Early reading treatment in children with developmental dyslexia improves both reading and spelling

Anna Judica[1], Maria De Luca[1], Paola Angelelli[2], Donatella Spinelli[1,3], Pierluigi Zoccolotti[1,4]

[1] Neuropsychology Unit, IRCCS Fondazione Santa Lucia, Rome
[2] Department of History, Society and Human Studies, Lab. of Applied Psychology and Intervention, University of Salento, Lecce
[3] Department of Human Movement, Social and Health Sciences, University of Rome "Foro Italico"
[4] Psychology Department, Sapienza University of Rome

ABSTRACT. I disturbi specifici della lettura e scrittura sono i più comuni disturbi di apprendimento e causano frequenti insuccessi scolastici. Lo studio ha lo scopo di verificare l'efficacia di un trattamento del disturbo di lettura in bambini italiani con dislessia che frequentano la terza classe della scuola primaria e la sua possibile generalizzazione alla prestazione di scrittura. Hanno partecipato allo studio 10 bambini con dislessia evolutiva. La prestazione di lettura pre- e post-trattamento è stata valutata mediante due test di lettura standardizzati e la registrazione dei tempi di reazione vocale. La prestazione di scrittura è stata valutata mediante una misurazione pre- e post-trattamento ad un test standardizzato di competenza ortografica. La principale procedura di trattamento consisteva nella presentazione tachistoscopica di parole singole, scelte sulla base delle caratteristiche psicolinguistiche. Ciascun bambino ha effettuato 35 sessioni di trattamento. Il miglioramento dei parametri di accuratezza e velocità nella lettura di testi e di parole singole (diverse da quelle usate nel corso del trattamento) è stato significativamente superiore al miglioramento riscontrato nei coetanei normolettori nello stesso periodo di tempo. Per la comprensione della lettura non si sono riscontrati cambiamenti significativi. I risultati mostrano l'efficacia di un trattamento precoce della dislessia evolutiva e la stretta relazione tra abilità di lettura e scrittura in questa fascia d'età.

SUMMARY. Developmental reading and spelling disorders are the most common learning disabilities and they have severe scholastic consequences. The present study aimed to test the efficacy of reading treatment in Italian third-grade children with dyslexia and its possible generalization to writing performance. A group of 10 third-grade children with dyslexia participated in the study. The main procedure of the treatment was a computerized program that included a tachistoscopic presentation of single words. Each child underwent 35 treatment sessions. Pre- and post-training reading performance was measured by two standard reading tests and vocal reaction time recordings. Pre- and post-training spelling ability was also measured using a standard spelling test. The percentage of improvement in accuracy and speed in reading texts and lists of words (not included among the trained items) was greater than the developmental increase characteristic of non-disabled children. Reading comprehension was only moderately affected and did not change appreciably after therapy. Results indicate the effectiveness of a reading treatment in the early stages of reading acquisition and the strict relationship between reading and spelling systems at this age.

Keywords: *Dyslexia, Reading, Treatment, Learning disability*

INTRODUCTION

Developmental disorders in reading and writing are relatively frequent deficits with important consequences on scholastic achievement and personal adjustment. In recent years greater attention has been given to reading and writing deficits in young native speakers of languages with relatively regular grapheme-to-phoneme correspondences, such as German and Italian, as opposed to the previous prevalent focus on English orthography (e.g. Share, 2008). The present paper describes a study that investigated the efficacy of a reading treatment in Italian third-grade children with dyslexia and its possible generalization to writing performance.

There is evidence that deficits in literacy acquisition in Italian may be expressed differently than in languages with opaque orthographies, such as English or French (e.g. Wimmer & Goswami, 1994). In the latter cases dyslexia is marked by a large number of reading errors. By contrast, in orthographically regular languages such as German or Italian children with dyslexia may read in a relatively correct fashion but their reading is characteristically slow and laborious (Wimmer, 1993; Zoccolotti et al., 1999). This pattern has been interpreted as reflecting weakness in the lexical procedure resulting in prevalent reference to the sub-lexical route (Zoccolotti et al., 1999).

Reliance on a sequential mode of processing is clear when vocal latencies to words are examined: children with dyslexia depend on word length while non-disabled children show a nearly flat function (De Luca, Barca, Burani & Zoccolotti, 2008; Judica, De Luca, Spinelli & Zoccolotti, 2002; Spinelli et al., 2005; Zoccolotti, De Luca, Judica & Spinelli, 2008). In non-disabled children this pattern is present only in the early learning phases (Zoccolotti, De Luca, Di Pace et al., 2005). Eye movement analysis in children with dyslexia confirmed the presence of slow, fragmented scanning when they read meaningful texts (De Luca, Di Pace, Judica, Spinelli & Zoccolotti, 1999) and lists of words and non-words (De Luca, Borrelli, Judica, Spinelli & Zoccolotti, 2002).

Although reading data are available for languages with regular orthographies, such as Italian, relatively little is known about writing deficits in these languages. In Italian (as in other relatively consistent orthographies) there is a certain degree of uncertainty regarding phoneme-to-grapheme correspondence. Some phonological strings have more than one possible orthographic solution, though only one is correct. For example, the phonemic group [kw] may be transcribed by the orthographic sequences QU, CU, or CQU; there is no definite rule for choosing among these alternatives and reference to a lexical entry is required.

All these cases of unpredictable spelling have been successfully used to assess lexical spelling in children with dyslexia (Angelelli, Judica, Spinelli, Zoccolotti & Luzzatti, 2004; Angelelli, Marinelli & Zoccolotti, 2010; Angelelli, Notarnicola, Judica, Zoccolotti & Luzzatti, 2010), thus confirming poor orthographic lexical knowledge and prevalent reliance on phoneme-to-grapheme processing also for the spelling process.

In recent years a number of studies have investigated the effect of training on the reading of Italian children with dyslexia (Judica et al., 2002; Lorusso, Facoetti & Molteni, 2004; Lorusso, Facoetti, Paganoni, Pezzani & Molteni, 2006; Lorusso, Facoetti, Toraldo & Molteni, 2005; Tressoldi, Lonciari & Vio, 2000; Tressoldi, Vio & Iozzino, 2007). Based on the interpretation that dyslexia is due to weakness of the lexical procedure leading to prevalent reliance on the use of the sub-lexical route (Zoccolotti et al., 1999), Judica et al. (2002) tried to foster parallel processing in reading by using a tachistoscopic presentation of stimuli. By presenting words for a shorter time than the minimum necessary to start a saccadic eye movement, this procedure impedes the sequential scanning of the visual target. By the end of the treatment, the children with dyslexia were faster and more accurate in reading both meaningful texts and lists of words than a group of untreated children. The latter group showed similar improvements when submitted to therapy a year later. The efficacy of tachistoscopic presentation in treating dyslexia was also confirmed by studies carried out using the model of dyslexia proposed by Bakker (1992), which uses a lateralized presentation. However, no clear effect of the side of presentation was consistently present, presumably indicating that the crucial aspect of the intervention was linked to the tachistoscopic presentation of stimuli *per se* (Lorusso et al., 2004, 2005, 2006). A procedure that focuses on the recognition of successive syllables within a word also proved effective, but only if the time devoted to each syllable was forced by the automatic procedure (Tressoldi et al., 2007).

Although these studies were based on different theoretical premises, they all emphasize the importance of time constraints in stimulus presentation in modulating the effectiveness of training. Notably, all of these studies examined seventh graders (Judica et al., 2002) or groups of mixed-age children (from second to eighth grade: Tressoldi et al., 2007; from seven to 16 years of age in Lorusso and co-workers' studies). Therefore, these data do not allow establishing the age at which rehabilitation training can be effectively started.

The aim of the present study was twofold. First, we wished to ascertain the efficacy of the tachistoscopic treatment program (Judica et al., 2002) in young children who are learning to read. In general, a reliable distinction can be made between proficient and impaired readers as early as third grade (e.g., Zoccolotti, De Luca, Di Pace et al., 2005). If treatment is effective at such an early age, it could have a critical impact on a child's overall scholastic achievement.

To better evaluate the improvement of decoding abilities, we used vocal reaction times (RT) to single word reading as well as standard reading tests. Vocal RTs provide an indication of decoding time independent of pronunciation time and are particularly sensitive in detecting the word length effect. This indicates the reliance of children with dyslexia on a sequential mode of processing, which is an indication of the prevalent use of the sublexical procedure (De Luca et al., 2008; Judica et al., 2002; Spinelli et al., 2005; Zoccolotti et al., 2008). Reading training aimed at fostering more global word analysis should reduce the length effect and encourage lexical processing.

The second aim of the study was to evaluate whether the reading treatment also has an effect on spelling performance. We were interested in evaluating this possibility because of the association between reading and writing deficits in Italian children with dyslexia (Angelelli et al., 2004; Angelelli et al., 2010). However, only a few studies have examined the spelling outcomes of reading interventions and they were carried out in opaque languages (Wanzek et al., 2006; Williams, Walker, Vaughn & Wanzek, 2016). Brunsdon, Hannan, Coltheart & Nickels (2002) made an in-depth single-case study of a ten-year-old English-speaking child who was suffering from severe mixed dyslexia and co-morbid spelling difficulties. The child underwent two 10-week treatment periods in which the highest frequency words that were read incorrectly at the baseline were trained by presenting flash cards to increase the child's visual word recognition skills. The authors found a significant treatment effect particularly in the spelling of the treated target words (only treated words were tested). In their meta-analysis, Wanzek et al. (2006; Williams et al., 2016) cited three other studies of English-speaking children that adopted reading intervention and included measures of spelling. However, in the first study (Torgesen et al., 2001), a moderate effect size (ES = .46) on a standardized spelling measure was reported in a group of secondary school students. The second study (Keel, Slaton & Blackhurst, 2001) examined the effect of reading training on infrequent words and their spelling as well as the spelling of other words in a single case: the effect was much larger for the studied items. However, as very few words were examined the results have to be interpreted with caution. Finally, the third study (Jitendra et al., 2004) examined the effects of reading intervention in two second grade participants with learning disabilities. Following the intervention, the performance of both participants improved on the spelling measure. However, in this study the intervention was an extensive and systematic program with explicit reading instructions in phonological awareness, phonics, fluency, vocabulary and comprehension.

Also in Italian children with dyslexia, Lorusso et al. (2004) reported unexpected spelling improvement on a standard spelling test following a tachistoscopic reading treatment, with items displayed centrally. In a subsequent study (age range: 7-15 years), spelling skills also improved following lateralized training. However, this outcome was not different from that observed after a reading treatment based on metaphonological tasks, perceptual prerequisites and word reading (Lorusso et al., 2006). Overall, the limited (and partially contradictory) evidence in Italian children indicates the importance of further evaluating the possible effect of reading treatment on spelling in this population. This conclusion parallels the considerations of Wanzek et al. (2006) based on their meta-analysis of studies on English-speaking children.

The generalization of reading treatment to spelling has interesting theoretical implications. The first studies that investigated the generalization of a lexical reading treatment to spelling involved adults with acquired impairment and they failed to demonstrate improvements in spelling (Scott & Byng, 1989; Weekes, 1996). However, generalization from reading to spelling (and viceversa) might be more effective early in development because of the greater interaction between the reading and spelling systems, as suggested by developmental theories (Ehri, 1997; Frith, 1985). Therefore, it would be useful to examine generalization by testing untreated items. Note that the results of the cited studies do not allow drawing conclusions about this. In fact, these studies either tested spelling of the same words used in the reading treatment (Brunsdon et al., 2002) or did not explicitly say whether the words in the assessment tasks were used during training (Lorusso et al., 2004; Lorusso et al., 2006; Torgesen et al., 2001). In Keel and coworkers' study (2001), untrained items were tested but training was too limited to be conclusive. According to Weekes (1996), generalization of a reading treatment to the reading and spelling of untreated items indicates a general effect on access to orthography, and thereby improved access and use of untreated word representations. To evaluate the generalization of treatment, we tested spelling with words not used during the reading treatment.

Overall, we administered a reading training that was aimed at fostering global processing of single words to a group of third-grade children with dyslexia. Pre- and post-treatment examination included measures of text, word and non-word reading, vocal reaction times to single word presentation and spelling of regular and ambiguous words as well as non-words.

MATERIALS AND METHODS

Participants

The group of children with dyslexia included 10 third-graders (9 males, 1 female). Ages ranged from 8.0 to 8.7 years (Mean = 8.4; *SD* =.2 years). Criteria for inclusion in the sample of children with dyslexia were the following: a) marked reading delay on a standard reading test: performance 2 standard deviations (*SDs*) below the norms for either accuracy or speed on the MT *Reading test* (Cornoldi, Colpo & Gruppo MT, 1998); b) performance in the normal range on *Raven's Coloured Progressive Matrices* (above 10^{th} percentile = 19 for third grade; Pruneti et al., 1996); c) normal or corrected-to-normal visual acuity. Table 1 summarizes the main demographic and clinical characteristics of the sample. Note that mean group performance on the Vocabulary sub-test of the WISC-R was about average, indicating normal lexical ability from verbal input; similarly performance on Raven's test indicated average nonverbal skills.

The study was part of a research agreement between schools in Nettuno (near Rome) and the institutions the authors are affiliated with. As requested by the research agreement, all children screened who had a reading deficit were submitted to training; therefore, we did not have a control group with no treatment. The parents were given a description of the study and had to approve their child's participation. The study conformed to the standards of the Declaration of Helsinki and was approved by the Ethical Committee of the institutions the authors were affiliated with.

Study design

The study was carried out over a nine-month period. Performances of the children with dyslexia were measured pre-treatment in October. Reading performance was measured with two standard tests (*MT Reading test* and *Word and Non-word Reading test*) and the Vocal reaction times test; spelling ability with a standard instrument (DDO-2 *Spelling test*). Values of the pre-training evaluation of the standard reading and spelling tests are presented in Table 1 (for descriptions of these tests see Reading assessment and Spelling assessment, respectively).

Following the pre-training evaluation, the children underwent the reading treatment in their schools from November to May. A speech therapist administered the treatment program to each participant individually in a quiet room during school hours. We expected to carry out two one-hour sessions per week. However, for various reasons (holidays, special school activities and children's school absences), fewer sessions were actually performed. In practice, we were able to administer only 35 sessions to each child who participated over the seven-month training period. An effort was made to ensure that each child was submitted to the 35 sessions; in a few cases, this required additional training during the first days of June. In each session, the main treatment procedure was a computerized program featuring the tachistoscopic presentation of single words (see below).

The post-treatment evaluation was carried out in June using the same evaluation battery as in the pre-treatment assessment.

Reading assessment

- *Passage reading*: reading level was examined using a standard reading achievement test (*MT Reading test,* Cornoldi et al., 1998). The participant had to read aloud one passage within a 4-min time limit; speed (time in seconds per syllable read) and accuracy (number of errors, adjusted for the amount of text read) were scored. To measure comprehension, the participant read a second passage without a time limit and responded to ten multiple-choice questions. Stimulus materials (and related reference norms) varied according to grade; in the same grade, they were different at the beginning and the end of the year. Raw scores were converted to *z* scores according to standard reference data (Cornoldi et al., 1998).
- *Word and non-word reading*: three lists (each containing 30 items) from the *Word and Non-word Reading test* (Zoccolotti, De Luca, Di Filippo, Judica & Spinelli, 2005) were used: short (four-to-five letter) and long (eight-to-

Table 1 – Summary statistics for children with dyslexia at the assessment phase

		Raw scores		Standard scores	
		Mean	**SD**	**Mean**	**SD**
Age	Years	8.4	.2	–	–
Gender	Proportion M/F	9/1		–	–
Raven test	Correct responses (CR)	23.2	3.7	–	–
WISC-R	Vocabulary subtest	–	–	10.11	1.36
MT Reading test	Speed (s/syllable)	1.22	.51	−2.45	1.72
	Accuracy (errors)	21.3	4.7	−3.22	.91
	Comprehension (CR)	4.3	2.5	−.80	.92
Word and Non-word Reading test	Short words (s/item)	2.1	.7	−3.41	2.10
	Long words (s/item)	3.9	1.2	−4.12	2.09
	Short non-words (s/item)	2.5	.9	−2.38	1.78
	Short words (% errors)	19.0	12.3	−2.52	2.09
	Long words (% errors)	22.3	8.0	−2.28	1.20
	Short non-words (% errors)	38.7	13.6	−2.79	1.36
Spelling test	Regular words (CR/70)	55.9	8.9	−3.56	2.8
	Reg. words syll. conv. (CR/10)	6.0	1.9	−3.01	1.8
	Unpredictable words (CR/55)	29.7	7.3	−2.27	1.3
	Non-words (CR/25)	16.6	4.8	−3.25	2.3

Legenda. CR = correct responses.

Note. For gender, proportion of M/F is indicated. For all other reading and cognitive parameters, means (and SDs) for raw and standard scores are reported. For raw scores, specific parameters are indicated. For standard scores, *z*-values (with 0 +/−1) are reported in all cases except the Vocabulary test (where the expected mean is 10 +/−3).

nine letter) high frequency words, and short (four-to-five letter) non-words. Participants were asked to read each list of stimuli as quickly and accurately as possible. A short practice list was presented separately for words and non-words. The time needed to complete the task was measured separately for each list. The dependent measure was the reading time in seconds per item. Thus, we measured the time needed by the reader independently from accuracy. Errors were also measured during the test administration (1 = passed; 0 = failed). Omissions, insertions, reversals or substitutions of letters and wrong stress assignment were considered pronunciation errors. Also self-corrections (but not hesitations) were scored as errors. For off-line checks of reading times and errors the participant's vocal output was also tape-recorded. *Z*-scores (one value per grade) are available from a normative sample (Zoccolotti, De Luca, Di Filippo et al., 2005).

– V*ocal reaction times test*: vocal reaction times (RT) at stimulus onset were detected with a microphone and recorded using an Apple Performa computer. Both stimulus presentation and RT recording were controlled by SuperLab Pro 1.75 software. Stimuli were single words (black letters on a white background) of 2, 3, 4 and 5 letters (54 words for each length for a total of 216 stimuli as in Zoccolotti, De Luca, Di Filippo et al., 2005), displayed at the center of the computer screen. Each letter subtended .4 degrees horizontally at a viewing distance of 57 cm. The word-length sets were matched on the initial phoneme and the median frequency value. This was 7105 in 10,000,000 occurrences, which indicates a generally high frequency value (VELI, 1989). Frequency did not vary among different word lengths (Kruskal Wallis H (4) = 2.82, n.s.). A fixation point was displayed for 750 ms; after that, a word was displayed and remained on the screen until the participant responded (otherwise, within a 6-sec. time limit, in case of no response). Then a 250 ms blank screen followed. One block of 10 practice stimuli and six experimental blocks of 36 stimuli were administered interspersed with brief pauses. Word length was randomized within each block.

The task was to read the words aloud as quickly and accurately as possible when they appeared on the screen. Vocal RTs to correctly read words were measured. Errors (incorrectly named words) were also computed. In a few instances, trials were not valid because of outside noise or technical failures.

Spelling assessment

The *Spelling test* (DDO-2, Angelelli et al., 2016) consists of four sections: Section A: regular words with complete one-sound-to-one-letter correspondence (N = 70); Section B: regular words requiring syllabic conversion rules (N = 10). Syllabic conversion is required when the orthographic realization of a consonant is determined by the vowel that follows it; Section C: words with unpredictable transcription along the phonological-to-orthographic conversion routine (e.g. [kwo] in [kwota], the quota: QUOTA and not *CUOTA) (N = 55); Section D: non-words with one-sound-to-one-letter correspondence (N = 25).

Each participant was tested individually. Words and non-words were presented in random order on separate lists. The examiner read each item aloud in a neutral tone. The child was asked to repeat each item before he/she wrote it to ensure he/she had perceived it correctly. No feedback was provided on the correctness of the responses. Spontaneous repairs were accepted as correct responses. The number of correctly spelled words in each category was the dependent measure. *Z*-scores (one value per year) are available from a normative sample. Spelling performances were available for 7 out of the 10 children studied.

Reading treatment

- *Computerized training*: training was controlled by the Tachistoscopio software (Morchio, Ott, Pesenti & Tavella, 1989). A single word (white letters on a blue background) was briefly presented (60 to 150 ms) in the center of the PC screen, followed by a mask (to prevent the support of iconic memory). The screen was set at a 45 cm viewing distance. Mean character width (center-to-center letter distance) was .6 degrees of visual angle.
  Lists of words from different categories (nouns, verbs, adjectives) were used. Word length varied from 2 to 6 letters and word frequency (De Mauro & Moroni, 1996) could be "very high" (from a pool of 2000 words including items at the core of the Italian language; hereafter, "core" words) or "high" (from a list of 3000 words used with high frequency in both speaking and writing).
  About 800 words were selected and used in the present study to generate 40 lists of 20 words (20 lists with "core" words and 20 with "high" frequency words). None of these stimuli were present in the *Word and Non-word reading test*, in the V*ocal reaction time* set of words, or in the *Spelling test* used for the assessment. From six to ten lists were administered in each session. Overall, about 6000 stimuli were administered to each child. On five to nine lists, the participant's task was to read the word aloud. On one list the task was to read it silently and print it on the keyboard. Treatment difficulty was adjusted individually for the children so that they started with stimuli yielding optimal performance (e.g. three-letter very high frequency words with a 150 ms presentation time). Then, we increased the difficulty of the computerized training by using shorter presentation times or longer and less frequent words. Manipulation of the materials and exposures was adjusted to keep the number of correct responses relatively high (60-70% in each session).
- *Additional training*: to facilitate reading, functional exercises were also given in each session (Judica, Baldoni, Chirri, Cucciaioni & Del Vento, 2006). The training is based on various game-like exercises (word reading, crossword puzzles, "memory" like exercises) that forced the children to practice the same stimuli in different contexts. Stimuli were words grouped in different categories (e.g. colors, animals, fruit, body parts etc.) of high frequency (De Mauro & Moroni, 1996) and appeared regularly in elementary textbooks (Marconi, Ott, Pesenti, Ratti & Tavella, 1994). For more details, see Judica et al. (2006).

Data analysis

Pre- and post-training measures from the reading assessment tests were used to evaluate the efficacy of the reading treatment program. Pre- and post-training measures on the spelling test were used to evaluate the effect of reading training on spelling performance.

Regarding the *MT Reading test*, *z*-scores of speed, accuracy and comprehension from pre- and post-treatment were submitted to a MANOVA with treatment (pre- and post) as repeated measure. Univariate tests for each dependent variable (speed, accuracy and comprehension) were also carried out. The presence of separate norms in the *MT Reading test* for the beginning and end of the school year allows directly evaluating treatment gains with respect to normal reading acquisition.

In the *Word and Non-word Reading test*, reading time and accuracy z-scores from pre- and post-treatment were entered in a MANOVA with treatment (pre- and post-) and type of stimulus (short words, long words and short non-words) as repeated measures. Univariate tests for both reading time and accuracy measures were also carried out and multivariate and univariate effect sizes are reported. Note that separate norms for the beginning and end of the year are unavailable for the *Word and Non-word Reading test*. Therefore, to evaluate the impact of treatment with respect to normal acquisition, the change in performance (in terms of raw values) as a function of treatment was graphically compared to the performances of non-disabled readers in a larger age range. Data of second (N = 40), third (N = 55) and fourth (N = 44) grade non-disabled readers from a previous study of our group (Zoccolotti, De Luca, Di Filippo, Judica & Martelli, 2009) were used.

Vocal RTs at onset (raw data in msec.) to correctly responded items were analyzed by an ANOVA with treatment (pre-, post-) and word length (two-, three-, four-, five-letter words) as repeated measures. Errors were also examined to evaluate a possible trade-off in performance. However, they were too few (percentage of errors < 1 in the control group) and variable from condition to condition to allow for parametric analysis. Data of children with dyslexia as a function of treatment (raw values) were graphically compared with those of a group of 28 non-disabled third-grade children who were tested with the same materials (Zoccolotti et al., 2005).

As for the *Spelling test*, *z*-scores were submitted to an ANOVA with treatment (pre-, post-) and stimulus category (regular words, regular words with syllabic conversion, unpredictable transcription words and non-words) as repeated measures. Separate norms were used for the beginning and the end of the year. The improvement of performance (total raw score) as a function of treatment was graphically compared to the performances of non-disabled children in second (N = 74), third (N = 110) and fourth (N = 136) grade (data from Angelelli et al., 2016).

Size effects for main effects and interactions were evaluated for both multivariate (i.e. multivariate eta-squared; Gall, Gall & Borg, 2011) and univariate analysis (i.e. partial eta-squared; Cohen, 1988). Conventional reference values for small, medium, and large effects are considered to be .01, .06 and .13, respectively. However, it has been proposed that empirical benchmarks can be identified for gauging effect sizes of the achievement outcomes of educational interventions. According to Bloom, Hill, Black & Lipsey (2008), interventions should be compared relative to the magnitudes of normal increases in performance in a given cognitive skill. Therefore, we used recently established normative values to determine the expected increase in reading/writing performances in the various tests used. Changes in performance passing from third to fourth grade were computed to establish normal annual increases (Bloom et al., 2008) and were used as benchmarks to evaluate the treatment effect (with the exception of the *Vocal reaction times test* for which only data for second and third grade were available).

RESULTS

Effect of training on reading performance

- *Passage reading*: at the pre-treatment evaluation, reading speed and accuracy were severely affected on the *MT Reading test*, with group means exceeding −2 *SD*; by contrast, comprehension was within normal values (Table 1).

  The MANOVA on these data indicated a significant effect of treatment (λ = .31, $F_{(3, 7)}$ = 5.21; p<.05; multivariate eta-squared = .44): performance improved from −2.15 to −1.11. In proficient readers, the mean performance increase passing from third to fourth grade was .38 (Tressoldi, 2008); therefore, the change observed after treatment in children with dyslexia was 174% of normal reading acquisition. The univariate tests showed that the improvement regarded both reading accuracy (passing from −3.22 to −1.92; $F_{(1, 9)} = 10.81$; $p<.01$; partial eta-squared = .81) and speed (passing from −2.45 to −.99; $F_{(1, 9)} = 8.64$; $p<.05$; partial eta-squared = .49); however, comprehension was not affected even prior to treatment and did not show significant modification following the reading training (passing from −.80 to −.42; $F_{(1, 9)} = 2.75$; n.s).

– *Comments*: at the pre-treatment evaluation, reading speed and accuracy were severely affected, whereas comprehension was only mildly affected (Table 1). This pattern is common in Italian children with dyslexia (Judica et al., 2002). At the post-test, performance improved significantly for both accuracy and speed. By contrast, text comprehension did not improve as a function of training. Therefore, the treatment seemed to have a specific effect only on decoding skills. This general pattern seems consistent with the characteristics of the training, which emphasized practice in correctly identifying isolated words. The finding that performance improvement was present in reading meaningful passages indicates that improvement due to training on single words generalized to some extent to functional reading.

The improved performance after treatment cannot be explained by the normal increase due to age/school attendance, because separate norms are available for this test for different periods during the school year. In fact, the effect of the training was 1.74 times larger than the normal annual improvement in performance on the MT test (note that the training lasted ca. seven months).

– *Word and non-word reading*: at the pre-treatment evaluation (Table 1) reading time and accuracy on the *Word and Non-word Reading* test were both severely affected for all stimulus categories.

The MANOVA on reading time and accuracy *z*-scores indicated a main effect of treatment ($\lambda = .21$, $F_{(2, 8)} = 15.16$; $p<.01$; multivariate eta-squared = .54) and type of stimulus ($\lambda = .21$, $F_{(4, 6)} = 5.94$; $p<.05$; multivariate eta-squared = .55). The interaction effect of treatment x type of stimulus was also significant ($\lambda = .21$, $F_{(4, 6)} = 5.97$; $p<.05$; multivariate eta-squared = .55).

The univariate test on reading times indicated a main effect of treatment ($F_{(1, 9)} = 18.52$; $p<.01$; partial eta-squared = .67): across stimulus materials, reading times improved from −3.30 to −1.70 *z*-values. The mean performance increase passing from third to fourth grade in non-disabled readers was .50 (Zoccolotti et al., 2009); therefore, the change following treatment in children with dyslexia was 134% which occurs in normal reading acquisition. The main effect of stimulus type was significant ($F_{(2, 18)} = 14.09$; $p<.0005$; partial eta-squared = .61): performance on long words (−3.13) was more impaired than performance on both short words (−2.36; $p<.01$) and short non-words (−2.01; $p<.001$); these two latter conditions did not differ from each other. The treatment x type of stimulus interaction was significant ($F_{(2, 18)} = 5.31$; $p<.05$; partial eta-squared = .37): post-hoc comparisons showed an effect of treatment over performance on short (passing from −3.41 to −1.31) and long (passing from −4.12 to −2.14) words (both $p<.001$). Performance on short non-words did not change significantly after treatment.

The univariate test on accuracy showed the significance of the main effect of treatment ($F_{(1, 9)} = 11.49$; $p<.01$; partial eta-squared = .56): performance improved from −2.53 to −1.40 *z* values. In non-disabled readers, the mean performance increase passing from third to fourth grade was .19 (data from Zoccolotti et al., 2009); therefore, the change following treatment in children with dyslexia was 294% with respect to normal reading acquisition. The main effects of type of stimulus ($F_{(2, 18)} = 1.94$; n.s) and the treatment x type of stimulus interaction ($F_{(2, 18)} = .62$; n.s) were not significant.

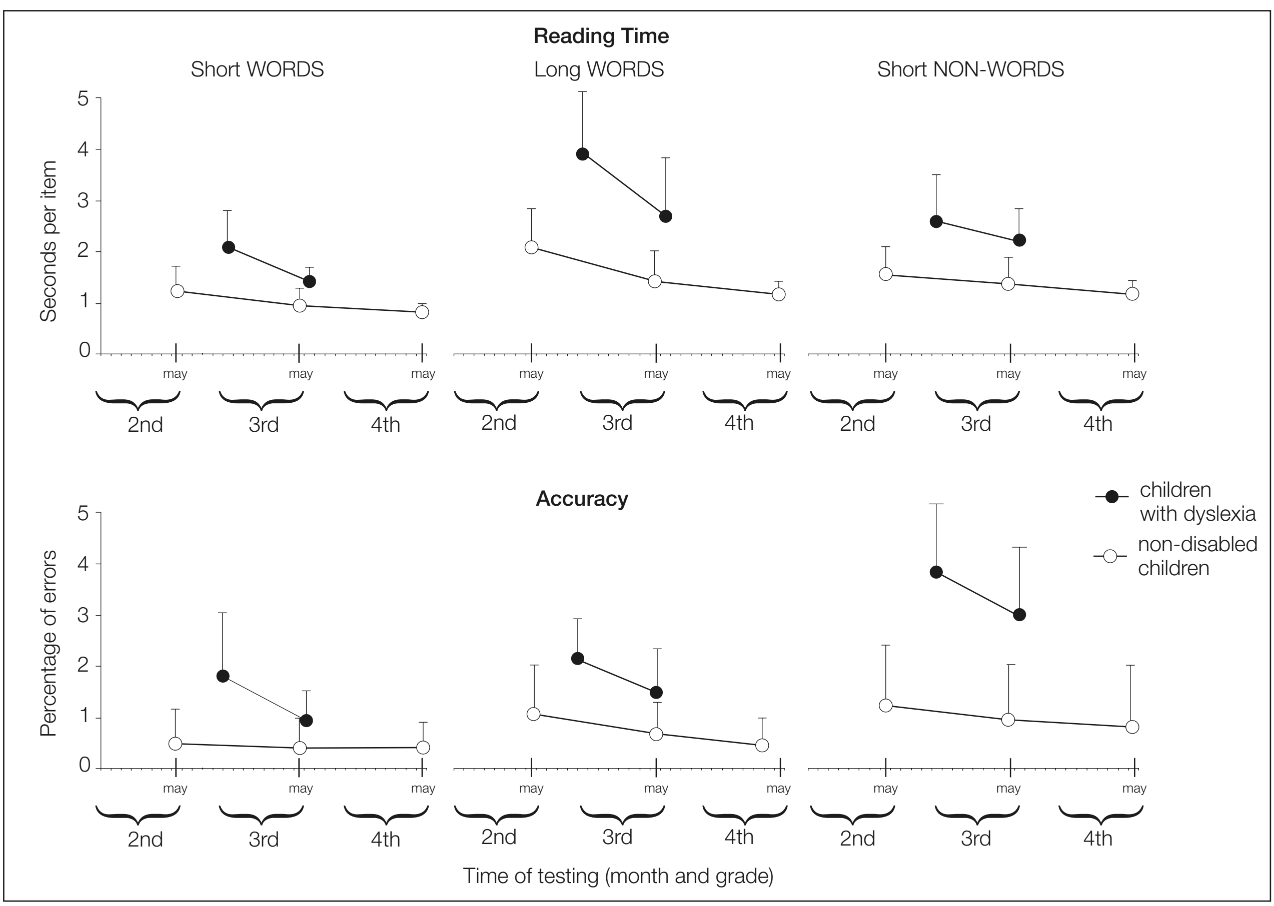
To graphically illustrate the effect of treatment versus normal reading acquisition, Figure 1 shows the performances of non-disabled readers in second, third and fourth grade (Zoccolotti et al., 2009) and of the present study's children with dyslexia. Reading time (upper graphs) is expressed as seconds per item; accuracy (lower graphs) is expressed as percentage of errors. Inspection of the figure indicates that, for reading time, the change in performance of children with dyslexia as a function of treatment, is steeper than that of non-disabled children for short and long words (but not non-words). In the case of accuracy, changes in performance during treatment are greater than the annual improvement of reading performance for all types of stimuli.

– *Comments*: before training the children were severely impaired in all reading measures. Non-word reading was not more affected than word reading (in fact, it was somewhat less in the case of reading time). This finding confirms previous observations of non-selective deficits in reading non-words in Italian children with dyslexia (e.g., Zoccolotti et al., 1999). A length effect was also evident for reading time, i.e., children with dyslexia were more severely impaired on long than on short words.

At the post-test, performance improved significantly both for reading time and accuracy. For reading time, the performance improvement was limited to words, whereas for accuracy it was present for both words and non-words. The graphical comparison with reading acquisition over a three-year period indicated that training had a larger effect than the normal annual increase in performance in this test. In the case of accuracy it must be noted that Italian readers reach relatively high accuracy in early grades (Zoccolotti et al., 2009) and show only modest increases in performance after third grade. Accordingly, children with dyslexia (who still make many errors) show an extremely large improvement in performance compared with what occurs in normal reading acquisition.

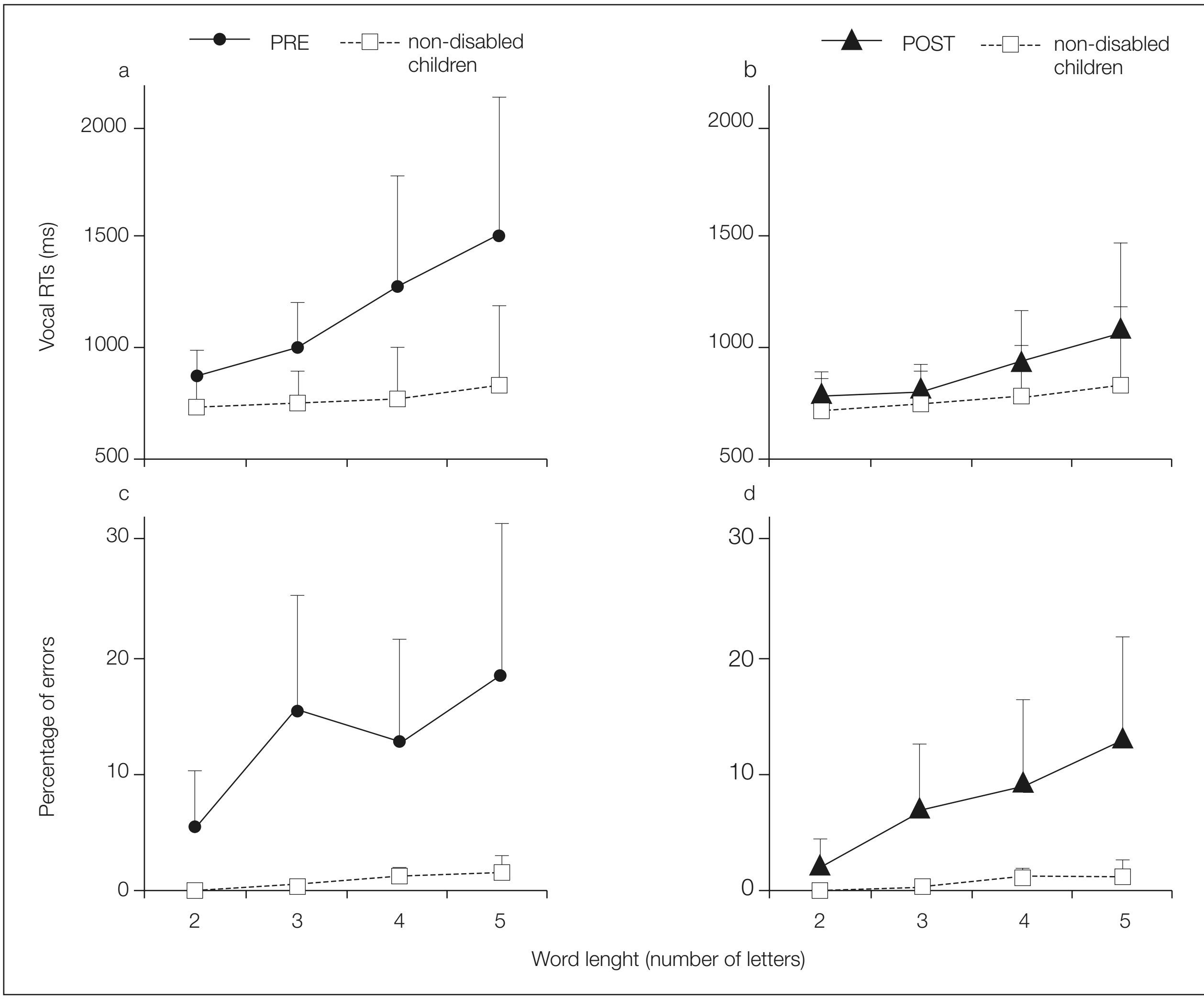
– *Vocal Reaction Times*: the vocal RTs in naming words for children with dyslexia (pre- and post-testing) and non-disabled children are presented at the top of Figure 2 (panels a and b) as a function of word length. The bottom part of the figure (panels c and d) shows a similar plot based on the percentage of errors. An inspection of the figure indicates that before treatment RTs increase with a steep slope as a function of stimulus length. The pattern of errors is similar to that of vocal RTs; therefore, differences in RTs cannot be easily interpreted in terms of a speed/accuracy trade-off. For the sake of comparison, data from a group of 28 non-disabled third-grade children who were tested with the same materials are also presented (Zoccolotti

Figure 1 - The pre- and post-treatment mean performances of children with dyslexia on the *Word and Non-word Reading test*



Note. Reading time (upper graphs) is expressed as seconds per item; accuracy (lower graphs) is expressed as percentage of errors. Bars depict upward SDs. Control data are based on performances of 40 non-disabled children in second grade, 55 in third grade and 44 in fourth grade (Zoccolotti et al., 2009).

Figure 2 – Mean pre- and post-treatment performances of children with dyslexia on the *Vocal reaction time test*



Note. Vocal reaction times are plotted as a function of the number of letters in a word (i.e., word length). For comparison, data of non-disabled peers (Zoccolotti et al., 2005) are also presented. Panels a and b: mean vocal RTs as a function of word length for children with dyslexia (a: pre-treatment; b: post-treatment) and non-disabled children. Panels c and d: mean percentage of errors as a function of word length for children with dyslexia (c: pre-treatment; d: post-treatment) and peer non-disabled children.

et al., 2005). After treatment, vocal RTs of children with dyslexia improve (and depend less on word length) but are still slower than those of non-disabled children.

The ANOVA showed a main effect of treatment ($F_{(1, 9)} = 7.09$, $p<.05$; partial eta-squared = .44): vocal RTs were shorter post- (922) than pre-treatment (1182). Information on the mean performance increase in non-disabled readers was available only from second to third grade (i.e., it was .41; data from Zoccolotti, De Luca, Di Pace et al., 2005); therefore, the change observed in children with dyslexia following treatment was 107% that of normal reading acquisition. The effect of word length was significant ($F_{(3, 27)} = 14.2$, $p<.001$; partial eta-squared = .61): vocal RTs increased with increasing word length. The treatment by word length interaction was only marginally reliable ($F_{(3, 27)} = 2.25$, $p = .10$; partial eta-squared = .20): inspection of Figure 2 indicates a trend for RTs of children with dyslexia to be less dependent upon word length after treatment.

– *Comments*: before treatment the vocal RTs of children with dyslexia were greatly influenced by word length. After treatment, these children significantly reduced their vocal RTs; however, their performance still partially reflected the influence of word length. The graphical comparison showed that treatment had a slightly greater effect than the increase in performance passing from second- to third-grade. Note that changes in performance characteristically decrease with increasing age (Bloom et al., 2008); therefore, reference to this age change probably leads to an under-estimation of the actual effect.

Naming isolated words with the instruction of being fast is a task somewhat similar to that used during the treatment, where words were tachistoscopically presented, and the child named the words (without a time constraint). Consequently, some of the improvement may be task specific. However, the words used in the RT task were different from those used during training; therefore, the changes in performance indicate improvements in word decoding not in item-specific learning.

– *Effect of training on spelling performance*: at the pre-treatment evaluation (Table 1), spelling performance was severely affected in all spelling categories.

The ANOVA showed a main effect of treatment ($F_{(1, 6)}$ = 7.73, p<.05; partial eta-squared = .56): accuracy improved across stimulus materials from −3.02 to −1.53. The mean performance increase in proficient readers passing from third to fourth grade is .46 (Angelelli et al., 2016); therefore, the change observed following treatment in children with dyslexia was 122% that of normal spelling acquisition. The main effect of type of stimulus and its interaction with treatment were not significant.

To evaluate the effect of treatment versus normal acquisition of writing skills, the spelling performance (total raw score) of children with dyslexia is presented in Figure 3 along with that of non-disabled children in second, third and fourth grade (Angelelli et al., 2016). Inspection of the figure indicates that the increase in the performance of children with dyslexia was greater than that observed in the non-disabled children.

– *Comments*: before training the children were severely impaired in all sub-sets of the spelling test. This is a common finding in children with dyslexia, who usually have spelling deficits (Angelelli et al., 2004). After the reading treatment the children's spelling performance generally improved but was still defective.

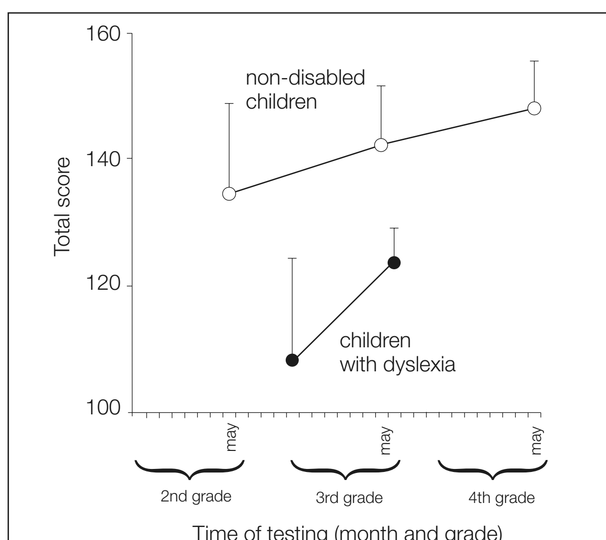
The graphical comparison with spelling acquisition over a three-year period indicates that the effect of training was larger than the normal annual increase in performance. Note that the words of the spelling test were not trained in the reading training.

DISCUSSION

Two main findings were observed. First, the present results show the efficacy of a tachistoscopic treatment program in improving the reading of children with dyslexia at an early stage of reading acquisition. Second, they indicate that a treatment program focussed on reading also has positive effects on spelling.

After treatment, the Italian children with dyslexia showed improved reading performance in terms of both speed and accuracy. Confirming previous work (Judica et al., 2002; Lorusso et al., 2004, 2005, 2006), the use of a tachistoscopic presentation proved helpful for children who are native speakers of a transparent language. Presenting words for an insufficient amount of time to sequentially scan the stimulus apparently improves the child's ability to analyze the stimulus as a whole. Improvement was evident not only in the recognition of words presently singly on a PC but also in reading meaningful texts and lists of words. Furthermore, it should be noted that stimuli used in the pre- and post-treatment assessment were not presented during treatment. Therefore, the changes after therapy indicate a general improvement in decoding skills rather than in stimulus specific learning. Overall, these findings confirm and extend previous evidence found in older children (Judica et al., 2002).

Figure 3 – Mean pre- and post-treatment total raw scores on the *Spelling test* for children with dyslexia



Note. Control data are based on performances of 74 non-disabled children in second grade, 110 in third grade and 136 in fourth grade (Angelelli et al. 2016).

To evaluate the efficacy of an intervention, the effect of treatment must be disentangled from normal reading acquisition expected as an effect of school attendance and general age changes. Particularly in the early school years non-disabled children improve their decoding skills quite rapidly. Children with dyslexia also improve in the absence of a specific treatment, although at a slower rate than non-disabled children (Tressoldi, Stella & Faggella, 2001). As an effect of this differential learning slope, the gap in performance between non-disabled children and children with dyslexia characteristically increases with age/reading experience (Tressoldi et al., 2001).

One way to evaluate treatment efficacy is to compare the experimental group with an untreated group of children with dyslexia. However, in a developmental perspective a control group of children with dyslexia who receive no treatment raises deontological problems. In our particular case, the research agreement with the schools required that all children with a reading deficit be given immediate treatment. Therefore, we evaluated treatment efficacy in comparison with the changes observed as an effect of normal reading acquisition. In particular, as suggested by Bloom et al. (2008), we compared the improvement in performance due to the treatment to that observed in non-disabled children over a year. For all reading materials (i.e. meaningful texts, lists of words and single word naming) the effect of treatment over a seven-month period was larger than the performance improvement obtained in non-disabled children passing from third to fourth grade. The proportion varied from 122% in the case of the spelling test to 294% in the case of the *Word and Non-word Reading test* (reading accuracy). The improvement in performance was 107% in the case of the vocal RTs to single words, where only norms from second and third grade were available. Note that using normal reading acquisition as a benchmark produces a conservative estimate (i.e., underestimation) of the treatment effectiveness. In fact, as stated above, in the absence of specific treatment children with dyslexia improve at a much slower rate than non-disabled children (Tressoldi et al., 2001). Therefore, the observed size effects indicate substantial improvements as a function of the rehabilitation treatment. We also graphically compared the change in performance as a function of treatment to the performances of non-disabled readers over a larger age range. These comparisons also indicated that the improvement in children with dyslexia clearly exceeded that shown by non-disabled children.

Overall, these findings indicate that substantial treatment effects can be demonstrated at a relatively early stage of reading acquisition. Of course, intervening at earlier stages is preferable because it helps prevent a gap in scholastic achievement. Furthermore, when necessary, follow-up interventions can be more easily programmed.

One important finding was the generalization to spelling skills of the treatment program aimed at developing the lexical route for reading. The present results are consistent with the literature which reports a significant reading treatment effect generalizing to spelling of untreated target stimuli in children (Lorusso et al., 2004; Lorusso et al., 2006; Torgesen et al., 2001). Moreover, while improved spelling of target stimuli after reading treatment is not surprising (because a child may gradually build up correct orthographic representations after several attempts to read the correctly spelled item), generalization to untrained items could be ascribed to treatment effects on the general process of entering the word recognition system (Weekes, 1996). Overall, these results support the reciprocal relationship between the processing of reading and spelling as proposed by developmental models of literacy acquisition (e.g. Ehri, 1997; Frith, 1985).

A number of limitations of the present study must also be mentioned. Because of the relatively small size of the sample tested (as well as the absence of multiple assessments) over the course of training and of a control group of children without treatment, the present observations must be confirmed in future studies. Furthermore, it should be noted that improvement after treatment was incomplete. The performance of children with dyslexia remained below the means of non-disabled children for all parameters. Also, some evidence of the persistence of sequential analysis in reading was detected in reading lists of short and long words and in the length effect in the case of vocal RTs to single words. Further work is needed to determine whether the partial recovery shown by these children will hold (or further improve) in time or whether they will require further treatment periods. Finally, as stated above, we compared the effects of training with respect to the performance changes observed during normal reading acquisition. To this aim, we referred to established (but different) data sets in the literature. Referring to data from different sources is certainly a limitation of the present study. Therefore, caution must be taken in generalizing the present results. Future research should consider the possibility of gathering data on typical development across tests within a single sample of children.

CONCLUSIONS

Overall, the results indicate the effectiveness of a reading treatment that focused on the global decoding of words by using a tachistoscopic presentation of stimuli; an additional result was the presence of some generalization to spelling. Treatment can be successfully started in third graders who already show a significant lag in the acquisition of written language.

Acknowledgements
We would like to thank teachers and principals of the primary schools in Nettuno for their help in carrying out the intervention project. We would also like to thank Claire Montagna for editing the manuscript and Dr. Chiara Valeria Marinelli for advice in carrying out the statistical analyses.

References

ANGELELLI, P., JUDICA, A., SPINELLI, D., ZOCCOLOTTI, P. & LUZZATTI, C. (2004). Characteristics of writing disorders in Italian dyslexic children. *Cognitive and Behavioral Neurology*, *17*(1),18-31.

ANGELELLI, P., MARINELLI, C.V., IAIA, M., NOTARNICOLA, A., COSTABILE, D., JUDICA, A., ZOCCOLOTTI, P. & LUZZATTI, C. (2016). *DDO-2 Diagnosi dei disturbi ortografici in età evolutiva*. Trento: Erickson.

ANGELELLI, P., MARINELLI, C.V. & ZOCCOLOTTI, P. (2010). Single or dual orthographic representations for reading and spelling? A study on Italian dyslexic and dysgraphic children. *Cognitive Neuropsychology*, *27*, 305-333.

ANGELELLI, P. NOTARNICOLA, A., JUDICA, A., ZOCCOLOTTI, P. & LUZZATTI, C. (2010). Spelling impairment in Italian dyslexic children: Does the phenomenology change with age? *Cortex, 46*, 1299-1311.

BAKKER, D.J. (1992). Neuropsychological classification and treatment of dyslexia. *Journal of Learning Disabilities*, *25*(2), 102-109.

BLOOM, H.S., HILL, C.J., BLACK, A.R. & LIPSEY, M.W. (2008). Performance trajectories and performance gaps as achievement effect-size benchmarks for educational interventions. *MDRC Working Papers on Research Methodology*.

BRUNSDON, R., HANNAN, T.J., COLTHEART, M. & NICKELS, L. (2002). Treatment of lexical processing in mixed dyslexia: A case study. *Neuropsychological Rehabilitation*, *12*(5), 385-418.

CORNOLDI, C., COLPO, G. & GRUPPO MT (1998). *Prove di Lettura MT per la scuola elementare - 2. Manuale*. Firenze: Giunti O.S. Organizzazioni Speciali.

DE LUCA, M., BARCA, L., BURANI, C. & ZOCCOLOTTI, P. (2008). The effect of word length and other sublexical, lexical and semantic variables on developmental reading deficit. *Cognitive and Behavioral Neurology*, *21*(4), 227-235.

DE LUCA, M., BORRELLI, M., JUDICA, A., SPINELLI, D. & ZOCCOLOTTI, P. (2002). Reading words and pseudo-words: An eye movement study of developmental dyslexia. *Brain and Language*, *80*(3), 617-626.

DE LUCA, M., DI PACE, E., JUDICA, A., SPINELLI, D. & ZOCCOLOTTI, P. (1999). Eye movement patterns in linguistic and non-linguistic tasks in developmental surface dyslexia. *Neuropsychologia*, *37*(12), 1407-1420.

DE MAURO, T. & MORONI, G.G. (1996). DIB. *Dizionario di base della lingua italiana*. Torino: Paravia.

EHRI, L. (1997). Learning to read and learning to spell are one and the same, almost. In C. Perfetti, L. Rieben & M. Fayol (Eds.), *Learning to spell: Research, theory and practice*. Mahwah, NJ: Erlbaum.

FRITH, U. (1985). Beneath the surface of developmental dyslexia. In K. Patterson, J.L. Marshall & M. Coltheart (Eds.), *Surface Dyslexia*. Hillsdale, NJ: Erlbaum.

GALL, M.D., GALL, J.P. & BORG, W.R. (2011). *Applying Educational Research, 6th ed.* Boston, MA: Pearson.

JITENDRA, A.K., EDWARDS, L.L., STAROSTA, K., SACKS, G., JACOBSON, L.A. & CHOUTKA, C.M. (2004). Early reading instruction for children with reading difficulties: Meeting the needs of diverse learners. *Journal of Learning Disabilities*, *37*(5), 421-439.

JUDICA, A., BALDONI, L., CHIRRI, L., CUCCIAIONI, C. & DEL VENTO, G. (2006). *Parole in corso. Materiali per il recupero delle difficoltà di lettura*. Trento: Erickson.

JUDICA, A., DE LUCA, M., SPINELLI, D. & ZOCCOLOTTI, P. (2002). Training of developmental surface dyslexia modifies performance and eye fixation duration in reading. *Neuropsychological Rehabilitation*, *12*(3), 177-197.

KEEL, M.C., SLATON, D.B. & BLACKHURST, A.E. (2001).

Acquisition of content area vocabulary for student with learning disabilities. *Education and Treatment of Children*, *24*(1), 46-71.

LORUSSO, M.L., FACOETTI, A. & MOLTENI, M. (2004). Hemispheric, attentional, and processing speed factors in the treatment of developmental dyslexia. *Brain and Cognition*, *55*(2), 341-348.

LORUSSO, M.L., FACOETTI, A., PAGANONI, P., PEZZANI, M. & MOLTENI, M. (2006). Effects of visual hemisphere-specific stimulation versus reading-focused training in dyslexic children. *Neuropsychological Rehabilitation*, *16*(2), 194-212.

LORUSSO, M.L., FACOETTI, A., TORALDO, A. & MOLTENI, M. (2005). Tachistoscopic treatment of dyslexia changes the distribution of visual-spatial attention. *Brain and Cognition*, *57*(2), 135-142.

MARCONI, L., OTT, M., PESENTI, E., RATTI, D. & TAVELLA, M. (1994). *Lessico elementare. Dati statistici sull'italiano scritto e letto dai bambini delle elementary*. Bologna: Zanichelli.

MORCHIO, B., OTT, M., PESENTI, E. & TAVELLA, M. (1989). *Tachistoscopio. Un programma per migliorare l'abilità di lettura di parole. II edizione (CNR ITD Genova)*. Bologna: A.S.P.H.I.

PRUNETI, C., FENU, A., FRESCHI, G., ROTA, S., COCCI, D., MARCHIONNI, M., ROSSI, S. & BARACCHINI-MORATORIO, G. (1996). Aggiornamento della standardizzazione italiana del test delle Matrici Progressive Colorate di Raven (CPM). *Bollettino di Psicologia Applicata*, *217*, 51-57.

SCOTT, C. & BYNG, S. (1989). Computer assisted remediation of a homophone comprehension disorder in surface dyslexia. *Aphasiology*, *3*(3), 301-320.

SHARE, D.L. (2008). On the anglocentricities of current reading research and practice: The perils of overreliance on an "outlier" orthography. P*sychological Bulletin*, *134*(4), 584-615.

SPINELLI, D., DE LUCA, M., DI FILIPPO, G., MANCINI, M., MARTELLI, M. & ZOCCOLOTTI, P. (2005). Length effect in word naming latencies: Role of reading experience and reading deficit. *Developmental Neuropsychology*, *27*(2), 217-235.

TORGESEN, J.K., ALEXANDER, A.W., WAGNER, R.K., TASHOTTE, C.A., VOELLER, K.K. & CONWAY, T. (2001). Intensive remedial instruction for children with severe reading disabilities: Immediate and long-term outcomes from two instructional approaches. *Journal of Learning Disabilities*, *34*(1), 33-58.

TRESSOLDI, P.E. (2008). I brani della batteria MT si possono leggere tutti con la stessa velocità? Norme trasversali dal secondo anno della primaria al terzo della secondaria di primo grado. *Dislessia*, *5*, 339-345.

TRESSOLDI, P.E., LONCIARI, I. & VIO, C. (2000). Treatment of specific developmental reading disorders, derived from single- and dual-route models. *Journal of Learning Disabilities*, *33*(3), 278-285.

TRESSOLDI, P.E., STELLA, G. & FAGGELLA, M. (2001). The development of reading speed in Italians with dyslexia: A longitudinal study. *Journal of Learning Disabilities*, *34*(5), 414-417.

TRESSOLDI, P.E., VIO, C. & IOZZINO, R. (2007). Efficacy of an intervention to improve fluency in children with developmental dyslexia in a regular orthography. *Journal of Learning Disabilities*, *40*(3), 203-209.

WANZEK, J., VAUGHN, S., WEXLER, J., SWANSON, E.A., EDMONDS, M.E. & KIM, A. (2006). A synthesis of spelling interventions and their effects on the spelling outcomes of student with LD. *Journal of Learning Disabilities*, *39*(6), 528-543.

WEEKES, B. (1996). Surface dyslexia and surface dysgraphia: Treatment studies and their theoretical implications. *Cognitive Neuropsychology*, *13*(2), 277-315.

WILLIAMS, K.J., WALKER, M.A., VAUGHN, S. & WANZEK, J. (2016). A synthesis of reading and spelling interventions and their effects on spelling outcomes for students with learning disabilities. *Journal of Learning Disabilities*, doi: 10.1177/0022219415619753.

WIMMER, H. (1993). Characteristics of developmental dyslexia in a regular writing system. *Applied Psycholinguistics*, *14*(1), 1-33.

WIMMER, H. & GOSWAMI, U. (1994). The influence of orthographic consistency on reading development: Word recognition in English and German children. *Cognition*, *51*(1), 91-103.

ZOCCOLOTTI, P., DE LUCA, M., DI PACE, E., JUDICA, A., ORLANDI, M. & SPINELLI, D. (1999). Markers of developmental surface dyslexia in a language (Italian) with high grapheme-phoneme correspondence. *Applied Psycholinguistics*, *20*(2), 191-216.

ZOCCOLOTTI, P., DE LUCA, M., DI FILIPPO, G., JUDICA, A. & SPINELLI, D. (2005). *Prova di lettura di parole e non parole*. Roma: IRCCS Fondazione Santa Lucia, http://www.hsantalucia.it/modules.php?name=Content&pa=showpage&pid=1032

ZOCCOLOTTI, P., DE LUCA, M., DI PACE, E., GASPERINI, F., JUDICA, A. & SPINELLI, D. (2005). Word length effect in early reading and in developmental dyslexia. *Brain and Language*, *93*(3), 369-373.

ZOCCOLOTTI, P., DE LUCA, M., JUDICA, A. & SPINELLI, D. (2008). Isolating global and specific factors in developmental dyslexia: A study based on the rate and amount model (RAM). *Experimental Brain Research*, *186,* 551-560.

ZOCCOLOTTI, P., DE LUCA, M., DI FILIPPO, G., JUDICA, A. & MARTELLI, M. (2009). Reading development in an orthographically regular language: Effects of length, frequency, lexicality and global processing ability. *Reading and Writing*, *22*(9), 1053-1079.