD remains scarce. The few studies focus mainly on older children (10- to 11-year-olds) with DLD. Specifically, Dockrell et al. (2014) reported that handwriting (as measured with the alphabet writing fluency task) was a significant predictor of many aspects of written text production in children with DLD. Moreover, according to Connelly et al. (2012), children with DLD seem to write at a slow pace, making a grand effort to form the letters of the alphabet, which in turn constraints the composition of a written text. Also, copying skills were found relate to writing measures in Chinese-speaking TD children, as well as in peers with Dyslexia (McBride-Chang et al., 2011). Yet, only few studies have systematically explored handwriting skills in relation to written text production among young children with DLD (e.g. see study by Kim et al., 2014 with first graders).

The Greek language

As noted above, evidence on written text production and its predictors mostly stems from studies with English-speaking children, despite possible modulation of its development by the characteristics of the language spoken. Greek, for example, a language that differs significantly from English, is among the languages that written text production has been examined the least. Specifically, Greek is a language with average-size vowel and consonant inventories, complex syllable structure, and lexical stress (see Protopapas, 2017). It is strongly suffixing and fusional in terms of inflectional morphemes, characterized by SVO/VSO with respect to the dominant order of subject, verb, and object, and uses prepositions (preceding the noun phrase) (Dryer et al., 2011). Moreover, the Greek language is considered an orthographically transparent language, but while its alphabetic system has high reading consistency, it is also characterized by substantial spelling inconsistencies (Protopapas, 2017). Spelling in Greek is based on etymology which goes back to Ancient Greek (Porpodas, 1992), as well as on spelling rules related to the inflectional system and on assimilation effects. Consequently, Greek-speaking children have the most pronounced and persistent problems with spelling acquisition (Protopapas, 2017). Given these differences of the Greek language from English, it would be insightful to study written text production, as well as its underpinnings, among Greek-speaking school-age children with and without DLD. To our knowledge, there are no such studies so far.

The present study

Summing up, two previous studies have so far examined the contribution of oral language to a single global score of writing competence in children with DLD (Dockrell et al., 2007, 2009). In these studies, vocabulary was found to be the strongest predictor of overall writing ability at ages 11 and 16. Also, to our knowledge, only one study has explored the unique contribution of oral language to three key writing components in 10 year-old children with DLD, concluding that receptive grammar made a significant contribution to writing complexity and accuracy, but not to productivity (Mackie et al., 2013). Furthermore, evidence is inconclusive regarding visual memory and written text production among children with DLD, whereas, the prediction of the latter by rapid automatized naming, visual-motor coordination, and handwriting skills, remains relatively unexplored in both TD children (Shanahan, 2006) and children with DLD. Finally, most previous studies have focused on isolated factors of the "Not-So-Simple-View of Writing" model, mainly in English-speaking, older elementary school children.

Within this context, the present study attempts for the first time the combined investigation of oral language, cognitive, visual-motor coordination, and handwriting skills in relation to written text production (productivity, accuracy, and complexity), involving Greek-speaking TD children and peers with DLD, that attend the second grade of primary school. Exploring written text production in Greek, a language with a transparent orthography and rich morphology, is expected to be informative for research on writing development more generally, as well as to guide applied research and practice aiming to support literacy development in children with DLD.

We stated the following research questions:

1. To what extent do oral language, cognitive, visual-motor coordination and handwriting skills differentiate Greek-speaking school-age children with and without DLD? Children with DLD were expected to perform poorer in all these measures relative to TD children.
2. To what extent do children with DLD differ from TD peers in written text production (productivity, accuracy, and complexity)? Children with DLD were expected to be outperformed by TD children in all text production measures.
3. What is the relative contribution of oral language, cognitive, visual-motor coordination, and handwriting skills to the prediction of written text production (productivity, accuracy, complexity) in the TD and the DLD groups? The specific research question is exploratory in nature and is not followed by a specific hypothesis. There are few studies pointing to significant roles of these factors in written text production, yet examining them mostly in isolation, relying mostly on general measures of text production, rather than on specific dimensions of the latter, and not involving both TD children and peers with DLD.

Method

Participants

The sample consisted of 60 Greek-speaking children attending the second grade of primary school: 30 children (19 boys and 11 girls; mean age in months 92.27), who were diagnosed with DLD, and 30 TD children, matched on age (mean age in months: 91.87, $t(58) = 0.660$, $p = 0.512$) and gender (19 boys and 11 girls in each group). All participants had average non-verbal intelligence, with a standard score of 85 or above in the Raven's Educational CPM/CVS (standardized in Greek by Sideridis et al., 2015; see description of both tasks below). Children with DLD were identified by professionals in speech and language centers. Diagnosis was additionally confirmed by assessment with an expressive vocabulary standardized measure (the Word Finding Vocabulary Test-4th ed., in its Greek standardized edition; (Vogindroukas et al., 2009). Specifically, children with DLD were found to perform approximately 1.25 SDs or more below the mean on the expressive vocabulary language test, confirming diagnosis of DLD according to DSM-5 (2013). The two groups did not include any children with other developmental disorders, hearing deficits, sensorimotor and neurological difficulties, special educational needs, or bilingual children.

All participants attended general public schools in one urban and one semi-urban region in Greece and had Greek as their native language. Informed parental consent was obtained prior to the study. Anonymity and protection of privacy of all the individuals who participated was secured. Children participated only if they wished and both children and their parents were informed that they could terminate assessment at any point, without any justification.

Measures and procedure

Screening measures

Nonverbal intelligence The Raven's Colored Progressive Matrices (Raven, 1998); as standardized in Greek by Sideridis et al. (2015) was used to assess children's nonverbal intelligence (Cronbach's alpha = 0.90). The test consists of 36 items, and the child is asked in each case to choose among six figures, the one that is missing from and best completes a given colored pattern.

Expressive vocabulary The Word Finding Vocabulary Test (4th ed.) (Renfrew, 1995), as standardized in Greek by Vogindroukas et al. (2009); (Cronbach's alpha = 0.90), was used to assess children's expressive vocabulary. Each child was asked to name 50 pictures depicting nouns and received one point for every correct answer and 0 points for every wrong answer. The administration was interrupted if the child made five consecutive errors. A child's total raw score in the test equated to the number of pictures he/she named correctly until discontinuation or completion of the assessment.

Main measures

Participants were also administered a battery of measures to further assess oral language (phonological awareness, receptive and expressive grammar), as well as their cognitive skills (verbal working memory, visual memory, RAN-digits and RAN- objects), visual-motor coordination, and handwriting skills (alphabet writing fluency and copying shapes). They were also administered a story writing task.

Assessment took place individually, in a quiet room at the child's school, and was split into two sessions, each lasting approximately 45 min (with a break in the middle). All tests were administered based on the standard procedures in the manuals. For the story writing task, children were asked to read back their written texts and the researcher noted the unclear words on a separate sheet, to prevent penalizing children who were poor spellers. All measures are described in detail in the sections that follow.

Oral language skills

Phonological awareness

The participants were administered three tasks (phoneme discrimination, phoneme segmentation, phoneme elision) from the standardized Test for Detecting and Investigating Reading Difficulties in Kindergarten and 1st–2nd grade (Porpodas, 2007). The phoneme discrimination task includes 24 pairs of non-words. They were read out loud by the researcher and the child was required to say whether the non-words in each pair (e.g. /ra/ and /va/ and) were phonologically same or different. In the phoneme segmentation task, the researcher read out loud another 24 non-words and the child was asked to break each one down into its individual sounds. Finally, in the phoneme elision task, the researcher read out loud 24 monosyllabic non-words and asked the child to eliminate the first or last phoneme of each one. The administration of each task was discontinued if the child made three consecutive errors. For each task, the child received one point for every correct answer and 0 points for every wrong answer. Raw scores were calculated for each task summing up the points received until task discontinuation or completion. A composite phonological awareness score was also calculated, based on a child's mean score in all three tasks (Cronbach's alpha = 0.80).

Receptive grammar

The Receptive Grammar task (Cronbach's alpha = 0.85) from the standardized Test of Language Aptitude (L-a-T-o) (Tzouriadou et al., 2008) was administered to assess participants' receptive grammar skills. Each child was presented with three pictures and was asked to select the one that matched the sentence that the researcher read out loud. The test included 13 items and the administration stopped if the child made three consecutive errors. The child received one point for every correct answer. A score was calculated for each child based on the sum of correct responses.

Expressive grammar

The Expressive Grammar task (Cronbach's alpha = 0.88) from the standardized Test of Language Aptitude (L-a-T-o) (Tzouriadou et al., 2008) was used to assess children's ability to complete unfinished sentences. This measure is assumed to be reflective of the organization of oral language. It included 13 items. The examiner read out loud each sentence (while pointing at a relevant picture) and asked the participant to add the missing word/words in order to complete the sentence (e.g. "This man is painting. He is a …"). The administration stopped if the child made three consecutive errors. Each child received one point for every correct answer. A score was calculated for each child based on the sum of correct responses.

Cognitive skills

Verbal working memory

Two measures from the Working Memory Battery Test for Children (Pickering & Gathercole, 2001), the backwards digit recall task, and the listening recall task (as adapted for use in Greek by Chrysochoou, 2006; see also Chrysochoou & Bablekou, 2011; Chrysochoou et al., 2011, 2013), were administered to examine the participants' verbal working memory. In the backwards digit recall task, the examiner read out loud a series of digits and the child was asked to recall them backwards. In the listening recall task, the researcher read out loud a series of sentences and the child was asked to determine if each one was true or false. Then, after all sentences in a sequence had been presented, the child had to recall the last word of each sentence, in the same order the sentences were presented. The child received one point for every successful recall attempt and 0 points for every unsuccessful attempt. Raw scores were calculated for each test by summing up the points received until the assessment was completed or discontinued (when the child made three unsuccessful recall attempts in each given block of sentences). Finally, a composite verbal working memory score was calculated for each child, based on his/her mean performance on the two tasks.

Visual memory The standardized Short Test of Visual Memory, for 5- to 8-year-old children (see Bezevegis et al., 2007), was used to measure participants' visual memory. Five dots on a matrix were presented to each child and were removed after a few seconds. The child was asked to recall the exact place of each dot on the matrix (immediate recall). The researcher repeated the process until the child correctly placed all dots on the matrix (the maximum number of efforts was five). After a short recess of 5–10 minutes, the child was asked again to recall the exact place of each dot on the matrix (delayed recall).

Rapid automatized naming

Two tests were used to measure rapid automatized naming ability: RAN-digits and RAN-objects (Denckla & Rudel, 1974). RAN-digits (Cronbach's alpha = 0.91) involved presentation of five different digits (disyllabic in Greek; 1, 2, 5, 7, 8, pronounced /ˈena/, / ˈðio/, /ˈpɛndɛ/, /ɛˈfta/,/ /o'hto/, respectively), which were repeatedly presented in random order, in five rows of ten digits each (50 stimuli presented in total). The child was asked to name all digits, as quickly as possible, starting from left to right. RAN-objects (Cronbach's alpha = 0.80) involved presentation of five objects (disyllabic in Greek; cat, apple, fish, sun, and bird, pronounced /gata/, / ˈmilo/, /psari/, /ilios/, respectively). Presentation of stimuli, number of trials and assessment procedure were the same as with RAN-digits. The measure obtained for each participant was the time needed (in seconds) to name all 50 stimuli in each task version.

Handwriting skills

Alphabet writing fluency

Children were instructed to write the lowercase letters of the alphabet as fast and as carefully as possible, until told to stop, at 60 s. This task has been used extensively in previous studies both with TD children and children with DLD (Connelly et al., 2012; Dockrell et al., 2014; Kent et al., 2014; Kim et al., 2013; Puranik & Al Otaiba, 2012; Puranik et al., 2017). The task evaluates the child's ability to access, retrieve, and write the letters of the alphabet automatically. Each child was given one point for every lowercase letter, correctly formed and in the right sequence; unrecognizable letters, capital letters, omissions, reversals, and transpositions were counted as errors (Berninger et al., 1992). At the end a total raw score was calculated for each child based on his/her correct attempts (Cronbach's alpha = 0.89).

Copying shapes

In the Copying Shapes task (Cronbach's alpha = 0.80) of the standardized Athena Diagnostic Test of Learning Difficulties (Paraskevopoulos et al., 1999), each child was asked to copy six geometric forms, arranged in order of increasing difficulty. Attempts were scored according to specific criteria: the child received three points if his/her shape was generally similar to the prototype, as a geometric form; two points were given for a main morphological feature of the shape (e.g. the triangle's base had to be horizontal), and one point, for a secondary feature of the shape. A child's score on the task equals to the sum of the points received for all six copying attempts.

Visual-motor coordination skills The Labyrinth task (Cronbach's alpha = 0.80) of the standardized Athena Diagnostic Test of Learning Difficulties (Paraskevopoulos et al., 1999), was used to assess visual motor coordination. Each child was asked to draw a line with the pencil through a labyrinth route, divided in 12 sections, without touching the sidelines. The child had to use the dominant hand, but at some point, he/she was asked to switch and use the other hand, for a small part of the "route". The child was given one point for each section of the labyrinth route that he/she pass successfully (without touching the sideline). A total score was calculated for each child based on the sum of the points received.

Written text production

Story writing task

Story prompts are recommended in general as reliable measures for the evaluation of written text production in the first and second grade of primary school (Berninger et al., 1992; Connelly et al., 2012; Dombek & Al Otaiba, 2015; Kent et al., 2014; Kim et al., 2011; Puranik & Al Otaiba, 2012). Additionally, the above task is frequently being used in the Curriculum-based measurement of Writing (CBM-W; see Dombek & Al Otaiba, 2015; Kim et al., 2013). In the present study, each child was given a story prompt ("One day, when I got home from school…") and was asked to complete it by writing a short story. The child had 30 s to think and 5 min to write his/her story (Berninger et al., 1992; Connelly et al., 2012; Dockrell et al., 2014; Kim et al., 2013).

Coding of written text production

Children's written texts were evaluated with regard to three writing dimensions: (a) *productivity*, (b) *accuracy*, and (c) *complexity* (Diakogiorgi et al., 2021; Mackie et al., 2013; Puranik et al., 2007).

Productivity was measured based on the following: (a) *Number of written words;* if the child had copied the story prompt at the beginning of his text, those words were not counted, and (b) *Number of different words* (every original word, used for the first time in the text, was counted).

Accuracy was measured based on the following: (a) *Percentage of spelling errors* among the total number of words written, (b) *Percentage of lowercase-capital letters errors* among the total number of words written; errors included the use of a lowercase letter after a full stop, the use of a lowercase letter in the beginning of a proper noun, the use of a capital letter in the beginning of common nouns, (c) *Percentage of stress mark errors* among the total number of words written; it is noted that in Modern Greek, all words with two or more syllables must be written with a stress mark (an acute accent) over the vowel of the stressed syllable, and (d) *Percentage of subject–verb agreement errors* among the total number of subject–verb pairs produced.

Complexity was measured based on the following: (a) *Number of clauses;* namely, the total number of main and subordinate clauses produced in the text, (b) *Percentage of subordinate clauses,* among the total number of clauses produced, and

(c) *Number of coordinating clauses;* a coordinating clause was defined as two main clauses connected with a coordinating conjunction (Mackie et al., 2013).

Inter-rater agreement (for two raters; Everitt & Skrondal, 2010) was examined for each writing measure, based on the texts provided by a randomly selected sample (25% of children) from each group (DLD-TD). Overall, agreement rates ranged between 95 and 100%, as expected, given the nature of the evaluation criteria (e.g. number of words per text, e.g. percentage of spelling errors, etc.). In any case of inter-rater disagreement, scores were recalculated and corrected upon agreement.

Results

In response to the first research question, a series of independent samples t-tests were carried out (see Table 1) to examine group differences between children with DLD and TD peers in the oral language, cognitive, visual-motor and handwriting measures obtained. In order to exclude a possible type I error, given the different mean comparisons conducted, Bonferroni corrections were applied. The new accepted level of significance was 0.013 for the analyses run on the four oral language measures, 0.01 for the analyses regarding the five cognitive measures, and 0.025 for the analyses conducted for the two handwriting measures. These corrections did not influence the results patterns. Specifically, in line with our first hypothesis, children with DLD were outperformed by TD peers on all oral language and

Table 1 Descriptive statistics for the oral language, cognitive, visual-motor coordination, and handwriting measures per group and t-test results

	Groups		t-tests and effect sizes (Cohens'd)
	DLD Mean (SD)	TD Mean (SD)	
Oral language measures			
Expressive vocabulary	20.03 (3.79)	40.30 (4.96)	$t\,(58) = -17.789$, $p < 0.001$, $d = 4.59$
Phonological awareness	41.73 (10.37)	61.37 (7.53)	$t\,(58) = -8.391$, $p < 0.001$, $d = 2.16$
Receptive grammar	8.27 (1.68)	12.17 (0.83)	$t\,(58) = -11.388$, $p < 0.001$, $d = 2.94$
Expressive grammar	4.70 (1.66)	11.27 (1.20)	$t\,(58) = -17.524$, $p < 0.001$, $d = 4.53$
Cognitive measures			
Verbal working memory	6.03 (2.39)	9.27 (2.88)	$t\,(58) = -4.725$, $p < 0.001$, $d = 1.22$
Visual memory (immediate recall)	22.93 (4.44)	22.43 (7.77)	$t\,(58) = 3.76$, $p = 0.708$, $d = 0.08$
Visual memory (delayed recall)	3.27 (1.78)	4.40 (1.00)	$t\,(58) = 3.03$, $p = 0.004$, $d = 0.78$
RAN-objects	75.27 (13.25)	50.90 (8.17)	$t\,(58) = 8.573$, $p < 0.001$, $d = 2.21$
RAN-digits	40.37 (9.99)	35.77 (8.70)	$t\,(58) = 1.902$, $p = 0.062$, $d = 0.49$
Handwriting measures			
Alphabet writing fluency	15.73 (5.84)	22.17 (3.04)	$t\,(58) = -5.354$, $p < 0.001$, $d = 1.38$
Copying shapes	18.60 (8.55)	27.43 (5.37)	$t\,(58) = -4.793$, $p < 0.001$, $d = 1.23$
Visual-motor coordination measures			
Labyrinth task	6.93 (3.16)	8.87 (2.84)	$t\,(58) = -2.493$, $p = 0.016$, $d = 0.64$

handwriting measures, as well as on the visual-motor coordination measure. Our hypothesis was partially confirmed with regard to the cognitive measures though. Children with DLD performed lower than TD children in the verbal working memory, the delayed recall measure of visual memory and the RAN-objects tasks, but they did not differ from TD peers in the immediate recall measure of visual memory and the RAN-digits measures.

Our second research question regarded the extent to which participants with DLD differ from TD peers in written text production (productivity, accuracy, and complexity). Descriptive statistics and the results of the t-tests conducted to compare the performance of the two groups on the relevant measures are presented in Table 2. Once again, a Bonferroni correction was applied for each category of measures, and the new accepted significance levels were 0.025 for the two writing productivity measures, 0.016 for the three writing accuracy measures, and 0.016 for the three writing complexity measures. Taking the above into consideration, TD children were outperformed by DLD peers on both writing productivity criteria, on all writing accuracy criteria except for the percentage of lowercase-capital letters errors, as well as on the number of clauses produced among the writing complexity measures, but not also on the number of coordinating clauses and the percentage of subordinate clauses with regard to the same category of measures. Thus, besides three exceptions, our findings seem aligned with our second hypothesis, expecting children with DLD to face more difficulties in written text production relative to TD peers.

Our third research question regarded the relative contribution of oral language, cognitive, visual-motor coordination, and handwriting skills to the prediction of

Table 2 Descriptive statistics for the written text production (productivity, accuracy, complexity) measures per group and t-test results

	Group		t-tests and effect sizes (Cohens'd)
	DLD Mean (SD)	TD Mean (SD)	
Writing productivity			
Number of written words	17.10 (11.44)	27.07 (8.14)	$t\,(58) = -3.889, p < 0.001, d = 1.00$
Number of different words	13.00 (7.70)	19.87 (5.58)	$t\,(58) = -3.957, p < 0.001, d = 1.02$
Writing accuracy			
Spelling errors (%)	21.33 (21.63)	6.42 (4.77)	$t\,(58) = 3.689, p < 0.001, d = 0.95$
Lowercase-capital letters errors (%)	4.23 (6.18)	1.53 (2.03)	$t\,(58) = 2.272, p = 0.027^*, d = 0.58$
Stress mark errors (%)	33.87 (32.83)	7.08 (9.87)	$t\,(58) = 4.279, p < 0.001, d = 1.10$
Subject–verb agreement errors (%)	4.78 (11.69)	0	
Writing complexity			
Number of clauses	5.17 (3.30)	7.47 (2.36)	$t\,(58) = -3.104, p = 0.003, d = 0.80$
Subordinate clauses (%)	11.97 (17.96)	23.36 (22.02)	$t\,(58) = -2.197, p = 0.032^*, d = 0.56$
Number of coordinating clauses	2.70 (2.97)	3.93 (1.91)	$t\,(58) = -1.912, p = 0.061$, (ns), $d = 0.49$

The asterisk denotes non-significant group differences following Bonferroni correction written text production criteria (productivity, accuracy, complexity) in children with and without DLD. Correlation analyses within the TD group demonstrated significant relationships in the following cases: (a) between the number of written words (productivity measure) and the expressive vocabulary measure ($r=0.48$, $p=0.007$), (b) between the number of different words (productivity measure) and both the expressive vocabulary ($r=0.44$, $p=0.014$) and the phonological awareness ($r=0.38$, $p=0.040$) measures, (c) between the number of clauses (complexity measure) and again, both the expressive vocabulary ($r=0.37$, $p=0.044$) and the phonological awareness ($r=0.38$, $p=0.038$) measures, and (d) between the number of coordinating clauses (complexity measure) and the expressive vocabulary measure ($r=0.36$, $p=0.049$).

Based on these results, we conducted stepwise regression analyses within the TD group, to examine the relative contribution of expressive vocabulary and phonological awareness to the prediction of the writing productivity and complexity criteria they significantly correlated with; i.e. the number of different words and number of clauses measures, respectively. As seen in Table 3, only expressive vocabulary proved a significant predictor of the number of different words produced, explaining 20% of the variance in the specific productivity criterion, whereas it was only phonological awareness that significantly predicted the number of clauses produced, explaining 11% of the variance in the specific complexity criterion.

A greater number of significant correlations between the written text production criteria and the oral language, cognitive, visual-motor and handwriting measures were observed in the analyses conducted for the children with DLD. Specifically, performance in the RAN-digits task was negatively related to both measures of writing productivity: the number of written words ($r=-0.60$, $p=0.001$) and the number of different words ($r=-0.56$, $p=0.001$). With regard to writing accuracy, the percentage of spelling errors measure was related to the RAN-digits measure ($r=0.44$, $p=0.016$), the visual-motor coordination ($r=-0.48$, $p=0.008$), and the alphabet writing fluency ($r=-0.57$, $p=0.001$) measures; moreover, the stress mark errors measure was found related to alphabet writing fluency only ($r=-0.45$, $p=0.013$). Among the writing complexity indices, the number of clauses and the number of coordinating clauses produced was each related to performance in the RAN-digits

Table 3 The final models of the stepwise regression analyses conducted within the TD group to examine the prediction of number of different words (writing productivity index) and number of clauses (writing complexity index) by expressive vocabulary and phonological awareness

Criterion variable/significant predictors	B	Standard error	β
Writing productivity: Number of different words			
Expressive vocabulary	0.499	0.191	0.443*
$R^2=0.20$, *Adjusted* $R^2=0.17$, F (1, 28) = *6.847, p = 0.014*			
Writing complexity: Number of clauses			
Phonological awareness			
$R^2=0.11$, *Adjusted* $R^2=0.14$, F (1, 28) = *4.671, p = 0.039*	0.118	0.055	0.378*

*Significant at the 0.05 level

task ($r = -0.66$, $p < 0.001$, and $r = -0.49$, $p = 0.006$, respectively), whereas percentage of subordinate clauses was related to the expressive grammar measure ($r = 0.44$, $p = 0.015$).

Based on these results, we conducted stepwise regression analyses within the DLD group, to examine the relative contribution of the RAN-digits, alphabet writing fluency, and visual-motor coordination measures to the prediction of spelling errors. All three measures proved significant predictors, explaining 66% of variance in the specific writing accuracy index (Table 4).

Discussion

The present study attempted for the first time the combined investigation of oral language, cognitive, visual-motor coordination, and handwriting skills, in relation to written text production (productivity, accuracy, and complexity of writing) in Greek-speaking school-age children with and without DLD, at the first phases of writing development. Greek-speaking children constitutes an under-studied population in the field of written text production more generally, despite the value of conducting studies in languages that differ significantly from English, that most available evidence regards (e.g. Greek has a transparent orthography and is a morphologically rich language).

Our first research question regarded the extent to which oral language, cognitive, visual-motor coordination, and handwriting skills differentiate Greek-speaking school-age children with and without DLD. A general hypothesis was stated, given inconclusive findings in the relevant literature, as well as lack of evidence with Greek-speaking children: TD children were expected to outperform peers with DLD in the aforementioned measures.

This first hypothesis was confirmed for all oral language measures (expressive vocabulary, phonological awareness, receptive and expressive grammar). The present findings, which to our knowledge are the first stemming from such a comprehensive assessment of Greek-speaking children with DLD and TD peers, are aligned with evidence demonstrating the challenges faced by English- or French-speaking

Table 4 The final model of the stepwise regression analysis conducted within the DLD group to test the prediction of spelling errors (writing accuracy index) by the alphabet writing fluency, RAN-digits and visual-motor coordination measures

Criterion variable/significant predictors	B	Standard error	β
Writing accuracy: spelling errors (%)			
Alphabet writing fluency	−2.07	0.43	−0.56***
RAN-digits	0.84	0.25	0.39**
Visual-motor coordination	−2.5	0.80	−0.37**
$R^2 = 0.66$, *Adjusted* $R^2 = 0.62$, F (3, 26) = 16.80, $p < 0.001$			

**Significant at the 0.01 level

***Significant at the 0.001 level

children with DLD in developing oral language skills (see Conti-Ramsden & Durkin, 2011; Leonard, 2014; Robertson et al., 2012), and specifically, in vocabulary (Dockrell & Connelly, 2009; Dockrell et al., 2007), phonological awareness (Bishop & Clarkson, 2003; Dockrell & Connelly, 2015; Zourou et al., 2010), receptive grammar (Connelly et al., 2012; Dockrell et al., 2014; Royle & Reising, 2019), as well as expressive grammar skills (Clark et al., 2007; Moscati et al., 2020; Stothard et al., 1998).

Regarding cognitive skills, our first hypothesis was partially confirmed. Specifically, children with DLD were outperformed by TD peers in the verbal working memory task, the RAN-objects task, and on the delayed recall measure of the visual memory task. The two groups did not differ though on the immediate recall measure of the visual memory task and the RAN-digits measure. Our findings are aligned with those suggesting difficulties faced by children with DLD in simultaneous processing and storage (i.e. working memory; Archibald & Gathercole, 2006; Henry & Botting, 2016), as well as in delayed recall of visual stimuli (e.g. Marton, 2008, involving slightly younger children, i.e. 5- to 6-year-olds). On the other hand, lack of group differences in the immediate recall measure of the visual memory task is consistent with evidence stemming from studies with English-speaking children (e.g. Archibald & Gathercole, 2006; Baird et al., 2010). Our findings regarding rapid automatized naming are mixed; the significant differentiation of the two groups in RAN-objects seems aligned with evidence suggesting lexical access difficulties underlying the specific developmental disorder (Katz et al., 1992; Wiig et al., 2000). Yet, our groups were not also differentiated in the RAN-digits measure, rendering further investigation necessary.

Moreover, children with DLD were outperformed by TD peers in the visual-motor coordination measure (labyrinth task), as well as in both measures of handwriting (alphabet writing fluency and copying shapes). Lack of previous studies, to our knowledge, regarding visual-motor coordination in children with DLD limits further discussion. On the other hand, poorer handwriting skills in children with DLD have been observed in previous studies, mostly involving older participants though (Connelly et al., 2012; Dockrell et al., 2014; Nicola & Watter, 2016), except for one study with first grade children (Kim et al., 2014). Further exploration of these important foundation skills for early writing (Berninger et al., 1992) is deemed necessary.

Our second research question regarded the extent to which children with DLD differ from TD peers in written text production (productivity, accuracy, and complexity). As expected, children with DLD performed more poorly on the written production measures, with three exceptions though. The two groups did not differ significantly in the percentage of lowercase-capital letters errors (writing accuracy), as well as in the number of coordinating clauses and the percentage of subordinate clauses produced (writing complexity).

Specifically, in line with our second hypothesis, children with DLD performed worse than TD peers in both writing productivity measures (number of written words and number of different words). This pattern, stemming from a first study on writing productivity that involved Greek-speaking school-age children with and without DLD, is consistent with previous evidence regarding English, where children with DLD (6- to 7-year-olds) were found to produce shorter texts relative to TD peers (Bishop & Clarkson, 2003; Fey et al., 2004; Kim et al., 2015).

Regarding writing accuracy, children with DLD produced more errors overall relative to TD peers, in spelling, stress mark and subject-verb agreement. Difficulties in spelling are frequently reported as an associated literacy difficulty in English-speaking children with DLD (Joye et al., 2018), also characterized as a "window" into residual language deficits (Bishop & Clarkson, 2003). Our findings could be related to the nature of the Greek orthography. Spelling in Greek is characterized by an extensive system of morphological word-ending rules, which vary according to the part of speech in focus (verb, noun, adjective, etc.) (Papanastasiou, 2008) whereas the Greek language is further characterized by substantial spelling inconsistencies, that render typical spelling acquisition harder (Protopapas, 2017). Further investigation on spelling is deemed necessary, however, as it remains unclear whether all children with DLD encounter such difficulties (McCarthy Maeder et al., 2012), if the reported difficulties reflect children's general oral language skills (Mackie & Dockrell, 2004), or whether difficulties are modulated by characteristics of the language spoken (Broc et al., 2013) or the demands set by the spelling tasks employed (Dyslexia, McCarthy Maeder et al., 2012; Phonology, Bishop & Clarkson, 2003).

Moreover, the greater number of stress mark errors made by children with DLD relative to TD children in our study could be attributed to the extensive use of stress mark in the Greek language, and its role in spelling accuracy (e.g. in which syllable to put the stress mark?) and meaning assignment to words (e.g. *τζάμι* vs *τζαμί*, corresponding to *window* vs *mosque*; *άλλα* vs *αλλά*, corresponding to *other* vs *but*, etc.). Also, the spelling convention for Greek regarding the stress mark, contains an element of inconsistency, since its application depends on the number of syllables and not only on the presence of phonological stress. In other words, monosyllables do not bear a diacritic, while every word with two or more syllables must do so. This is phonologically appropriate in most cases, as most monosyllables are grammatical words that attach themselves metrically to adjacent content words. On the other hand, most polysyllables are content words and bear phonological stress, which is always correctly stress marked. There are exceptions though: Monosyllable content words, which bear phonological stress, are not marked with the diacritic due to the spelling convention, whereas disyllabic function words, which do not bear phonological stress, are marked with a diacritic (Petrounias, 2002). Future, preferably longitudinal, **c**ross-linguistic comparisons could shed light into the spelling (as well as overall written text production) profiles of children with DLD (see also Joye et al., 2018).

Finally, regarding writing accuracy, our participants with DLD produced several subject-verb agreement errors in comparison to TD children, who didn't produce any such error. The observed difference in this first investigation with Greek-speaking children is consistent with evidence stemming from studies in other languages, such as German (Rothweiler et al., 2012), English (Rispens & Been, 2007) or Russian (Rakhlin et al., 2014).

Last, with regard to the writing complexity criteria, children with DLD produced a smaller number of clauses in total (main and subordinate) in comparison to TD peers. Similar findings have been obtained in studies with English-speaking children with DLD (Mackie et al., 2013). The two groups did not differ, more specifically, in the number of coordinating clauses and the percentage of subordinate clauses. On the other hand, the significant group differences in the general complexity index (number of clauses), fits well with the aforementioned group differences in the related writing productivity criteria (i.e. number of words and number of different words).

Thus, despite few exceptions, our findings seem overall aligned with the hypothesis expecting children with DLD to face more difficulties in written text production relative to TD peers. This pattern is consistent with scant evidence with English-speaking children of a similar (Bishop & Clarkson, 2003; Fey et al., 2004) or older age (Connelly et al., 2012; Dockrell & Connelly, 2009, 2015; Mackie & Dockrell, 2004; Mackie et al., 2013; Puranik et al., 2007). Future studies could additionally focus on languages with more transparent orthographies and richer morphology relative to English (such as Greek), as well compare the developmental trajectories of different written text production skills in children with and without DLD, throughout the primary as well as secondary school-age years.

Finally, a third research question regarded the relative contribution of oral language, cognitive, visual-motor coordination, and handwriting skills to the prediction of written text production criteria (productivity, accuracy, complexity) in the TD and DLD groups. In the regression analyses conducted for the TD children, expressive vocabulary (but not phonological awareness) constituted a significant predictor of the number of different words (writing productivity), while phonological awareness (but not expressive vocabulary) predicted the number of clauses in children's texts (writing complexity). The above findings are consistent with previous suggestions that spoken vocabulary constitutes a critical building block for written text production (Green et al., 2003), as well as with evidence suggesting that oral language processing, more generally, is predictive of advanced written language levels in English-speaking older primary school children (Abbott et al., 2010; Berninger & Abbott, 2010; Connelly et al., 2012; Olinghouse, 2008; Silverman et al., 2015; Wagner et al., 2011) as well as younger age groups (Kent et al., 2014; Kim & Schatschneider, 2017; Kim et al., 2011, 2015).

For children with DLD, it was also found that expressive grammar was significantly related to written complexity, as tapped by the percentage of subordinate clauses. This finding is aligned with evidence suggesting significant relationships between oral language measures and quality of written texts, yet in older age primary school children (Dockrell & Connelly, 2009, 2015; Dockrell et al., 2007; Mackie et al., 2013). It is noted though that previous studies, both with TD children and peers with DLD, have measured either receptive or expressive vocabulary, and have included less refined measures of written text production (mostly overall measures). Future studies should employ more comprehensive assessments, following children speaking different languages as they develop oral and written language.

Finally, the regression analysis conducted for the children with DLD, demonstrated that the RAN-digits, visual-motor coordination, and alphabet writing fluency measures explained a significant proportion of variance in the percentage of spelling errors measure (66%). Our findings add to the limited in number studies highlighting the possible role of rapid automatized naming ability in the establishment of fully specified orthographic representations (Caravolas et al., 2012; Plaza & Cohen, 2003; Stainthorp et al., 2013). This fits well with, the account that written text production can place significant demands on working memory, consuming the limited relevant available resources and thus, possibly resulting in further retrieval failures. The role of ease of lexical access could be further investigated in the context of developmental models of writing, such as “the Not So Simple View of Writing” (e.g. Berninger, 2000; Berninger et al., 2002).

The present study also highlighted the independent role of visual-motor coordination in the prediction of spelling errors among children with DLD. This is consistent with Berninger et al.’s (1992) suggestion that visual-motor coordination, among other skills, constitutes a critical foundation in the beginning stages of writing development. Its role in DLD however remains so far unexplored. Finally, our study showed that alphabet writing fluency (handwriting skill) significantly contributed to the prediction of the percentage of spelling errors produced by children with DLD. This finding is consistent with previous evidence with children, yet in senior elementary school grades (Connelly et al., 2012; Ding et al., 2020). Evidence on the role of handwriting in the early phases of written text production remains scarce (e.g. Kim et al., 2014).

Going beyond prior work, the present study attempted for the first time the combined investigation of oral language, cognitive, visual-motor coordination, and handwriting skills in relation to written text production (productivity, accuracy, and complexity) among Greek-speaking children with and without DLD, in their first phases of writing development. Relevant investigations in languages other than English remain limited in number. Our findings seem overall aligned with the hypothesis expecting children with DLD to face more difficulties than TD peers in the measures obtained; in the oral language, visual-motor coordination, and handwriting measures, in most cognitive tasks employed, as well as in all writing productivity and most writing accuracy criteria involved, and in the general index of writing complexity. Moreover, the present study demonstrated the role that oral language skills may play in writing productivity and complexity among TD children (see prediction by expressive vocabulary and phonological awareness, respectively). Also, new evidence was offered by analyses within the DLD group on the role of rapid automatized naming, visual-motor coordination and alphabet writing fluency in spelling.

The present study constitutes a first attempt for a comprehensive assessment of oral language, cognitive, visual-motor coordination, and handwriting skills, as well as written production aspects, in Greek-speaking children with DLD and TD peers. It comes to enrich the relevant literature, focusing on a language (Greek) that differs significantly from English, that most evidence regards. Future studies could further enrich oral language skills assessment, adding measures on the receptive, besides the expressive level, as well as measures at the sentence and discourse levels (Cragg & Nation, 2006; Craig & Washington, 2000; Dockrell et al., 2007). Such studies could additionally inform developmental writing models, such as “the Not -So sSmple View of Writing” (Berninger, 2000; Berninger et al., 2002) about the seemingly important roles of oral language skills, next to those of transcription, executive function and text generation. Future longitudinal research, with larger sample sizes and language-age matched groups formed as well, could shed further light into the developmental trajectories of writing skills in TD children and peers with DLD. The ways in which multiplicative effects on writing interact at different points in development and for different writing tasks also requires further study (Joye et. al. 2018; Dockrell & Connelly, 2015; Van Hell et al., 2008).

In doing so, future research could additionally focus on the role of key executive functions, not assessed in the present study (e.g. inhibition, updating, or shifting; see Ralli et al., 2021), and self-regulation in writing development (Berninger et al., 2002; Graham & Perin, 2007; Hooper et al., 2011). Finally, future studies could also enrich written text production assessments; while written products may appear similar, the cognitive processes supporting their production may differ (Dockrell & Connelly, 2015). For example, the writing task that was employed in the present study had a 5-min time limit (Dombek & Al Otaiba, 2015; Kim et al., 2013). We did not also measure what the children actually did within that 5-min period. It could be the case that children with DLD paused more often when writing more complex language or produced shorter written language bursts, for example (Connelly et al., 2012; Dockrell & Connelly, 2015; Hayes & Chenoweth, 2007; Sumner et al., 2013). Moreover, in the present study, writing was only assessed at one time point and was limited to a single narrative prompt. Future studies could employ different genres (information, explanatory, or opinion) and focus on both the process and the product of writing, across different writing tasks. The latter could also be examined in relation to environmental factors, such as type and quality of teaching or cultural experiences regarding writing.

Essential in efficiently teaching children to write, especially in the first stages, is a holistic view and an accurate understanding of other skills under development—oral, cognitive, visual-motor or handwriting skills—that can support writing (Dockrell & Connelly, 2015; Dockrell et al., 2016). A relevant line of research can provide the basis for the development or enrichment of interventions, that are tailored to the needs of not only TD children, but also of peers with DLD, aiming to support this vital educational as well as life skill (Dockrell & Connelly, 2015).

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