



# ■ Morpheme-based Reading and Spelling in Italian Children with Developmental Dyslexia and Dysorthography

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Italian sixth graders, with and without dyslexia, read pseudowords and low-frequency words that include high-frequency morphemes better than stimuli not including any morpheme. The present study assessed whether morphemes affect (1) younger children, with and without dyslexia; (2) spelling as well as reading; and (3) words with low-frequency morphemes. Two groups of third graders (16 children with dyslexia and dysorthography and 16 age-matched typically developing children) read aloud and spelt to dictation pseudowords and words. Pseudowords included (1) root + suffix in not existing combinations (e.g. lampadista, formed by lampad-, 'lamp', and -ista, '-ist') and (2) orthographic sequences not corresponding to any Italian root or suffix (e.g. livonosto). Words had low frequency and included: (1) root + suffix, both of high frequency (e.g. bestiale, 'beastly'); (2) root + suffix, both of low frequency (e.g. asprigno, 'rather sour'); and (3) simple words (e.g. insulso, 'vapid'). Children with dyslexia and dysorthography were less accurate than typically developing children. Root + suffix pseudowords were read and spelt more accurately than non-morphological pseudowords by both groups. Morphologically complex (root + suffix) words were read and spelt better than simple words. However, task interacted with morphology: reading was not facilitated by low-frequency morphemes. We conclude that children acquiring a transparent orthography exploit morpheme-based reading and spelling to face difficulties in processing long unfamiliar stimuli. Copyright © 2017 John Wiley & Sons, Ltd.

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## INTRODUCTION

According to the psycholinguistic grain-size theory of reading acquisition (Ziegler & Goswami, 2005), learners of transparent orthographies rely on small grain-size units (e.g. single phonemes and letters) more than on larger ones, as the former prove to be highly consistent. Conversely, learners of opaque orthographies, such

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as English, are induced to develop different strategies at more than one grain size, varying the units they use, because in their orthography, units of larger grain sizes (e.g. bigrams or trigrams) are generally more consistent than smaller ones. However, a main reliance on units of a small grain size does not prevent that larger grain-size units are also exploited and assist reading development, as well as reading in skilled adult readers even for languages with consistent orthographies (Grainger et al., 2012).

Studies on reading and spelling acquisition in Italian, a language with a highly regular orthography, confirmed reliance on sub-lexical fine-sized units in the initial phases. Stimulus length, an index of serial-analytic processing, was the most powerful factor modulating first graders' reading times (Zoccolotti et al., 2009). In spelling, the regularity of phoneme-to-grapheme transcription influenced accuracy in all grades examined, with one-sound-to-one-letter stimuli being always spelt more accurately than stimuli with unpredictable transcriptions (Notarnicola, Angelelli, Judica, & Zoccolotti, 2012).<sup>1</sup> Cross-linguistic studies comparing Italian-speaking with English-speaking children confirmed a smaller reliance on large grain-size units in Italian in both reading (Marinelli et al., 2016) and spelling (Marinelli, Romani, Burani, & Zoccolotti, 2015). However, very early indicators of whole-word lexical processing that became progressively stronger as a function of age and schooling were present in Italian children (Notarnicola et al., 2012; Zoccolotti et al., 2009). Evidence indicated that proficient reading is attained by accessing whole-word lexical representations, which allow rapid and fluent word decoding (e.g. Zoccolotti et al., 2005; Zoccolotti et al., 2009). Similarly, accurate spelling may require reliance on whole-word lexical representations, at least for stimuli with unpredictable sound-to-spelling correspondences.

Children with dyslexia of regular orthographies such as Italian and German did not display difficulties in learning the alphabetic code (because of the high consistency of phoneme-to-grapheme mappings) but presented a severe deficit in whole-word processing (De Luca et al., 2002; Hutzler & Wimmer, 2004; Zoccolotti et al., 1999). This difficulty produced over-reliance on sub-lexical strategies, which hampered especially reading speed (e.g. Wimmer, 1993; Zoccolotti et al., 2005). The main reliance of children with dyslexia on sub-lexical processing in reading was evident in orthographic judgement tasks, in which they failed to recognize real words from their phonologically plausible but orthographically incorrect fakes (\*CUOTA form QUOTA/kwota/(=rate); Marinelli, Angelelli, Notarnicola, & Luzzatti, 2009). Only reliance on input lexical orthographic representations may allow to correctly identify the presence of such errors, and this seems poor in children with dyslexia.

When the characteristics of the concomitant spelling deficit (i.e. dysorthography) were examined, spelling difficulties mirrored reading ones: children with dyslexia were able to use phoneme-to-grapheme mappings, although with some delay, and displayed a more severe and long-lasting lexical acquisition deficit, with selective failure in spelling words with unpredictable transcriptions and a prevalence of phonologically plausible misspellings (Angelelli, Notarnicola, Judica, Zoccolotti, & Luzzatti, 2010b; Angelelli et al., 2004). Once the specificity of the lexical orthographic representations of these children was investigated through an item-by-item analysis, they showed a defective and/or underdeveloped orthographic lexicon that served, inefficiently, both reading and spelling (Angelelli, Marinelli, & Zoccolotti, 2010a).

Although children with dyslexia exposed to a consistent orthography do not rely on whole-word lexical representations in processing written stimuli, they do not depend exclusively on small grain-size units. Their reading and spelling may benefit from lexical activation. Studies on morphological facilitation in children with dyslexia highlighted that they show sensitivity to units of intermediate grain sizes such as morphemes (for reviews, see Burani, 2010; Deacon, Tong, & Mimeau, in press). Morpheme-based reading in children with dyslexia was firstly demonstrated in a study on Danish children (Elbrö & Arnbak, 1996). Fifteen-year-old dyslexic Danish students read words with morphological structure (e.g. *sunburn*) faster than words without morphological structure (e.g. *window*). They also read faster sentences displayed in morphemic units than in syllabic units.

A series of studies demonstrated that morpheme-based reading is effective in secondary-school Italian readers with dyslexia (Burani, Marcolini, De Luca, & Zoccolotti, 2008; Marcolini, Traficante, Zoccolotti, & Burani, 2011; Traficante *et al.*, 2011). These students read aloud pseudowords made up of a root and a derivational suffix (e.g. *donn-ista*, 'woman-ist') faster than pseudowords that did not include morphemes (e.g. *dennosto*; Burani *et al.*, 2008). Consistently with reliance on a sequential reading strategy, they especially benefitted from the presence of a root, while the presence of a suffix had no significant effects on vocal reaction times (Traficante *et al.*, 2011). Readers with dyslexia also read words with a morphological structure (e.g. *cass-iere*, 'cashier') faster than matched simple words (e.g. *cammello*, 'camel'). The advantage for morphologically complex words was present in poor readers irrespective of word frequency (Marcolini *et al.*, 2011). Finally, the presence of morphemes positively affected reading accuracy for pseudowords (Burani *et al.*, 2008; Traficante *et al.*, 2011), but not in the case of words, irrespective of word frequency or reading skill (Burani *et al.*, 2008; Marcolini *et al.*, 2011).

A replication of the findings obtained in Italian came from a study on Spanish-speaking children (Suárez-Coalla & Cuetos, 2013): 7- to 10-year old children with dyslexia read isolated words and pseudowords with morphological structure faster than simple ones. However, no significant differences in accuracy were found between complex and simple stimuli.

The facilitation induced by morphology on the performance of readers with dyslexia has received two main interpretations. It is well known that readers with dyslexia experience difficulty in processing the whole word as one reading unit, and this difficulty leads them to rely on units (graphemes and phonemes) of a smaller size than the word, which determine a very slow reading behaviour. Following Burani (2010), morphemes (roots and affixes) are reading units of an intermediate size between graphemes (which entail extremely slow and analytical sub-lexical processing) and the word (which is too long for readers with dyslexia to be processed as a whole), and so easily exploitable. According to this view, faster reading aloud of stimuli structured in morphemes reflects access to familiar lexical units (the morphemes) that are larger than single graphemes although shorter than the whole word. In this view, morpheme-based reading promotes decoding based on lexical access instead of sub-lexical correspondences and speeds up processing when either the word is not present in the reader's lexicon or it is too long to be identified within a single fixation (Burani, 2010). Another interpretation of morphological facilitation in dyslexia relies on the consideration that morphemes are meaningful units. Following this view, activation of

morphemes' meaning is central in morphological decomposition, and also children with dyslexia, given their preserved vocabulary and comprehension abilities, may develop a morpho-semantic level of representation (e.g. Casalis, Colé, & Sopo, 2004; Elbrö & Arnbak, 1996; Quémart & Casalis, 2015).

Studies on the use of morphology in the spelling of children with limited reading and spelling abilities are few; they prevalently concern orthographies with a high degree of sound-to-letter irregularity and present contrasting results. For example, Bourassa, Treiman, and Kessler (2006) studied spelling to dictation of a group of English-speaking children with dyslexia (9–14 years old) compared with spelling age-matched controls in order to examine the extent to which children with dyslexia and younger typically developing children use morphological information to overcome spelling difficulties at the phonological level. The authors found that both groups spelt more accurately words containing /t/ and /d/ sounds when they were present in morphologically complex words (e.g. *waiting* and *needed*) compared with simple ones (e.g. *daughter* and *spider*). So children with dyslexia as well as younger typically developing children benefitted from morphology to some extent, showing some knowledge of the principle of 'root consistency' (i.e. the root maintains its spelling in a family of words).

Recently, Quémart and Casalis (2016) reported that 10- to 15-year-old French students with dyslexia took benefit of morphological processing in word spelling more than spelling age-matched pairs. The authors investigated the performance of both groups of students in spelling silent final letters, which were either morphologically conditioned (e.g. *tricot*, 'knit', where the final 't' is pronounced in morphologically related words as *tricoter* 'to knit' and *tricoteur* 'knitter') or not morphologically justified (e.g. *effort*, 'effort') and found that the morphological status of silent final letters helped students with dyslexia to spell them more accurately than non-morphologically justified ones. In contrast, the control group showed equal performance in spelling final letters in the two spelling conditions.

Tsesmeli and Seymour (2009) found that English-speaking secondary-school students with dyslexia, similarly to their spelling age-matched controls, successfully used morphological knowledge to improve spelling of derived words, following an explicit morphological training. The goal of such training was to improve students' skills necessary to carry out morphological decomposition of complex words (so encouraging awareness of the division of written words into subsets of letters corresponding to morphemes). Similar indications come from morphological interventions not specifically addressing spelling (for a meta-analysis of morphological intervention studies in children with learning disabilities, see Goodwin & Ahn, 2010).

Few studies suggested that morphology may facilitate the spelling of individuals learning in a transparent orthography. Lehtonen and Bryant (2005) studied typically developing children learning to spell Finnish, a richly inflected language with highly transparent orthography. The authors used two-morpheme words in which target clusters of letters (the sequences LL and SS) appeared in different morphemes of the words, either in the root or in the inflection for case (in Finnish, case inflections are a more prominent part of morphology than derivation, because they occur in nouns, adjectives, pronouns and numerals). The authors tested children at two different times during the first year of school and found that by the end of the year they began to spell target clusters better in case inflections than in roots, which suggested emerging sensitivity to the morphological structure

of words in spelling. Similar results were found for pseudowords: letter clusters that occurred in endings corresponding to case inflections were spelt with greater accuracy than those occurring in pseudo-roots, suggesting that case-like endings prompted morphological parsing during spelling.

In a recent study, we found evidence for morphological facilitation in the spelling process of third-grade and fifth-grade typically developing Italian children (Angelelli, Marinelli, & Burani, 2014). In our study, children read aloud and spelt the same sets of pseudowords and low-frequency words. Pseudowords were made up of a real root and a real derivational suffix in a combination that either does not exist in the Italian language or had no morphological constituents. Low-frequency words were manipulated for the presence of morphological structure (morphemic words versus non-derived words). Morphemic words could vary for the frequency (high versus low) of roots and suffixes. Results showed that both third and fifth graders benefitted from the presence of morphological constituents when processing newly encountered stimuli not only in reading but also in spelling: pseudowords made up of morphemes were read and spelt more accurately than non-morphemic pseudowords. As to words, morphological facilitation was present in reading but not in spelling, with a peculiar pattern of morphological modulation that interacted with reading ability. We concluded that the facilitation in spelling novel stimuli structured in morphemes arises from access to smaller (than the whole stimulus) and more manageable lexical units (also Tssemeli & Seymour, 2009). For developing readers, exposure to these frequently occurring chunks of sound and meaning in speech and their corresponding orthographic patterns in writing allows morphemes to become relatively independent and manageable spelling units. This may enable children to process them correctly, thus avoiding time-consuming and error-prone phoneme-grapheme analysis. Additionally, in spelling to dictation, morphological chunking may positively influence accuracy by lightening the working memory load, as shown in Italian children with specific language impairment (Casalini *et al.*, 2007). Finally, the contribution of morphemes as meaningful units to facilitate spelling may also be considered.

Overall, evidence of morphological facilitation on spelling in transparent orthographies comes from studies on typically developing readers and spellers. To our knowledge, only one study (Diamanti, Goulandris, Stuart, & Campbell, 2014) investigated the spelling of derivational and inflectional suffixes of children with dyslexia. These authors found that although Greek-speaking children with dyslexia spelt words with morphological structure less accurately than typically developing peers, their spelling performance was similar to that of younger spelling-level-matched controls, supporting the hypothesis of a spelling delay rather than a deviance in this population. However, it is worth noting that Greek is a moderate-to-transparent language in the oral to written direction (Seymour, Aro, & Erskine, 2003); thus, the development and use of morphological information in Greek children necessarily face instances of sound-to-spelling ambiguities.

In the present study, we investigated the effects of morphology on both reading and spelling accuracy of pseudowords and words in third-grade Italian children with developmental dyslexia and concomitant dysorthography (DD), and typically developing (TD) pairs. We studied reading and spelling of young children with DD, to evaluate if they might benefit from the presence of morphological constituents to improve correctness in both tasks. Similarly, we aimed to verify to what extent

young TD children might take advantage of the presence of morphological constituents in reading and spelling non-lexical and lexical stimuli. Children's reading and spelling performance on pseudowords made up of familiar morphemes (roots and derivational suffixes) was compared to that on matched pseudowords that did not include any morphemic constituent. As to words, reading and spelling performance on low-frequency morphologically complex words was compared to performance on words with no derivational structure. In order to better qualify the effects of morphology, we investigated two types of morphologically complex words: words made up of high-frequency morphemes (root and suffix) and words with low-frequency morphemes.

Overall, we expected that morphological knowledge would enhance not only reading but also spelling performance in DD Italian children, by facilitating the parsing process of the stimulus and by allowing the retrieval of lexical units larger than single phonemes/graphemes. Similarly to what has been observed for morpheme-based reading, morphological facilitation in spelling was expected to occur for both non-lexical and lexical stimuli. Consistently with the findings of Angelelli et al. (2014), the morphological facilitation was expected to occur also in the reading and spelling of third-grade typically developing children, in both lexical and non-lexical morphemic stimuli, under the assumption that children of this age when dealing with non-familiar (new or low-frequency) stimuli may take advantage of reading and spelling units (the morphemes) that are more efficient than both whole-word units on the one side, and units corresponding to single phonemes/graphemes on the other. For both groups of children, low-frequency morphemes were not expected to facilitate reading and spelling performance to the same extent than high-frequency ones, because low-frequency morphemes are not likely to be present in the lexicon of children attending third grade.

## MATERIAL AND METHODS

### Participants

Participants were 16 DD children (4 girls and 12 boys, mean age = 8.80 years, standard deviation (SD) = 0.45) and 16 typically developing readers and spellers (mean age = 8.57 years, SD = 0.30) attending third grade. The DD children were selected after screening in local schools as a part of a research agreement between the University of Salento and the local public primary schools. Parents were informed and approved their child's participation.

The DD children were selected for a marked reading and spelling delay on standard tests and normal performance at Raven's Colored Progressive Matrices (CPM) (Pruneti et al., 1996). Participants who scored at least 1.65 SDs below the mean of the normative sample for reading speed or accuracy (MT Reading test, Cornoldi & Colpo, 1998) and spelling (DDO-2 spelling test, Angelelli et al., 2016) were included in the group of DD children. A selective failure either in speed or in accuracy was considered to satisfy the inclusion criteria, because children with reading problems may strategically modify their ability to read faster (with loss of accuracy) or more accurately (at the expense of speed) (Hendriks & Kolk, 1997). None of the children had received treatment for his or her reading impairment. None had concomitant motor disorders or other certified learning



disabilities. As can be seen in Table 1, DD participants were severely impaired in reading a text passage, especially for accuracy, while text comprehension was spared. Spelling performance was highly below norms, in all spelling subtests.

The TD readers and spellers were selected from the same classes of DD children and were matched one to one to them for gender, performance on Raven's CPM test and age. They showed spared reading speed and accuracy (MT Reading test) and spelling skills (DDO-2 test). TD children performed close to zero for Raven's CPM, reading speed and accuracy and all spelling tasks (and the total scores), indicating marginal deviations from the proper normative sample. TD children did not differ from DD children for age ( $t(31) = 1.70$ , ns), gender distribution ( $\chi^2 = 0.0$ , ns) and Raven's CPM performance ( $t(31) = 1.24$ , ns), but they differed for all reading and spelling measures (at least  $p < 0.0001$ ).

#### Characterization of reading and spelling disorder

The nature of the reading disturbance of DD children was further examined by additional tasks. In order to assess the effect of stimulus lexicality, we tested

Table 1. Data (mean Z scores) on the performance at the Raven CPM and the reading and spelling tasks administered to typically developing (TD) children and children with dyslexia and dysorthography (DD)

Test	TD children		DD children		t test	p
	M	SD	M	SD		
CPM Raven	-0.18	0.42	-0.42	0.63	1.24	—
MT Reading test						
Speed	0.11	0.43	-1.74	0.34	7.29	<0.0001
Accuracy	0.35	0.45	-3.03	1.98	6.73	<0.0001
Comprehension	0.22	0.59	-0.34	0.77	0.03	—
Spelling						
Total	0.63	0.61	-2.63	1.15	10.19	<0.0001
Pseudowords	0.49	0.48	-1.72	1.63	5.22	<0.0001
Regular words	0.16	0.74	-2.79	2.64	4.33	<0.0001
Regular words with contextual rules	0.25	0.48	-1.82	1.90	4.23	<0.0001
Ambiguous words	0.65	0.68	-1.81	0.58	11.23	<0.0001
Word and pseudoword reading						
Words: Time	0.74	0.44	-1.51	2.14	3.37	0.01
Words: Errors	0.63	0.36	-2.49	1.68	5.80	<0.0001
Pseudowords: Time	0.86	0.52	-0.98	2.04	2.87	0.01
Pseudowords: Errors	0.29	0.97	-3.34	1.67	6.21	<0.0001
Orthographic judgement task						
High-frequency irregular words	86.36	9.77	83.75	11.18	0.63	—
Low-frequency irregular words	85.00	14.66	82.19	12.38	0.54	—
High-frequency irregular fakes	66.36	17.04	35.94	17.72	4.35	<0.0001
Low-frequency irregular fakes	67.73	16.94	40.94	18.99	3.69	0.001
High-frequency regular words	97.27	3.44	89.06	8.98	2.84	0.01
Low-frequency regular words	84.09	8.61	86.88	6.80	0.94	—
High-frequency regular fakes	94.55	6.11	59.38	21.36	5.13	<0.0001
Low-frequency regular fakes	94.09	5.84	59.69	21.17	5.07	<0.0001
Correctness of pseudo-homophone			1.67	1.39		

In all cases, negative values indicate performance below the norm. Note that for TD, children did not perform the 'correction of pseudo-homophones' task and that for the 'orthographic judgement task' (Marinelli et al., 2009) normative data were not available and only raw (percentage of accuracy) data are reported. CPM, Colored Progressive Matrices.

groups in reading aloud single words and pseudowords (DDE- 2; Sartori, Job, & Tressoldi, 2007). Lexical processing was assessed by means of two tests. In the *correction of homophone words* task (Sartori et al., 2007), participants were asked to read a list of stimuli: half were orthographically correct, and half were pseudo-homophones generated in almost all cases by the insertion of an apostrophe or a space (e.g. \*C'IELO, pseudo-homophone of CIELO, 'sky'; \*DI VERSO, pseudo-homophone of DIVERSO, 'different'). Participants were asked to judge whether or not the spelling of the items was correct. The incorrect items have no meaning but sound like their correct counterparts. Therefore, reference to the orthographic input lexicon is required to solve the task. In the *orthographic judgement task* (Marinelli et al., 2009), children judged the orthographic correctness of printed stimuli. Stimuli could be orthographically correct, orthographically incorrect but phonologically plausible (e.g. QUORE derived from CUORE, heart), or orthographically incorrect but phonologically implausible (e.g. PRIETE derived from PRETE, priest). Similarly to the correction of homophone words task, the incorrect but phonologically plausible items have no meaning but sound like their correct counterparts and can be recognized only by accessing the orthographic input lexicon. Stimuli were controlled for regularity of transcription (regular versus ambiguous), length (short versus long) and word frequency (high versus low). For the purpose of this study, only accuracy in judging fake stimuli was analysed, being the only condition that allows to evaluate the efficiency of lexical reading (whereas accuracy in judging correct words could be obtained via both lexical and sub-lexical processing). However, accuracy in judging correct stimuli is reported in Table I for both groups. For the sake of brevity, in Table I as well in the analyses, performances on short and long stimuli have been collapsed.

Table I reports the performance (with respect to normative data) of DD and TD children in all tasks used for better characterizing their reading and spelling performance. Additionally, raw data were also analysed through analyses of variance (ANOVAs) comparing DD with TD children in each subtest.

The ANOVA on the spelling task (Angelelli et al., 2016) revealed significant main effects of *group* ( $F(1, 34) = 67.86; p < 0.0001$ ) and *stimulus type* ( $F(3, 90) = 14.20; p < 0.0001$ ), as well as the *group by stimulus type* interaction ( $F(3, 90) = 3.78; p < 0.05$ ). The interaction showed that DD children underperformed in the various categories of stimuli (at least  $p < 0.01$ ) except for regular words. However, large group differences were evident in spelling words with unpredictable transcriptions and regular words requiring the application of context-sensitive sound-to-spelling rules<sup>2</sup> (about 30% of difference between groups, at least  $p < 0.001$ ).

The DD children were severely impaired also in single word and pseudoword reading with respect to normative data. The ANOVA on reading times highlighted significant main effects of *group* ( $F(1, 30) = 11.38, p < 0.01$ ) and *lexicality* ( $F(1, 30) = 38.94, p < 0.0001$ ), and *lexicality by group* interaction ( $F(1, 30) = 7.25, p < 0.01$ ): lexicality affected performance of DD children (difference between words and pseudowords = 90 ms,  $p < 0.0001$ ) but not of TD children (difference = 36 ms, ns); groups also differed in word reading (difference = 114 ms,  $p < 0.05$ ) but not in pseudoword reading (60 ms, ns). ANOVA on reading errors showed significant main effects of *group* ( $F(1, 30) = 52.59, p < 0.01$ ) and *lexicality* ( $F(1, 30) = 6.73, p < 0.01$ ), indicating lower percentages of errors for TD than DD children (3.4% vs. 17.6%, respectively) and in reading words with respect to



pseudowords (9.0% vs. 12%, respectively). The *lexicality by group* interaction was not significant ( $F < 1$ ), owing to the similar effect of lexicality in the two groups (difference between pseudowords and words = 2% and 4%, in TD and DD children, respectively).

Results of the two tasks specifically assessing lexical reading are reported in Table 1. In the orthographic judgement task, DD children had a very low accuracy: while regular fakes were recognized in 59.5% of cases, phonologically plausible fakes were recognized in 38.4% of cases. The ANOVA showed significant main effects of *group* ( $F(1, 30) = 29.81, p < 0.0001$ ) and *regularity* ( $F(1, 30) = 86.05, p < 0.0001$ ), indicating lower accuracy in DD than in TD children (49.0% vs. 80.7% accuracy) and in recognizing phonologically plausible fakes than non-phonologically plausible stimuli (52.7% vs. 76.9% of accuracy). In the correction of homophone words test (Sartori et al., 2007), DD children failed in detecting phonologically plausible homophonic pseudowords. Their performance was 1.67 SDs below the mean according to normative data, indicating failure to access lexical representations and reliance on sub-lexical procedures in performing the task.

Overall, DD children had an impaired performance if compared with normative data in reading and spelling all orthographic stimuli (words and pseudowords). However, DD children differed from TD children especially for the severe deficit in spelling words with unpredictable transcription and words requiring the application of contextual rules. Similarly, tasks that tapped the use of lexical representations in reading revealed that DD children suffered from impaired lexical processing and relied prevalently on grapheme-to-phoneme small-sized correspondences. Thus, it seemed that participants presented a deficit in both lexical and sub-lexical processing, but with main difficulties in tasks requiring access to input and output whole-word orthographic representations.

## Materials

Materials were pseudowords and low-frequency words used in Angelelli et al. (2014).

Two sets of 16 pseudowords of three to four syllables (length range, 8–10 letters) were used: pseudowords in the first set (root + suffix) consisted of a root and a derivational suffix ( $R^+S^+$ ) in a combination not existing in the Italian language (e.g. lampadista, constituted by the root lampad-, ‘lamp’, and the suffix -ista, ‘-ist’). Pseudowords in the second set (non-root + non-suffix) were made up of orthographic sequences that did not correspond to any existing Italian root or suffix ( $R^-S^-$ ) (e.g. livonosto). The subsets were matched for the number of contextual rules, consonant clusters, geminate letters, length (in letters) and bigram frequency (all  $t_s < 1$ ). The two sets of pseudowords were matched also for the frequency of the final orthographic sequence, corresponding to a real suffix in the  $R^+S^+$  set, and to a non-suffix in the  $R^-S^-$  set.

Three sets of 15 low-frequency words were used. Words in the first set (e.g. bruttezza, ‘ugliness’) consisted of a root (brutt-, ‘ugly’) and a derivational suffix (-ezza, ‘ness’), both of high frequency (HD). Words in the second set (e.g. agrumeto, ‘citrus grove’) consisted of a root (agrum-, ‘citrus plant’) and a derivational suffix (-eto, indicating a place where trees or flowers grow) of low frequency (LD). Frequency values of words, roots and suffixes were drawn from the child

frequency count by Marconi et al. (1993). The third set of words included simple non-derived words (ND) (e.g. aragosta, 'lobster'). The three sets of words were matched for the phonetic features of the initial phoneme and did not differ for other relevant psycholinguistic variables such as length (number of letters), consonant clusters, geminate letters, number of contextual rules, bigram frequency, word frequency and familiarity (all  $t$ s about 1). The first and second sets of words were only different for root frequency ( $t(29) = 4.19, p < 0.0001$ ) and suffix frequency ( $t(29) = 5.65, p < 0.0001$ ).

As in Angelelli et al. (2014), 33 filler stimuli were added to the list in order to have similar numbers of words and pseudowords, and similar numbers of morphologically complex and simple stimuli, to assess lexical reading without explicitly inducing morphological decomposition.

### Procedure

For the spelling condition, pseudowords and words were randomized and given in a spelling-to-dictation task. The examiner read each item aloud in a neutral tone; children were asked to repeat each item before writing it down (so that the examiner could ensure that participants had correctly perceived the item) in capital letters. No feedback was provided on the correctness of the written response. Pauses were allowed if requested. Spontaneous repairs were accepted.

For the reading condition, words and pseudowords were randomized and presented in three blocks. Stimuli were displayed in the centre of the computer screen in black and lower case (font Arial, 24 pts). Each trial consisted of the following sequence: a fixation point for 500 ms; a blank stimulus for 250 ms; and the stimulus, which remained visible until the onset of pronunciation. Participants read each stimulus aloud as accurately as possible. Mispronunciation errors were recorded and noted by two experimenters, who at the end of the experimental sections verified their annotations. The experimental sections were preceded by a training block of 10 stimuli, consisting in five words and five pseudowords.

The spelling and reading tests were administered with an interval of about 20 days between them. The order of the tasks was balanced in the experimental sample: half of the children performed first spelling then reading, the other half performed the tasks in the inverse order; the assignment to the first or second sub-group was random. Children were tested individually in a quiet room at their school.

### DATA ANALYSIS

Spelling and reading accuracy were analysed with logistic mixed effect models (Guo & Zhao, 2000; Quené & Van den Bergh, 2008) to control for the presence of a floor effect, as well as for items' and participants' variability. This analysis assumes a logistic distribution of data, allowing to manage repeated-measures designs with dichotomic data and then with the presence of several 0, as in the case of accuracy (e.g. Dixon, 2008). Additionally, this analysis prevents the potential lack of power of the by-subject and by-item analyses and limits the loss of information due to the prior averaging of the by-item and by-subject analyses

(Baayen, Tweedie, & Schreuder, 2002; also Brysbaert, 2007). Data on words and pseudowords were analysed separately.

Group (children with dyslexia and dysorthography versus typically developing children), Task (spelling versus reading) and Morphology were entered as fixed factors, while Items and Participants were Random factors. In the case of words, Morphology refers to words made up of high-frequency roots and high-frequency derivational suffixes [HD]; low-frequency roots and low-frequency derivational suffixes [LD] and non-derived words [ND]; in the case of pseudowords, Morphology refers to pseudowords made up of real roots and derivational suffixes [ $R^+S^+$ ] and pseudowords with orthographic sequences not corresponding to any existing Italian root or suffix [ $R^-S^-$ ].

The logistic mixed effect models estimate the probability to have an error. For the sake of simplicity, from now on, we will refer to percentages of errors or simply to error rates.

## RESULTS

### Pseudowords

Percentages of errors on pseudoword reading and spelling by children with dyslexia and dysorthography (DD) and typically developing (TD) children are reported in Figure 1. The logistic mixed effect model showed significant effects of Group ( $F(1, 2103) = 160.24, p < 0.0001$ ), Task ( $F(1, 2103) = 9.09, p < 0.01$ ) and Morphology ( $F(1, 2103) = 24.42, p < 0.0001$ ), with higher error rates for DD children (42.7%) than for TD age-matched children (13.7%); in reading (29.2%) than in spelling (22.2%); and in  $R^-S^-$  pseudowords (31.7%) than in  $R^+S^+$  pseudowords (20.3%). The Task  $\times$  Group interaction was significant ( $F(1, 2103) = 4.70, p < 0.05$ ), highlighting that reading was more difficult than spelling for TD children (difference between the two tasks = 7.6%,  $p < 0.01$ ), while DD children had similar impaired performances in both tasks (difference = 1.7%, ns).

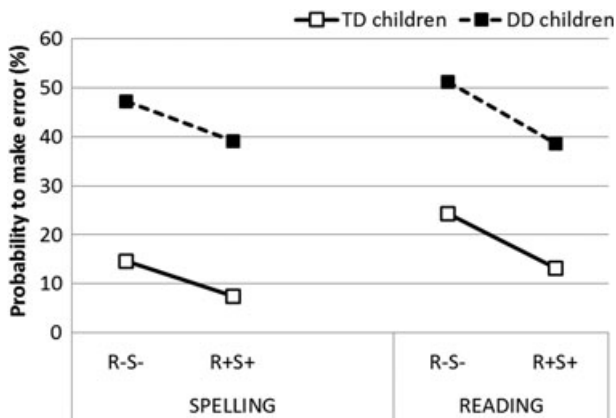


Figure 1. Reading and spelling performance on pseudowords made up of real roots and derivational suffixes [ $R^+S^+$ ] and pseudowords with orthographic sequences that do not correspond to any existing Italian root or suffix [ $R^-S^-$ ] by typically developing (TD) children and children with dyslexia and dysorthography (DD).

The random effects of Items and Participants were not significant ( $Z_s < 1$ ). Note that Morphology did not interact with Group ( $F$  about 1), indicating that morphology modulates in a similar way performance of TD and DD children in processing pseudowords.

### Words

The logistic mixed effect model showed a significant effect of Group ( $F(1, 2868) = 171.73, p < 0.0001$ ), with DD children more prone to make errors (42.8%) than age-matched TD children (12.3%), and Morphology ( $F(2, 2868) = 21.84, p < 0.0001$ ): errors on HD words (13.7%) were fewer than on LD words (32.2%;  $p < 0.0001$ ) and ND words (31.2%;  $p < 0.0001$ ); the difference between LD and ND words was not significant. The main effect of Task was not significant ( $F(1, 2868) = 2.57, ns$ ), but Task  $\times$  Morphology interaction ( $F(2, 2868) = 7.69, p < 0.0001$ ) and Morphology  $\times$  Group interaction ( $F(2, 2868) = 4.80, p < 0.01$ ) were significant. The random effects of Items and Participants were not significant ( $Z_s < 1$ ).

The higher level interaction Task  $\times$  Morphology  $\times$  Group was significant ( $F(2, 2868) = 4.69, p < 0.01$ ) and is presented in Figure 2. Exploration of the interaction highlighted that in spelling, there were effects of morphology for both TD and DD children. TD children showed significantly lower error rates on derived words with high-frequency constituents (HD) than on simple non-derived (ND) words (17.9% and 9.6%, respectively,  $p < 0.05$ ). Derived words with low-frequency constituents (LD) induced intermediate percentages of errors (12.4%) relative to HD and ND words (not significantly different from both HD and ND words). DD children also showed lower error rates in spelling HD (36.2%) words, which significantly differed from both LD words (51.3%,  $p < 0.001$ ) and ND words (52.5%,  $p < 0.0001$ ). LD and ND words did not differ in error rates.

In reading, TD children showed very low percentages of errors on HD words (2.5%), with respect to both LD (24.9%,  $p < 0.0001$ ) and ND (22.2%,  $p < 0.0001$ ) words; these two word types did not differ from each other. DD children committed a lower percentage of errors in reading HD words (29.3%), than in LD (50.9%),

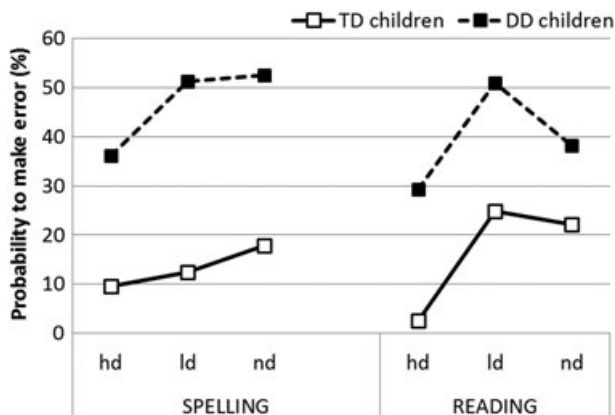


Figure 2. Reading and spelling performance on words with high-frequency roots and suffixes (HD), low-frequency roots and suffixes (LD) and non-derived words (ND) by typically developing (TD) children and children with dyslexia and dysorthography (DD).

$p < 0.0001$ ) and ND (38.2%,  $p < 0.05$ ) words. Interestingly, DD children were worst in reading LD words than ND words ( $p < 0.01$ ).

A Task effect was not detectable in DD children, who made similar percentages of errors in the two tasks, except in the case of ND words, which induced more errors in spelling than in reading ( $p < 0.01$ ). Group differences were always very large and significant (at least  $p < 0.001$ ).

## DISCUSSION

In the present study, we investigated whether Italian primary-school children with dyslexia and dysorthography make use of morphological information to improve accuracy in reading and spelling, and whether the frequency of morphemes modulates the use of morphology in both tasks. In Italian, the regularity of the grapheme-to-phoneme and phoneme-to-grapheme mappings is in principle sufficient to process correctly most words; thus, morphological units may not be necessary for reading and spelling accuracy. Nevertheless, there is evidence of morpheme-based reading in Italian students with dyslexia (Burani *et al.*, 2008; Marcolini *et al.*, 2011; Traficante *et al.*, 2011), but no indications are present for the spelling process.

Present results confirmed that also young DD children, although generally underperforming with respect to typically developing children, take advantage of morphological information in both reading and spelling. Administration of the same pseudowords and words for both reading and spelling allowed us to directly compare children's performance on the two tasks.

Morphology was helpful to a similar extent for DD children and TD children in reading pseudowords. Both groups benefitted from the presence of morphological constituents when processing newly encountered stimuli: pseudowords made up of existing morphemes were read more accurately than non-morphemic pseudowords, irrespective of the presence of a literacy acquisition deficit. Thus, it seems that the reading of never encountered printed stimuli takes advantage of the presence of known morphemes in both children with dyslexia and dysorthography and typically developing children.

Also in reading low-frequency words, DD children benefitted from the presence of high-frequency constituents. Words made up of high-frequency roots and suffixes were read better than simple ones by both DD and TD children. However, a difference between groups emerged for words composed of low-frequency morphemes: while TD children read words with low-frequency morphemes at a comparable level of accuracy as non-derived words, DD children showed a detrimental effect of the presence of low-frequency morphemes, revealing a higher percentage of errors in reading words containing low-frequency morphemes than in reading simple words. These results may indicate that young TD children do not adopt morphological parsing in reading when morphemes are of low frequency, because these morphemes are unknown to them. Consequently, they treat words with low-frequency morphemes like simple words. In contrast, children with limited reading and spelling abilities showed an unexpected behaviour that needs to be further explored. Some interpretation of what caused more errors in children with dyslexia when they read words containing low-frequency morphemes than when they read simple words may be advanced: it

could be thought that children with dyslexia, because of their difficulty with whole-word processing, systematically attempt at parsing a printed stimulus into smaller lexical chunks. Thus, they may develop a parsing strategy that leads them to maximally exploit the presence of a possible root to process the rest of the word. However, while such strategy is successful when both root and suffix are well known, it is likely to result in misreadings when morphemes are not well known. In the latter case, attempts at parsing may result in root and/or suffix substitutions. Some hints to this interpretation come from the inspection of reading errors made by DD children on complex words formed of low-frequency morphemes. When children read aloud a word like 'poppatoio' (feeding bottle), they made errors like 'poppato' (sucked) or 'poppa' (breast), which are suffix substitutions (-ato, -a) with root preservation (popp-). Or they could read the target word as '\*pappatoio' or '\*pompatoio', which are non-existing words made up of a different root ('papp-', din-dins; 'pomp-', pump) combined with the correct suffix ('-toio', with instrumental value). Finally, they could read the target word as '\*doppiatorio', a non-existing word in which both the root ('doppi-', double) and the suffix ('-torio', alternate suffix for '-toio') were substituted to the target morphemes.

Overall, present results on reading confirm those found in previous studies on Italian adolescents with dyslexia who benefitted from the presence of morphemes in both pseudoword (Burani et al., 2008; Traficante et al., 2011) and word reading (Burani et al., 2008; Marcolini et al., 2011). However, morpheme-based reading affected reading speed on all types of stimuli, whereas it had a positive effect on accuracy in the case of pseudowords only. A morphological facilitation in reading both lexical and non-lexical stimuli was also described in Spanish children with dyslexia (Suárez-Coalla & Cuetos, 2013).

The main novelty of this study is that evidence for morphological facilitation was extended to the spelling process of children with limited reading and spelling abilities learning in a transparent orthography. The administration of the same stimuli for both reading and spelling allowed us to directly compare children's performance on the two tasks and to find a parallelism of results. Similarly to what happened in reading, both DD children and TD children took advantage of the presence of morphological constituents when spelling pseudowords: morphemic pseudowords were spelt more accurately than non-morphemic ones. Similarly, in spelling low-frequency words, both DD and TD children benefitted from the presence of high-frequency constituents, while both groups spelt words with low-frequency morphemes at a comparable level of accuracy as non-derived words. Thus, it seems that handling with units larger than the single phoneme, but smaller than the entire stimulus, facilitates the oral-to-written transcoding as well as visual word recognition.

Present data are consistent with those of studies showing a positive influence of morphology in children with dyslexia learning in opaque orthographies (Bourassa et al., 2006; Quémart & Casalis, 2016; Tsesmeli & Seymour, 2009; also Goodwin & Ahn, 2010) and parallel those reported on typically developing children in transparent orthographies (Angelelli et al., 2014; Defior, Alegría, Titos, & Martos, 2008; Lehtonen & Bryant, 2005). In a previous study (Angelelli et al., 2014), using the same experimental conditions, both third and fifth typically developing graders were facilitated by morphology when spelling pseudowords, and facilitation was present also for morphemic words, at least in fifth-grade children. Present data on typically developing children confirm results of Angelelli et al. (2014) on third-grade children



and extend them to children of the same age with developmental dyslexia and dysorthography. Present findings show that lexical units are used in spelling in a transparent orthography despite the easiness of sub-lexical phoneme-to-grapheme correspondences and the sequential 'left-to-right' nature of the writing process. The facilitation from morphemic structure that we observed on spelling accuracy originates from accessing and retrieving pre-assembled lexical units (the morphemes) that reduce to a minimum assembling costs and errors.

Overall, present data extend to Italian primary-school children with dyslexia and dysorthography evidence for morphological facilitation on reading and spelling, for both new stimuli (pseudowords) and words, and show that familiar morphemes improve not only reading fluency but also reading and spelling accuracy of new and low-frequency words. These results are especially interesting, because children participating in the study showed a profile of surface dyslexia and dysorthography, with a fragility along the sub-lexical procedure but more severe deficits in whole-word processing. This profile has been described several times in Italian children with dyslexia and dysorthography and has been related to poor quality or availability of whole-word lexical representations (Angelelli *et al.*, 2010a). However, present findings support the view that although whole-word representations are not efficiently accessed or available, Italian children with dyslexia are able to use morphemes in reading and spelling.

Exposure to frequently occurring chunks of sound and meaning in speech and their corresponding orthographic patterns in writing could allow morphemes to become relatively independent reading and spelling units well represented in the mental lexicon (Perfetti, 2007; Perfetti & Hart, 2002), helping children to bypass their deficits in whole-word processing. Some data indicate that children with dyslexia are able to learn orthographic regularities. In a recent study (Nigro, Jiménez-Fernández, Simpson, & Defior, 2016), Spanish children with dyslexia showed comparable abilities to implicitly acquire positional regularities of letters or shapes in stimuli as those of typically developing children, indicating that they were not impaired in the acquisition of simple positional regularities, regardless of the nature of the stimuli. The morphological facilitation may specifically arise from the meaning properties of morphemes. Some authors suggest that the meaningfulness of morphemes influences morphological decomposition very early in the time course of word recognition (Casalis *et al.*, 2004; Elbrö & Arnbak, 1996; Quémart & Casalis, 2015). This view mainly relies on evidence from experiments of lexical decision using morphological masked priming that showed a larger amount of priming when prime–target pairs shared a semantically transparent (i.e. related in meaning) morphological relationship than when the relationship was semantically opaque (i.e. unrelated in meaning). In our present findings, the contribution of morpho-semantic processing to facilitate reading aloud and spelling of morphemic stimuli cannot be excluded, even if at least pseudowords had a low semantic interpretability. However, the semantic contribution of morphemes may show up more in tasks that require substantially deeper semantic processing like lexical decision (refer to studies cited earlier) or word comprehension (e.g. Burani, Bimonte, Barca, & Vicari, 2006) than transcoding tasks such as spelling under dictation or reading aloud. Reading aloud in particular has been found to be insensitive to meaning (e.g. Baayen, Wurm, & Aycocock, 2007; Burani, Dovetto, Spuntarelli, & Thornton, 1999; Burani, Marcolini, & Stella, 2002). Further research will help to clarify this issue.

The results of the present study have practical implications. The facilitatory effect of morphology in reading and in spelling might be used to enrich standard teaching methods and rehabilitation strategies for learning disabilities. Evidence from opaque orthographies (Goodwin & Ahn, 2010; Traficante, 2012) shows that an explicit training based on morphological parsing may induce children to identify letter patterns that are recurrent in several words and foster processing based on units larger than single phonemes/graphemes. However, future research is needed to further explore the possible benefits of morphological training, especially in regular orthographies.

Overall, the present study extends the investigation of morphological processing from reading to spelling and highlights the involvement of morphological knowledge in young children with developmental dyslexia and dysorthography in a language with transparent orthography. These results on Italian may reflect a morpheme-based organization of the lexicon and an attitude to parsing words in constituents, which are typical of morphologically rich languages (Lehtonen & Bryant, 2005).

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## ENDNOTES

1. Italian is more consistent in the grapheme-to-phoneme mappings than in the phoneme-to-grapheme mappings (Ziegler & Goswami, 2005), owing to the presence of unpredictable spelling in which a given phonological string has more than one orthographic solutions, although only one is correct (e.g., the phonemic group /kw/ can be transcribed with one of the orthographic sequences QU or CU (e.g., QUOTA (=share) instead of \*CUOTA, or SCUOLA (school) instead of \*SQUOLA)).
2. In Italian, a few phonemes are spelt in different ways according to the immediately following phoneme; that is, they are correctly spelt, only taking into consideration the phonemic context in which they are inserted. An example is the phoneme /g/, which is spelt as GH when followed by a front vowel as in GHIRO, ‘dormouse’, whereas it is spelt as G when followed by the other vowels or by a consonant, as in GOLA, ‘throat’ (for further characterization of the Italian spelling system and its impact on reading and spelling acquisition, see Burani, Thornton, & Zoccolotti, in press).

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