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Phonological and lexical reading in Italian children with dyslexia

Margherita Orsolini · Rachele Fanari · Sara Cerracchio · Luisa Famiglietti

Abstract In this study we explore the development of phonological and lexical reading in dyslexic children. We tested a group of 14 Italian children who have been diagnosed with dyslexia and whose reading age is end of grade 1. We compared this group with a group of 70 typically developing children who have been tested for reading at the end of grade 1. For each dyslexic child we also selected a participant who was attending the same grade, was close in age, and showed typical reading development when tested with a narrative passage reading task (Cornoldi, Colpo, & Gruppo MT, 1981) for correctness and reading speed. Children in this group are "same grade controls." We used a reading task consisting of 40 three syllables words. A qualitative and quantitative method of coding children's naming allowed us to distinguish several components of their reading performance: the grapheme and word recognition, the size of orthographic units involved in the aloud orthography–phonology conversion, the reading process used to recognize words. The comparison of the dyslexic group with the reading age and the same grade control groups reveals different trends of delayed reading processes. Considering dyslexic children's chronological age, lexical reading is greatly delayed. Considering dyslexic children's reading age, the type of reading process that is more deeply delayed is phonological reading. The rate of fragmented phonological reading (i.e., a type of syllabized phonological reading) is much higher in dyslexic children compared to

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the reading age group, suggesting that some factors undermine the possibility of internalizing the orthography–phonology conversion and the blending processes.

Keywords Developmental dyslexia · Development of phonological and lexical reading

Introduction

It is widely acknowledged that the ability to acquire and use grapheme–phoneme correspondences provides the foundation for reading. The acquisition of grapheme–phoneme correspondences, however, is not the whole story of learning to read alphabetic orthographies. First, there is an initial stage of phonological reading in which children tend to deploy a grapheme-by-grapheme conversion and have difficulties in blending phonemes and accessing phonological word forms in the lexicon (Job, Peressotti, & Mulatti, 2005; Orsolini, Fanari, Tosi, De Nigris, & Carrieri, 2006). Second, there is evidence that children learning regular orthographies are more likely, after an initial stage, to parse the string into units wider than the single grapheme (Burani, Marcolini & Stella, 2002; Goswami, Gombert & Fraca de Barrera,1998; Sprenger-Charolles & Siegel, 1997). Third, at some stage of their reading development children show the whole word recognition typical of lexical reading (Frith, 1985).

As Nation and Snowling (2004) emphasize, to become fluent readers children need to acquire a word recognition system. When children start to acquire orthographic memories of words they can deploy lexical reading for such words: The string pronunciation can be derived contacting the mental lexicon and retrieving a word's phonological representation. In this way pronunciations are not constructed through blending phonemes, as in phonological reading, and reading can be quicker and more fluent.

We do not have a detailed model of how a word recognition system develops in children and we do not yet know how the development of different reading processes is interrelated. Is the development of a word recognition system dependent on the effectiveness of phonological reading?

Share (1995) assumes that lexical reading is an item-based process that develops as a function of repeated phonological recoding of the same string. According to the self-teaching hypothesis (Share, 1995) each successful decoding of an unfamiliar word provides an opportunity to acquire the word-specific orthographic information that is then represented as a new entry in the orthographic lexicon (Cunningham, Perry, Stanovich, & Share, 2002; Kyte & Johnson, 2006). Exploring such hypothesis in a recent longitudinal study with Italian children (Orsolini et al., 2006) we found evidence that lexical reading is dependent on the acquisition of an advanced type of phonological reading in which the grapheme-phoneme conversion process is internalized and where whole strings are named without previous aloud decoding of small sublexical orthographic units. We observed that such type of phonological reading was prevailing at the end of grade 1. By the end of grade 2, lexical reading prevailed on phonological recoding in the large majority of children. Exploring the reading development profiles of children who became high or low in lexical reading at the end of grade 2, we found that low lexical readers had been either less correct on recognizing graphemes or less likely to use an advanced phonological recoding at the end of grade 1. In sum, effective use of grapheme-phoneme correspondences and internalization of the grapheme-phoneme conversion process at the end of grade 1 were powerful predictors of lexical reading at the end of grade 2.

In this study, we address the issue of whether a phonological reading impairment—the type of impairment one can observe in children with dyslexia—prevents children from developing and using lexical reading. This issue is particularly relevant for dyslexic children learning transparent orthographies as Italian. In a typical Italian educational context, children are not trained to whole string-word form correspondences. For Italian non dyslexic children, lexical reading seems to be a "natural" development of phonological reading, a development based on the relative speed of the orthography–phonology conversion and the blending process on one hand and on the relative frequency of exposure to specific orthographic and lexical patterns on the other hand. Do these same "unsupervised" learning conditions allow dyslexic children to acquire lexical reading?

Let us shortly overview evidence on the type of reading impairment shown by dyslexic children who learn to read highly regular alphabetic orthographies.

The phenotypic profile of developmental dyslexia in irregular orthographies such as English is characterized by impaired acquisition of grapheme-phoneme correspondences, low word recognition, and impaired ability to pronounce non-words (Rack, Snowling, & Olson, 1992). Consistently with this profile, it has been stated that "the classic developmental dyslexic fails to make the transition to the alphabetic phase of literacy development" (Snowling, 2001; p. 11). Although subgroups of dyslexic children have been identified, according to whether non-words or exception words are relatively more impaired (Castles & Coltheart, 1993; Manis, Seidenberg, Doi, McBride-Chang, & Peterson, 1996; McDougall, Borowsky, MacKinnon, & Hymel, 2005), the core characteristic of English dyslexia is phonological reading impairment (Snowling, 2000).

Dyslexic children who learn to read highly regular alphabetic orthographies such as German or Italian are relatively less impaired than English children in word recognition and non-word reading. Landerl, Wimmer, and Frith (1997) in comparing English and German 11-year-old dyslexic children found that long words such as *character* or *paradise* were exceedingly difficult for English dyslexics whereas similar long words could be read with few errors by German dyslexics. Word recognition was less affected by word frequency in German dyslexics and non-words reading was also more correct. Although it is clear that dyslexics learning regular, transparent alphabetic orthographies show an higher performance than English dyslexics in several types of reading tasks, a non-word reading deficit has been found in German (Ziegler, Perry, Ma-Wyatt, Ladner, & Schulte-Körne, 2003), Greek (Porpodas, 1999), French (Sprenger-Charolles, Colé, Lacert, & Serniclaes, 2000), Spanish (Gonzalez & Hernàndez Valle, 2000) and Italian (Chilosi et al., 2003; Facoetti et al., 2006; Paulesu et al., 2001) individuals with dyslexia. Ziegler et al. (2003) showed that with regard to reading speed a non-word reading deficit persists even when dyslexics are compared to much younger children.

Exceedingly slow and effortful phonological reading has been shown by Italian and German studies analyzing eye movement patterns. For text, word and non-word reading Italian children with dyslexia deploy a highly fractionated visual scanning with a prevalence of small amplitude saccades that dramatically increase as a function of the string length (De Luca, Di Pace, Judica, Spinelli, & Zoccolotti, 1999; De Luca, Borrelli, Judica, Spinelli, & Zoccolotti, 2002). Similar findings emerge from Hutzler and Wimmer (2004) observing 13-year-old German dyslexic children.

Slowness and lack of fluency in Italian dyslexics have been documented also by studies analyzing vocal reaction times. Spinelli et al. (2005) examined vocal reaction times in naming words of increasing length and found that latency of the onset of pronunciation was much higher and more dependent on word length in individuals with dyslexia than in children with typical reading development.

Ziegler et al. (2003) hypothesizes that dyslexic children deploy a serial, letter-by-letter type of phonological reading which slows down their reading process and generates great sensitivity to word length. Such hypothesis, however, does not seem to account for the patterns of reading effects that can be found with dyslexic children in a relatively advanced phase of reading development. Barca, Burani, Di Filippo, and Zoccolotti (2006) analyzed word frequency and grapheme contextuality effects on a group of Italian dyslexic children aged 11–12. They found that the pattern of reading effects was similar for dyslexics and typical developing controls. A great word frequency effect on vocal reaction times suggested that lexical reading was deployed with high frequency words whereas a grapheme contextuality effect (better performance in reading words with simple graphemes than words with context-sensitive graphemes) was restricted to low frequency words and suggested that phonological decoding was used with low frequency words.

In summary, dyslexic children who learn to read highly regular alphabetic orthographies such as German or Italian are more correct than English dyslexic children in word recognition and non-word reading but still are characterized by a non fluent reading. It is an open question, however, whether relatively slow reading stems from lack of lexical reading (Barca et al., 2006) or whether is an outcome of general slowness in the processing mechanisms involved with both phonological and lexical reading (e.g., visual recognition of letters).

In this study, we explore acquisition of phonological and lexical reading in a group of Italian dyslexic children whose reading age is end of grade 1. If, as hypothesized by Share (1995) and Share and Shalev (2004), lexical reading is an item-based process that develops as a function of repeated and correct phonological recodings of the same string, we should be able to predict that phonological and lexical reading are intertwined developments. The less correct children are in phonological reading, the smaller their word recognition system should be. Considering the findings from our longitudinal study on typically developing children (Orsolini et al., 2006) we should also predict that the more fragmented children are in their phonological reading, the smaller their word recognition system should be.

First, we will investigate whether in our group of dyslexic children the reading process most likely to be used is phonological reading, as we should predict from the children's reading age. We will then ask whether the relative proportion of words that are recognized through lexical reading shows individual variability and whether such variability can be predicted from correctness and lack of fragmentation of phonological reading.

Method

Participants

We selected a group of 14 children aged from 7.07 to 10.05 (mean age 8;11) who had been referred by either the "Synapsy" rehabilitation centre in Rome or the Complex Operative Unit of Developmental Neuropsychiatry in Viterbo. In order to be selected, children had to show performance lower than 1.5 standard deviation with respect to normative data both on a task in which participants are asked to read aloud a narrative passage (Cornoldi et al., 1981) and on one task in which isolated words or non-words are to be named (Sartori, Job, & Tressoldi, 1995). Moreover the exclusionary criteria relevant to a diagnosis of dyslexia were applied: IQ within normal limits, absence of emotional disorders, absence of comorbility with other developmental disorders (e.g., attention deficit). All participants in the dyslexic group performed within normal limits (standard scores of 85 or more) on the WISC-R (Wechsler, 1974) and are Italian native speakers.

In the narrative passage reading task (Cornoldi et al., 1981) children are scored for correctness (number of errors, adjusted for the amount of text read) and reading speed (syllables per second). Although the children read a narrative passage specific for each grade we were able to assess children's reading age considering a recent data base (see www.airipa.it) in which each different narrative text had correctness and reading speed norms for children of different grades (starting from grade 2).We considered that each dyslexic participant who was at least 1.5 standard deviations below the mean of typically developing children attending grade 2 in reading speed or correctness had a reading age comparable to that of end of grade 1 (grade 1 norms are not available in this data base). As shown in Table 1 all children are at least 1.5 standard deviations below the mean of grade 2 typical children in either reading speed or correctness. There is one child (Gi., grade 5) who is within normal limits for reading speed but who is much below the mean of grade 2 typical children in correctness. Conversely, there are two children (Al. and Lu. grade 3) showing the opposite pattern: within the normal limits for correctness but below the mean for reading speed.

Dyslexic children were also tested for isolated word and non-word naming using the subtests 4 and 5 from the Developmental Dyslexia and Dysorthography Battery (Sartori et al., 1995). As shown in Table 2, each child is below the chronological age norms in either word and non-word reading correctness or reading speed.

We compared this group of children with dyslexia to a group of 70 typically developing children who have been tested for reading at the end of grade 1. This group—recruited in a school district in a lower-to-middle class neighbourhood in Rome—has a mean age of 6;9 (range 6;6–7;3). Children in this group have been selected on the basis of being native speakers of Italian. We used such group to derive normative data for our experimental reading task (see below). As for genuine "normative" groups, children have not been selected because their reading was

Table 1 Correctness and Speed in narrative text reading: dyslexic children compared to chronological age norms and grade 2 typically developing children

	Correctness			Reading Speed		
	Number of incorrect words without self-correction	Standard scores using the norms of chronological age typically developing children	Standard scores using the norms of grade 2 typically developing children	Number of syllable per second	Standard scores using the norms of chronological age typically developing children	Standard scores using the norms of grade 2 typically developing children
Ad. 2nd grade	8	3.33	3.32	.54	−3.43	−3.13
Am. 2nd grade	8	2.48	2.48	1.56	−1.76	−1.76
Fl. 2nd grade	11	4.97	4.97	1.51	−1.61	−1.61
Fr. 2nd grade	12	5.52	5.52	.71	−3.03	−3.03
Ma. 2nd grade	22	8.75	8.75	.65	−3.30	−3.30
Al. 3rd grade	9	1.67	.17	1.15	−2.58	−2.00
Lc.3rd grade	17	6.10	4.89	1.36	−2.05	−1.53
Lu. 3rd grade	14	4.43	.74	1.44	−2.25	−1.58
GiP. 4th grade	24	9.69	7.80	.64	−3.46	−2.80
Ric. 4th grade	29	11.95	9.73	.79	−3.29	−2.56
Gi. 5th grade	9	2.06	1.82	1.91	−1.82	−.40
MaA. 5th grade	27	9.57	10.16	.88	−3.03	−2.39
Tam. 5th grade	25	8.79	9.29	.83	−3.08	−2.45
Val. 5th grade	20	6.73	6.25	.89	−3.13	−2.39

Table 2 Standard scores for isolated word and non-word reading in children with dyslexia (using chronological age norms)

	Words		Non-words	
	Correctness	Reading speed	Correctness	Reading speed
Ad. 2nd grade	−5.7	−11.6	−3.4	−6.9
Am. 2nd grade	−.1	−.7	−4.8	−.2
Fl. 2nd grade	−.4	−1.8	−1.28	−.3
Ma. 2nd grade	−4.7	−5.3	−3.5	−6.7
Fr. 2nd grade	−2.7	−3.0	−3.5	−3.2
Al. 3rd grade	−1.6	−6.3	−3.4	−3.0
Lc. 3rd grade	−8.0	−3.0	−4.1	−4.2
Lu. 3rd grade	−.2	−3.1	.0	−1.3
GiP. 4th grade	−6.2	−8.3	−2.0	−4.4
Ric. 4th grade	−8.4	−9.9	−1.7	−2.8
Gi. 5th grade	−2.7	−2.1	−2.6	−5.0
MaA. 5th grade	−5.8	−5.6	−3.1	−7.2
Tam. 5th grade	−4.6	−6.4	−3.6	−5.4
Val. 5th grade	−5.2	−4.0	−2.6	−5.1

normal, but for being representative of a population of end of grade 1 Italian children. We will refer to this group as either "reading age group" or "typically developing grade 1 children." With the latter phrase we mean that the norms drawn from such group can be considered typical of children who have received one year of formal instruction to reading. We should remind that in Italy a formal systematic instruction to reading starts in grade 1.

For each dyslexic child we also selected a participant who was attending the same grade, was close in age, was Italian native speaker, and showed typical reading development when tested with a narrative passage reading task (Cornoldi et al., 1981) for correctness and reading speed. Children in this group are aged from 7.05 to 10.08 (mean age 8;9). Each child in this group had a performance in reading correctness and speed above or close to the mean of her/his grade. The mean number of syllables per seconds was 3.8 (SD = 1.07) in this group whereas it was 1.1 (SD = .06) in the dyslexic group. We will refer to children in this group as "same grade controls".

The reading age and the same grade control groups are from a lower-to-middle class neighbourhood in Rome. Children of the dyslexic group are from middle class. We will compare the group of dyslexic children to the reading age group in each analysis that will be focused on correctness. We will compare the group of dyslexic children to both the reading age and the same grade control groups when the analysis will be focused on the reading process involved with recognized words irrespective of the absolute number of target words recognized by the participant.

The reading list

We used a list of 40 three syllables words for our task (see Appendix A). Half of the items had a typical stress pattern (stress on the penultimate syllable), whereas the other half had an atypical pattern (stress on the antepenultimate syllable, as in *t'avolo*, table). In fact, words with three or more syllables in Italian are mostly stressed on the penultimate syllable. Words with stress on the last but two syllables can be pronounced with a correct prosody only by using lexical look up. We used a list in which words have typical and atypical stress assignment to analyse whether children can deploy lexical reading (see below).

In the list there were high and low frequency nouns (frequency norms were drawn from Marconi, Ott, Pesenti, Ratti, & Tavella, 1993). The 40 nouns were matched in terms of mean bigram frequency, age of acquisition, familiarity, imageability, concreteness and orthographic neighbourhood (see Appendix A for details). Each word—printed in small letters—was displayed in a vertical list on a sheet of paper and shown to the child separately by covering the following ones. Children were instructed to read aloud as accurately as possible. Whenever the word had been somehow segmented, and the child had not spontaneously blended the phonological units, the experimenter asked, "Then what word was written there?" in this way, we could assess whether the reading process had lead the child to recognize the target word form or not.

The reading sessions were audio-recorded and fully transcribed. We transcribed every pronunciation attempt for each target, and marked the phonetic content and the segmentation of the child's pronunciation. The adult testing the children recorded on a coding sheet whether the child's pronunciation had come after a covert segmentation perceivable from the child's whispering or visible from her/his labial movements.

Coding grapheme recognition and units involved in the orthography–phonology conversion

Each transcript was coded with the method described as follows (examples of codes are provided in Orsolini et al., 2006).

We computed the number of graphemes that were correctly recognized. Double letters, as TT in GATTO (cat) were counted as 1 grapheme. The bigrams CH, SC, GL were counted as 1 grapheme. A correct grapheme-phoneme mapping that was afterwards wrongly assembled was still coded as correct. When the child pronounced a non-target form (word or non-word) we computed the number of graphemes shared by the target string and the non-target form. The number of recognized graphemes is a measure of the child's skill of recognizing the phonetic content of letters in a string, regardless of the sequence in which graphemes occur.

We identified the units involved in the aloud orthography–phonology conversion. For each string that was not immediately pronounced as whole word we computed the number of correct part-of-string/part-of-word mappings (e.g., [skar] [pa], 2 parts from the same string) or one grapheme-one-phoneme mappings (e.g., [s] [k] [a] [r] [p] [a], 6 graphemic units) produced by the child. When the child produced a self-correction we computed the latest unit produced by the child and disregarded the previous one. These analyses provide a measure of the child's tendency to fragment the orthography–phonology conversion process.

Word recognition

For each transcription we computed the number of recognized words. Whenever the child pronounced the string fluently we coded that pronunciation in terms of word recognition. When the child initially segmented the string and then spontaneously blended the phonological units, we coded blending in terms of word recognition. When the child segmented the string and did not spontaneously blend, the experimenter asked, "Then what word was written there?"; and we coded the child's answer to this question in terms of word recognition. Word recognition responses consisted of target word, non-target word, and non-word.

Coding the reading process involved with recognized words

For each recognized target word we analyzed the reading process using the categories as follows.

Fragmented phonological reading is characterized by aloud conversion of sublexical units consisting of either one-grapheme/one-phoneme mapping or part of string/part of word mappings. For instance the target word STAGIONE (season) has been pronounced as [ss][sa][i][o][ne] or [sta] [stagione]. In both cases the child has recognized the target word either spontaneously or after the adult's question, "Then what word was written here?", in both cases, the child's reading performance is coded as fragmented phonological reading.

In *advanced phonological reading* the strings are named aloud as whole word forms with no previous aloud conversion of small orthographic units but there are indicators that the child deploys either an internal conversion of sublexical orthographic units or an internal blending. In some cases there is a covert segmentation (detectable from the lips movements) that precedes naming the whole string aloud. In other cases this covert phonological conversion is absent, but the child still produces some hesitation in between syllables, suggesting that there is an internal blending which is paralleling in time the aloud pronunciation. In other cases, an atypically stressed word is pronounced with a regularized stress (e.g., [t'avolo] pronounced as [tav'olo]) showing that the word form is assembled rather than retrieved in the mental lexicon with its associated prosodic template. The difference between fragmented and advanced phonological reading is that the conversion of sublexical orthographic units and the blending process are internalized.

Lexical reading. An important variable that reveals lexical involvement in Italian reading is stress assignment. Italian words with three or more syllables differ in terms of stress assignment and in the majority of cases orthography does not mark the word's stress. A large proportion of polysyllabic words are stressed on the penultimate syllable (as in tes'oro, treasure) whereas in a minority of cases, the stress falls on the antepenultimate syllable, (as in t'avolo, table). The only way of assigning stress to such words is lexical look up.

Using on-line reading tasks where words have either typical (stress on the penultimate syllable) or atypical (stress on the antepenultimate syllable) stress assignment, frequency (Colombo, 1992), semantic priming (Colombo & Tabossi, 1992; Tabossi & Laghi, 1992) and orthographic neighbourhood effects (Burani & Arduino, 2004) emerge. Such effects all show an involvement of lexical representations in naming words from a list where there is both typical and atypical stress assignment.

In this study, we coded as lexical reading the child's fluent naming responses in which the whole string is mapped into a word form with a fluent prosody and no previous aloud or covert segmentation of sublexical units. We considered the child's correct and fluent prosody as a marker of accessing (rather than assembling) a phonological form in the lexicon. Such assumption was confirmed by the observation that lexical reading responses are more likely to occur with high frequency words in typically developing Italian children attending both grade 1 and 2 (Orsolini, Fanari, Famiglietti, & Maronato, submitted) whereas fragmented and advanced phonological reading are more likely to occur with low frequency words.

Inter-rater reliability

We computed the agreement percentage between two raters on 20 subjects randomly selected from a pool of 140 grade 1 and grade 2 children. First we compared the transcription of the audio-recordings and computed a Pearson product-moment correlation on the interscore agreement on number of correctly recognized graphemes ($r = .97$; $p < .0001$), number of correct "one grapheme-one-phoneme" mappings ($r = .92$; $p < .0001$), number of correct "part-of-string/part-of-word" mappings ($r = .99$; $p < .0001$). Second, each rater checked—starting from their own transcription—one of seven possible codes: the target word was recognized through (i) fragmented phonological reading; (ii) advanced phonological reading; (iii) lexical reading; (iv) other non classified processes; the target word was not recognized and was pronounced as (v) a non target word (vi) a non-word (vii) a word with regularised stress assignment. We computed the Cohen kappa over these seven codes (mutually exclusive and exhaustive) obtaining kappa = .85 (kappa was computed using the ComKappa software; see Robinson & Bakeman, 1998).

Results

Grapheme and word recognition

We computed the percentage of recognized graphemes and words and the standard scores for each participant using the mean and standard deviation of our group of 70 typically developing Italian children in grade 1. As shown in Table 3, the large majority of children with dyslexia had a much lower performance compared to that of typical children of the same reading age. We ran a one-way ANOVA with group as a between participants factor (dyslexic children versus grade 1 typical children) and percentage of correctly recognized graphemes as the dependent variable. There was a main effect of group ($F(1) = 13.64$, $p < .0003$, MSE = .004).

Table 3 Grapheme and word recognition: dyslexic children compared to grade 1 typically developing children (standard scores)

	Standard scores of recognized graphemes	Standard scores of recognized words
Ad. 2nd grade	−.87	−1.32
Am. 2nd grade	−1.66	−1.55
Fl. 2nd grade	−.87	−1.32
Fr. 2nd grade	−.48	−.41
Ma. 2nd grade	−.68	−1.55
Al. 3rd grade	−2.05	−1.09
Lc. 3rd grade	.50	.73
Lu. 3rd grade	.30	−.64
GiP. 4th grade	−3.41	−2.68
Ric. 4th grade	−1.26	−2.23
Gi. 5th grade	.30	.95
MaA. 5th grade	−.68	.27
Tam. 5th grade	−3.41	−2.00
Val. 5th grade	−3.21	−1.09

We should note that graphemes recognition reaches a ceiling effect at the end of first grade for typically developing Italian readers (M = 99%; standard deviation = 2%). Despite the fact that the percentage of recognized graphemes is high in absolute terms (M = 97%) in the group with dyslexia, each dyslexic child showed occasional errors and self-corrections in decoding graphemes and for some children the process of recognizing graphemes was particularly effortful and attention demanding. Only three out of fourteen children with dyslexia show reading age expected level for grapheme recognition (see Table 3).

As for word recognition, we ran a second one-way ANOVA in which the percentage of correctly recognized words was the dependent variable. There was again a main effect of group ($F(1) = 12.45$, $p < .0006$, MSE = .145). As shown in Table 3, even dyslexic children at grade 4 or 5 had a much lower performance than children who were at the end of first grade. Only four out of fourteen children with dyslexia show reading age expected level for word recognition. We should emphasize that dyslexic children's reading age was estimated according to the reading of a narrative text. Compared to the reading age group, our dyslexic children appeared to have more difficulties in a test consisting of isolated three syllables words.

Orthographic units involved in the aloud orthography–phonology conversion process

In this section we investigate whether dyslexic children deploy an initial type of phonological reading that is characterized by a grapheme-by-grapheme decoding. We analysed for each participant the number of correct one-grapheme-one-phoneme mappings (e.g., [s] [k] [a] [r] [p] [a]) or part-of-string/part-of-word mappings (e.g., [skar] [pa] for the target SCARPA, shoe) and for each type of unit computed the percentage over the total number of graphemes in the reading test. We ran a two

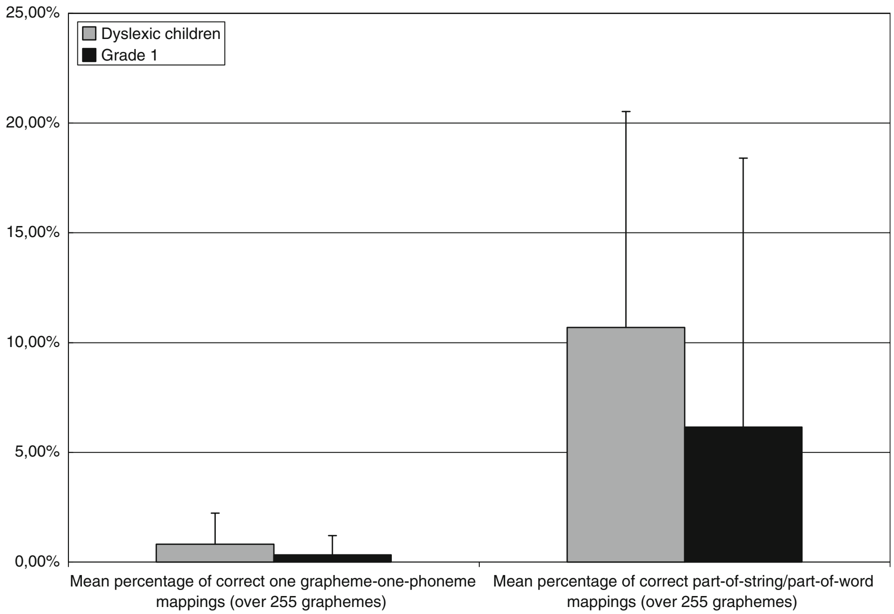

Fig. 1 Percentage of correct one-grapheme/one phoneme and part-of-string/part-of-word mappings in the aloud orthography–phonology conversion

way repeated measures ANOVA (group × type of orthographic unit) using the percentage of correct units as the dependent variable, with group (dyslexic children versus grade 1 typically developing children) as a between participants factor and type of unit (single graphemes vs. part of string) as within-participants factors. The main effect of group was not statistical significant whereas there was a statistical significant effect of type of unit ($F(1, 82) = 22.95$, $p < .00001$. MSE = .143). There was not any statistically significant interaction effect. For both dyslexic and typically developing children one grapheme-one-phoneme mappings are very rare whereas part-of-string/part-of-word mappings occur more frequently. In a nutshell, both dyslexic and grade 1 children occasionally tend to syllabize. However, this tendency shows high individual variability in both groups, as shown in Fig. 1.

The reading process involved with recognized words

We computed for each participant the percentage of target words that were recognized through *fragmented phonological reading* (the child first deploys an aloud conversion of sublexical units and then pronounces the whole word), *advanced phonological reading* (the segmentation and the blending process are internalized) and *lexical reading* (the whole string is mapped into a word form with a fluent prosody from the very beginning and there is not a previous phase of aloud or covert segmentation of sublexical units). Percentages were computed over the total number of target words recognized by each participant. This way we could assess to what extent the child's decoding relies on less mature (fragmented

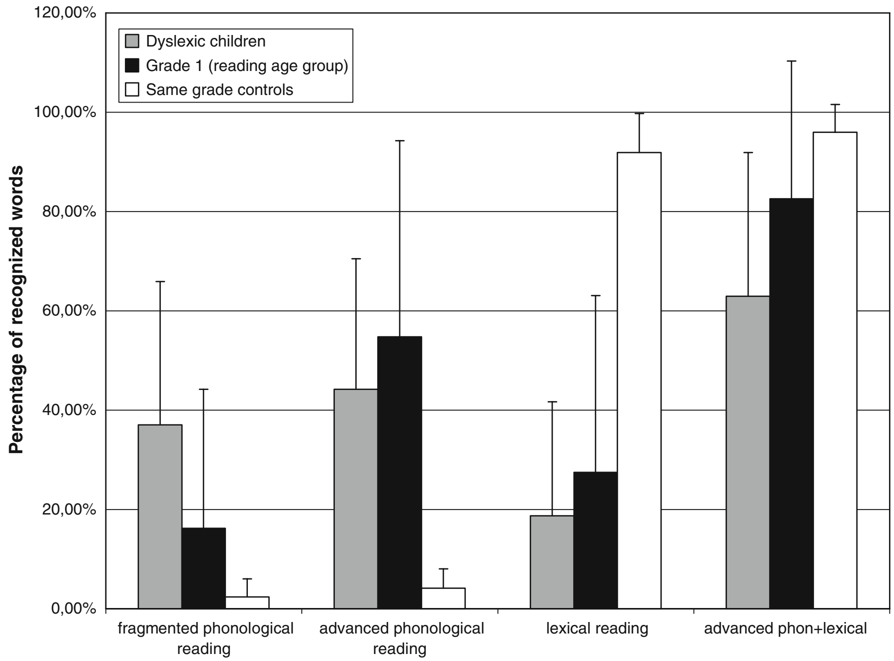

Fig. 2 Percentage of words recognized through fragmented, phonological and lexical reading in children with dyslexia, typically developing grade 1 children and same grade controls

phonological reading) versus more expert (advanced phonological or lexical reading) processes irrespective of the overall child's level of correctness.

We plotted the three types of reading strategy used by dyslexics, typically developing grade 1 children, and "same grade" controls on Fig. 2. Focusing on grade 1 children, we should first note that an advanced type of phonological reading in which the segmentation and the blending processes are internalized is the typical reading process and at this age is the measure in which intragroup variability is lower. On the contrary, the tendency to syllabize some parts of the string shows high individual variability in this group: there are only 19 children (27%) who deploy a fragmented type of phonological reading for not less than 5 words of the list. Lexical reading also shows high individual variability in this group: 30% of the children never deployed lexical reading and 35% used lexical reading for not less than 8 words of our list. Focusing on the same grade control group we observe a remarkable difference with grade 1 children: Lexical reading is deployed for 92% of the words in the list and is the measure in which intragroup variability is lower. Lexical reading is deployed for 100% of the words by 8 participants, for 90% of the words by 4 participants, and 85% by 2 participants in this group.

It is quite clear from Fig. 2 that the group of children with dyslexia is more similar to grade 1 typically developing children than to same grade controls. An advanced type of phonological reading is the most frequently deployed process in the group with dyslexia and is the measure in which intragroup variability is lower. A fragmented phonological reading, however, is more likely in this group than in grade 1 typically developing children. There are 10 participants (71%) out of 14 who deploy fragmented phonological reading for not less than 5 words of the list.

The percentage of words that are recognized through lexical reading shows high individual variability in the group with dyslexia. Six children (43%) never deployed lexical reading and only four children (28%) used lexical reading for not less than 8 words.

We collapsed into a fourth category the two processes typical of a more mature reading development, that is advanced phonological and lexical reading. In this way we could use a measure (advanced phonological summed up to lexical reading) whose distribution approaches normality. We ran a one-way ANOVA with group (dyslexic children versus grade 1 typically developing children vs. same grade controls) as a between participants factor and percentage of words that were recognized through the two more mature reading processes (lexical reading summed up to advanced phonological), as dependent variable. The main effect of group was statistically significant ($F(2) = 5.79$, $p < .004$. MSE = .39). A post-hoc Duncan test shows that there is a statistically significant difference between the dyslexic group on one hand, and the grade 1 typically developing children ($p < .02$) and the same grade controls ($p < .0002$). The difference between grade 1 typically developing children and same grade controls was not statistically significant. The two groups, as we can see from Fig. 2, differ in terms of the relative proportion of lexical reading, but do not differ in a statistically significant way in terms of occurrence of fragmented phonological reading (i.e., the less mature reading process). The more mature reading processes (i.e., advanced phonological and lexical reading) occurred with a similar frequency in both groups.

Thus, a fragmented type of phonological reading occurred in the group of dyslexic children more often than we should have expected according to their reading age.

Individual variability in reading development

Lexical reading does occur in our group of dyslexic children and shows the high intragroup variability that is also typical of grade 1 non dyslexic children as well. We analyzed such variability in more depth asking whether children who are less likely to develop and use lexical reading are more likely to syllabize and less likely to recognize graphemes. We computed linear Pearson correlations between the percentage of recognized graphemes (over the total graphemes of the list), the percentage of correct part-of-string/part-of-word mappings produced by each child (over the total graphemes of the list) and the percentage of target words that were recognized through *lexical reading*. We can observe in Table 4 that both in the dyslexic group and grade 1 typical children there is a negative statistically significant relationship between lexical reading on one hand and the percentage of correct part-of-string/part-of-word mappings produced by each child on the other. In other words, children who are less likely to deploy lexical reading are more likely to name aloud fragments of the string. The more children tend to syllabize words the less they deploy lexical reading. The correlation between the number of recognized graphemes and the percentage of target words that were recognized through lexical reading is statistically significant only in the grade 1 typical children group.

Table 4 Correlation between percentage of target words recognized through lexical reading, percentage of recognized graphemes and percentage of correct part-of-string/part-of-word mappings in the dyslexic group and grade 1 typically developing children

	Correlation between percentage of words recognized through lexical reading and percentage of recognized graphemes	Correlation between percentage of words recognized through lexical reading and percentage of correct part-of-string/part-of-word mappings
Group of dyslexic children (N = 14)	.48 ($p < .07$)	−.61 ($p < .03$)
Group of grade 1 typically developing children (N = 70)	.36 ($p < .001$)	−.25 ($p < .03$)

We analyzed in more depth individual variability within the dyslexic group asking whether children who were more likely to deploy a fragmented type of phonological reading had a more severe reading delay. For each child with dyslexia we identified whether the percentage of words recognized through a fragmented phonological reading was high or low compared to the target words that were recognized through more mature processes (i.e., advanced phonological and lexical reading). Using this criterion, we coded children as belonging to two subgroups, with percentages of words recognized through fragmented phonological reading ranging from 50%–100% (subgroup 1 consisting of 6 participants) to 3%–30.5% (subgroup 2 consisting of 8 participants). We analysed which combination of reading measures could predict children belonging to either subgroup. We considered the percentage of correctly recognized graphemes and words drawn from our test, and the standard scores in word and non-word reading derived from the Italian test that was used to assess reading impairment (Sartori et al., 1995). Age expected norms from this test were used to compute standard scores; correctness and speed standard scores were summed up in order to have, for each participant, two measures assessing word and non-word reading respectively. Each of these four measures (i.e., correctly recognized graphemes and words drawn from our test, sum of correctness and speed standard scores for word and non-word reading respectively) were entered into a stepwise forward discriminant function analysis (see Appendix B). In such exploratory statistical analysis, a model is built step-by-step evaluating which variable will contribute most to the discrimination between groups. The discriminant function was statistically significant ($F(3, 10) = 12.88$ $p < .0009$) and accounted for 80% of the deviance between the two subgroups (Lambda-Wilks = .205). Three variables entered the model: recognized graphemes and words drawn from our test, and the standard scores in word reading derived from the Italian test that was used to assess reading impairment (Sartori et al., 1995). Each of these variables has a high standardized beta weight (see Appendix B) and contribute to predict the participants belonging to subgroups 1 or 2. The discriminant function model allowed 93% of post-hoc correct classification of children in the two subgroups. Only one participant was miscategorized (from subgroup 1 to subgroup 2).

Thus individual variability in fragmented phonological reading is largely explained by the severity of the child's reading delay and the difficulty in recognizing graphemes and words. Dyslexic children with a more severe reading delay are more likely to deploy fragmented phonological reading.

Discussion

In this study, we compared a group of Italian children with dyslexia to a reading age and a "same grade" control groups using a reading task consisting of 40 three syllable words that were high and low in frequency and had typical and atypical stress assignment.

A qualitative and quantitative method of coding children's naming allowed us to distinguish several components of the reading performance: the grapheme and word recognition, the size of orthographic units involved in the aloud orthography–phonology conversion, the reading process used to recognize words.

We identified three types of reading process that are less or more developed in terms of synchronizing the orthography–phonology conversion procedure and the word naming phase. In fragmented phonological reading the two phases are clearly separated: first, the phonological units of the target string are identified and pronounced; second, phonological units are blended and a whole word is named. In advanced phonological reading, there is only one overt naming phase, the orthography–phonology conversion and the blending processes are internalized but there are signals (e.g., silent lips movements) that the child first engages in grapheme-phoneme decoding and then pronounces a word form. In lexical reading, a whole string is mapped into a word form with a fluent prosody from the very beginning, the orthography–phonology mapping is quick and almost synchronized with the naming response. In a list of Italian three syllables words whose stress assignment can be correctly produced only accessing word forms in the lexicon, such type of fluent and prosodically correct reading responses do suggest that lexical reading is involved. In lexical reading word phonological forms are retrieved in the mental lexicon rather than constructed through a blending process as in phonological reading.

We found that in the reading age group of 70 grade 1 typically developing children lexical reading showed high individual variability. About 30% of children in this group never deployed lexical reading whereas about 35% used lexical reading for not less than 8 words of the list. The proportion of dyslexic children who never deployed lexical reading was higher (six out of 14 children, that is 43%) but there were 4 dyslexic children (28%) using lexical reading for not less than 8 words. Differences between the dyslexic group and the reading age group were more striking as far as fragmented phonological reading is concerned. Out of 14 dyslexic children there were 10 participants (71%) who deployed fragmented phonological reading for not less than 5 words of the list. In the reading age group the percentage of children who deployed fragmented phonological reading for not less than 5 words was much lower (27%).

Focusing on same grade controls (i.e., typically developing children from the same grade and close in age to dyslexic children), we found that in this group lexical reading was deployed for a mean of 92% of the words in the list and was the measure with the lowest intragroup variability.

The comparison of the dyslexic group with the reading age and the same grade control groups reveals different trends of delayed reading processes. Considering dyslexic children's chronological age, lexical reading appears greatly delayed. Considering dyslexic children's reading age, the type of reading process that is more deeply delayed is phonological reading. The rate of fragmented phonological reading is much higher in dyslexic children compared to the reading age group, suggesting that some factors undermine the possibility of internalizing the orthography–phonology conversion and the blending processes. Thus both phonological and lexical reading are delayed in Italian dyslexic children, but phonological reading is the most delayed.

We found that the proportion of fragmented phonological reading could be predicted from the severity of the child's reading delay. Dyslexic children who were lower in grapheme and word recognition in our reading task, and were particularly incorrect and slow when they had been assessed for word recognition (Sartori et al., 1995), were more likely to deploy a fragmented, syllabized type of phonological reading. The factors underlying this relationship between severity of the reading delay and tendency to fragmentation in phonological reading remain to be investigated. Children might use fragmented phonological reading because their access to grapheme–phoneme correspondences is very slow and cannot occur in parallel with blending. Children might also use fragmentation as a strategy to improve short-term phonological memory of decoded phonemes, or to enhance grapheme recognition by focusing visual attention on component parts of the string.

Despite the fact that lexical reading was greatly delayed compared to children of the same age, we did find that some children with dyslexia occasionally used lexical reading and that variability in lexical reading could be largely explained by the rate of fragmented phonological reading: children who were more likely to name aloud sublexical parts of the string were less likely to deploy lexical reading. This relationship—observed in both the dyslexic and the grade 1 typically developing groups—confirms what we have found in a longitudinal study with typically developing children (Orsolini et al., 2006). Building orthographic memories of words is dependent on an advanced type of phonological recoding in which the grapheme-phoneme conversion process is internalized. Pronouncing a whole string without long delay from processing its component parts is likely to be a condition for memorizing a link between a sequence of graphemes and a "whole" phonological form. In general, our findings show that the child's level of phonological reading development is highly correlated to the rate of words that are recognized through lexical reading.

If dyslexic children are impaired in phonological reading and, as we argue in the Introduction section, phonological and lexical reading are intertwined developments, should not children with dyslexia be impaired in lexical reading as well? Let us consider why an impairment in phonological reading may not prevent some dyslexic children from developing lexical reading—though at a rate that is related to the child's tendency to syllabize and to reading age. Some of our dyslexic children have a relatively fluent and correct phonological recoding for some strings. Thus they can develop lexical reading for those strings that more often have been phonologically recoded in a fluent and correct way. This is a realistic hypothesis when we consider the type of phonological reading impairment shown by our Italian children with dyslexia. These children appear to have more difficulties, compared to a reading age group, with both grapheme and word recognition. However dyslexic children's difficulty with grapheme and word recognition did not stem from failure to acquire phonological reading. Our dyslexic children did not use the type of pre- or initial phonological reading that we had observed in some Italian children at the fourth month of grade 1 (Orsolini et al., 2006). A pre-phonological reading is characterized in Italian by a strategy of guessing the word from the phonetic content of few letters (usually the initial one). An initial phonological reading is characterized by a systematic grapheme-by-grapheme conversion along with a failure in blending the sequence of decoded phonemes. The reading process of each dyslexic child in our group was not characterized by such two types of early reading strategies. Dyslexic children deployed an aloud grapheme-phoneme mapping very rarely and when this occurred there was not a failure in blending the decoded phonemes. The basic aspects of phonological reading had been acquired by our children with dyslexia.

To recapitulate, lexical reading is likely to develop for those words that children with dyslexia have learned to phonologically recode in a relatively fluent way. Correct and relatively fluent phonological recoding is likely to occasionally occur when we consider that dyslexic children's problems with grapheme and word recognition are not of an all-or-none nature and do not stem from lack of acquisition of phonological reading. An atypical development of phonological reading does not prevent dyslexic children from developing lexical reading but does modulate the rate at which a word recognition system can increase (Share & Shalev, 2004). Namely, the more children are fragmented in phonological reading the smaller is the number of words they can recognize through lexical reading.

Our analysis of phonological and lexical reading in a group of Italian dyslexic children whose reading age was end of first grade is consistent with findings of other studies on Italian dyslexics (Barca et al., 2006; De Luca et al., 1999; De Luca et al., 2002; Spinelli et al., 2005). First, dyslexic children can acquire and use lexical reading although they do at a rate that is consistent with their level of phonological reading development. Second, fragmentation of phonological reading is a "continuous" characteristic of Italian dyslexia: the longer reading is delayed in terms of grapheme and word recognition the more phonological reading is fragmented.

All the differences we identified between Italian dyslexic children and typically developing children of the same reading age confirm that dyslexia, even in a regular orthography as Italian, is a case of atypical reading development (Snowling, 2000, 2001). What is atypical is the development itself of phonological reading. On one hand, Italian dyslexic children can acquire phonological procedures allowing them to recode orthographic units wider than the single grapheme and recognize a relatively large proportion of three syllable words. On the other hand, their grapheme and word recognition is less effective and their phonological procedure is more likely to be fragmented than that of typical children of the same reading age.

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Appendix A

Our reading list consists of 40 three syllable words and includes 20 high frequency (HF) and 20 low frequency (LF) words. Both the high frequency and low frequency sublists include 10 atypical (AS) and 10 typical (TS) stress assignment words. The range of the words length in letters is 6–8. The four sublists (HF-AS; HF-TS; LF-AS; LF-TS) have been balanced in terms of age of acquisition, familiarity, imageability, concreteness (norms drawn from Barca, Burani, & Arduino, 2002) and orthographic neighbourhood, as shown below (mean and standard deviation).

	Age of acquisition	Familiarity	Imageability	Concreteness	Orthographic neighbourhood
High freq-atypical stress	2.4 (.55)	6.6 (.20)	5.5 (.75)	5.5 (1.23)	.7 (.67)
High freq-typical stress	2.9 (.40)	6.7 (.15)	5.4 (.65)	5.3 (1.41)	.7 (.48)
Low freq-atypical stress	3.7 (.59)	6.2 (.35)	5.2 (.97)	5.7 (.85)	.5 (.71)
Low freq typical stress	3.8 (.68)	5.8 (.36)	5.4 (.97)	5.7 (.96)	.6 (.97)

The word set along with word frequency and bigram frequency is shown below

Typical stress	Word Freq.		Bigram freq.	Atypical stress	Word freq.		Bigram freq.
Canzone (song)	HF	178	10.88	Angolo (corner)	HF	173	10.73
Compagno (mate)	HF	748	10.77	Favola (tale)	HF	72	10.86
Estate (summer)	HF	377	11.33	Macchina (car)	HF	807	10.89
Farina (flour)	HF	88	11.12	Nuvola (cloud)	HF	222	10.14
Natura (nature)	HF	248	10.92	Pagina (page)	HF	139	10.96
Nipote (nephew)	HF	119	10.58	Pecora (sheep)	HF	80	11.22
Parete (wall)	HF	81	11.26	Polvere (dust)	HF	61	10.85
Patata (potato)	HF	66	11.32	Scatola (box)	HF	137	11.24
Stagione (season)	HF	202	11.15	Tavolo (table)	HF	129	10.92
Tappeto (carpet)	HF	71	10.72	Zucchero (sugar)	HF	71	10.02
Carciofo (artichoke)	LF	0	10.53	Brivido (shiver)	LF	17	10.34
Cometa (comet)	LF	9	11.22	Carcere (prison)	LF	9	11.18
Cratere (crater)	LF	7	11.28	Gomito (elbow)	LF	11	10.69
Galera (prison)	LF	15	11.10	Incubo (nightmare)	LF	25	10.17
Imbuto (funnel)	LF	0	10.37	Mandorla (almond)	LF	22	10.96
Menzogna (deceipt)	LF	0	10.38	Sigaro (cigar)	LF	0	10.88
Pomata (ointment)	LF	0	11.18	Sogliola (sole)	LF	0	10.97
Timone (tiller)	LF	0	11.05	Spigolo (edge)	LF	0	10.49
Vagone (carriage)	LF	16	10.75	Vedovo (widower)	LF	0	10.60
Velluto (velvet)	LF	16	10.86	Vipera (viper)	LF	14	10.83

Appendix B

Discriminant function analysis results

Lambda-Wilks: .205; approx. $F(3. 10) = 12.88$; $p < .0009$					
Variables	Lambda	*F*	GDL 1	GDL 2	*p*-level
Word reading (correctness + speed standard scores)	.4136	17.01	1	12	.001
Percentage of recognized words	.3513	10.15	2	11	.003
Percentage of recognized graphemes	.205	12.88	3	10	.0009

Standardized coefficients for canonical variables

Variables	Root 1
Word reading (correctness + speed standard scores)	1.01
Percentage of recognized words	1.31
Percentage of recognized graphemes	−1.33

Classification matrix

Rows: Observed classifications
Columns: Predicted classifications

Group	Percent correct	G_1 $p = .428$	G_2 $p = .571$
G_1	83.33	5	1
G_2	100.00	0	8
Total	92.85	5	9

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