Do Phonologic and Rapid Automatized Naming Deficits Differentially Affect Dyslexic Children With and Without a History of Language Delay? A Study of Italian Dyslexic Children

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Objective: The study aims to verify whether phonologic and rapid automatized naming (RAN) deficits are present and associated in Italian dyslexic children and whether they differentially affect dyslexics with and without a history of previous language delay (LD).

Background: According to the phonologic core deficit hypothesis, dyslexia may stem from impairment of the representation and manipulation of phonemes and may be closely associated with oral language deficits. However, deficits in tasks not requiring fine-grained phonologic representations, such as RAN, have also been described in dyslexic children.

Methods: Thirty-seven children were selected on the basis of a reading deficit and were assigned to 2 groups according to whether or not they had a history of early LD as determined retrospectively by parental report. A battery of reading and writing, verbal working memory, metaphonologic, RAN, and visual search tests were administered.

Results: RAN deficits were shared by most dyslexics (with and without a history of LD), whereas phonologic deficits were mainly associated with a previous LD. This last condition did not result in a more profound impairment of reading and writing decoding skills.

Conclusion: In a shallow orthography such as Italian, RAN, not phonologic deficits, may represent the main cognitive marker of developmental dyslexia.

Received for publication August 8, 2005; accepted February 12, 2006.

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Supported by fundings from the Italian Ministry of Health to the Scientific Institute Stella Maris (2003 to 2004) and from a grant of the Italian Ministry of Education, University and Research (MIUR 2002) to Daniela Brizzolara and Pierluigi Zoccolotti.

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Key Words: developmental dyslexia, language delay, phonologic deficits, rapid automatized naming (RAN), shallow orthography

(*Cog Behav Neurol* 2006;19:141–149)

Phonologic abilities are considered crucial for acquisition of the correspondences between letters and sounds, the foundation of reading in alphabetic systems. Developmental dyslexics' difficulties on oral language tasks requiring phonologic processing, such as nonword repetition and explicit manipulation of speech sounds requiring fine grained phonologic representations, have supported the so-called "phonologic core" deficit hypothesis of developmental dyslexia.[1,2] This hypothesis also predicts that children who have phonologic difficulties in the preschool years will be particularly at risk for developing reading problems, as reading requires accurate mapping between orthography and phonology. Relevant evidence comes from studies on children with specific language impairment (SLI) who often display phonologic problems: a higher than expected rate of literacy difficulties has been reported for these children.[3,4]

However, the relationships among expressive phonologic impairment, language and reading difficulties are still controversial (for a recent review see Bishop and Snowling[5]) because not all SLI children develop specific reading problems. This is particularly the case for children with an expressive isolated phonologic deficit (ie, a defect in the production of the full range of phonemes, often along with a persistence of immature or unusual phonologic patterns, in the absence of physical disorders affecting speech output). In fact, most studies[6–8] have demonstrated that expressive phonologic deficits in kindergarten do not necessarily result in reading difficulties at school age. However, literacy problems associated with phonologic deficits were reported in at least 1 study.[9] Differences in persistence and severity may account for the variable outcome of children with expressive phonologic impairment.[5]

For some authors (eg, Bishop and Adams[6]), the best predictor of literacy is phonologic processing ability at the beginning of literacy acquisition. Phonologic processing refers to the ability to encode and retrieve phonologic information from long-term memory, use phonologic codes in working memory, and segment speech into phonemic units.[10] As phonologic processing difficulties are also considered a marker of dyslexic children, the continuity between oral and written language problems has been hypothesized at the level of phonologic processing deficits. It has long been documented that language delay (LD) is more frequent in dyslexic than in matched control children.[11,12] This finding suggests that a delay in language acquisition, even a transitory one, may determine weak phonologic abilities, which in turn would be responsible for the reading difficulties. Therefore, differences among dyslexics in terms of rate and mode of language development should be carefully taken into account when studying phonologic processing abilities in this clinical population.

Evidence supporting the phonologic core deficit of dyslexia has been gathered primarily from the study of English-speaking children learning an ''opaque'' orthography characterized by inconsistent grapheme-phoneme correspondence rules. According to Snowling,[2] the variability in reading impairment seen in English dyslexic children is accounted for by differences in the severity of individual phonologic processing deficits. However, phonologic deficits may play a different role in learning to read in languages with different orthographies, and may be less crucial in the case of shallow orthographies. Wimmer[13] found that German dyslexic children with a reading fluency deficit did not exhibit any impairment in phonologic short-term memory and phonologic awareness, but rather a deficient performance in rapid automatized naming (RAN) tasks. These tasks, originally designed by Denckla and Rudel,[14] require participants to name an array of familiar digits, pictures, letters or color patches in serial order as rapidly as possible. Many studies have showed that RAN accounts for sizeable variance in word reading when intelligence quotient, phonologic working memory, and metaphonologic skills are partialled out (eg, Wimmer,[13] Ackerman and Dykman,[15] Bowers,[16] Manis et al[17]). As a consequence, some authors have posited that RAN measures map a different dimension than phonologic processing, such as the automaticity with which character codes can be accessed in memory[18] or a more general ability in the smooth integration of a variety of speeded operations, such as visual recognition, lexical access, and articulatory processes.[19]

Italian is a language with high grapheme to phoneme regularity. It has been shown that Italian dyslexic children are characterized by a reading fluency deficit but relatively accurate decoding. They do not seem to have a specific deficit in nonword compared with word reading and are markedly affected by word length.[20–23] Notably, a similar pattern of impairment has been reported for spelling.[24] Overall, these features seem compatible with Italian dyslexic children's over-reliance on sublexical procedures, induced by the grapheme-phoneme regularity of Italian orthography. This is different from dyslexics of opaque orthographies who have a specific deficit in nonword reading, hence in the sublexical route (see Rack et al[25]).

Although some studies have started to characterize developmental reading deficits in Italian, very little is known about the performance of Italian dyslexic children on phonologic and RAN tasks. In the present study, we focused on the influence of a previous LD on phonologic and RAN deficits in Italian dyslexic children. For this purpose, 2 groups of Italian dyslexics with and without a history of LD (noLD) were compared on a series of reading, spelling, phonologic and RAN tasks. As a control for the RAN task, we adopted a visual search test using the same stimulus material; we expected no deficit in this condition. Because normative data on Italian children are available for all of these test materials, we were able to evaluate the dyslexics' degree of impairment on all of the dimensions.

On the basis of the possible association between phonologic deficits and oral language deficits, we expected LD dyslexic children to be impaired on phonologic tests compared with noLD children. In contrast, as the reviewed evidence indicates that RAN performance taps a different dimension than phonologic processing, we expected that performance on this task would be independent of the presence of a previous LD.

MATERIALS AND METHODS

Subjects

Participants were selected on the basis of consecutive referrals to the Child Neurology Unit of the IRCCS Stella Maris from January 2002 to November 2004 for suspected reading disability. Children were included in the study if they met the following criteria:

- general intelligence level within normal limits, as assessed by Raven's Colored Progressive Matrices;
- impaired scores on standardized reading tests (see below);
- regular school attendance;
- absence of adverse conditions in prenatal, perinatal, and postnatal clinical history;
- no neurologic abnormalities on a standardized neurologic examination;
- no clinical evidence of specific oral language impairment at the time of assessment. Assessment was carried out by a child neuropsychiatrist with special expertise in speech and language disorders (A.C.) using a semi-structured interview. Normal fluency, well-formed sentences and the absence of phonologic, lexical and grammatical errors in conversation were considered as signs of adequate language organization.

Thirty-seven children fulfilled these criteria. They ranged in age from 8 to 15 years; 24 were males and 13 females. Three children had been previously diagnosed as attention deficit hyperactivity disorder (ADHD), according to Diagnostic and Statistical Manual of Mental Disorders Version IV criteria.[26] In a few cases, the children did not complete the experimental battery.

A child neuropsychiatrist investigated the clinical history of each child by means of an assessment interview with the parents. The parents were also asked to fill out a questionnaire (developed in our clinic) on the motor, cognitive, and language developmental milestones. To encourage the parents to recall basic language milestones, examples of typical children's utterances were provided. Each child also received an individual neurologic assessment to exclude the presence of abnormal neurologic signs.

Two independent raters (child neuropsychiatrists expert in speech and language pathology), who did not participate in further testing of the children, checked all the questionnaires. The presence of slow vocabulary growth (between 2 and 3 y of age), late combinatory use of words (after 30 mo) and/or delay in the use of first sentences, persistence of phonologic mispronunciations beyond the fourth year, were considered as signs of delayed language development. On the basis of the results of the questionnaires, the children were considered as having either a negative (noLD) or a positive (LD) history of LD.

Twenty-two children (14 male, 8 female) were considered as having had noLD. They had a mean age of 128.6 months (SD = 24.2); 2 male nontwin brothers were present in this group. Two of the children in this group had a history of ADHD. Retrospective evidence of early LD was found in 15 children (10 male, 5 female). They had a mean age of 129.4 months (SD = 21.7); 2 monozygotic female twins were present in this group. One child in this group was previously diagnosed as ADHD. No significant differences for age ($t_{(35)} = 0.10$) or sex ($\chi^2_{(1)} = .04$) were present between LD and noLD groups.

Test and Procedure

Intelligence

Normal performance on Raven's Colored Progressive Matrices (z score greater than -1.5, based on Italian normative data[27]) was used as a screening criterion. Consistently, both groups scored well within normal limits. However, on average noLD children scored higher ($z = 0.38$, SD = 0.70) than LD children ($z = -0.25$, SD = 0.70; $t_{(29)} = 2.4$, $P < 0.05$).

Reading

Reading and writing of single words, nonwords and reading comprehension of text were assessed by means of 2 standardized Italian batteries.[28–30]

Two subtests of the Developmental Dyslexia and Dysorthography Battery[28] were used to assess children's ability to read aloud a list of 112 words and 1 of 48 nonwords. Number of errors and speed of reading (syllables/s) were scored. Raw scores were converted to z scores according to standard reference data.[28]

A z score lower than –1.5 (either for accuracy and/or for speed) with respect to the mean of the normative sample in at least one of the conditions (words, nonwords) was taken as the pathologic performance cut-off. Most children failed on both tests and on both parameters (speed and accuracy of words and nonwords), that is, 67% failed on at least 3 out of 4 measures.

Text reading comprehension was examined (but not used as a screening test) with a standard reading achievement test (MT Reading test).[29,30] A meaningful passage was presented without a time limit. The participant had to read it silently and respond to multiple-choice questions. Stimulus materials, number of questions (10 or 15) and related reference norms varied for school level. Raw scores were converted to z scores according to standard reference data.[29,30]

Writing

Two subtests of the Developmental Dyslexia and Dysgraphia Battery[28] were used to check spelling. They consisted of a list of 48 words and a list of 24 nonwords. The number of errors was scored. Raw scores were converted to z scores according to standard reference data.[28]

Phonologic Skills

Phonologic processing abilities were measured with tasks tapping verbal working memory, phonemic awareness, and phonemic fluency. The tests used are outlined below.

Verbal Working Memory

Verbal working memory was assessed by a computerized test[31] requiring the repetition of lists of words of different length, lexical frequency, and phonologic similarity. Two lists of short (2-syllable) and long (4-syllable) high-frequency words (HF-short an HF-long) and 2 lists of phonologically similar and dissimilar 2-syllable, low-frequency words (Ph-sim and Ph-dissim) were presented. Stimuli presentation was controlled by a PC using dedicated software. For each list, sequences of increasing length were presented (2 to 7 words); 5 strings were given at each length. The child was required to repeat the words in the correct order. The list presentation was interrupted when the child failed on 4 out of 5 strings of the same length. For each subject (in each condition), a characteristic performance was defined as the length at which he gave 50% correct answers. Scores being discrete numbers, an exact 50% was not always hit; in such cases the expected estimate was given by linear interpolation. This scoring allows for a more fine-grained evaluation of individual performance than standard span measures. For example, a child who has repeated correctly 5 sequences of 2 and 3 words, 3 sequences of 4 and 1 of 5 words obtains a score of 4.21. With reference to a normative sample of 190 children between 5 and 17 years of age, the software transforms the raw score into a z score.

Phonologic Awareness

A spoonerism test was used to investigate phonologic awareness, modified from the competenze metafonologiche[32] battery of metaphonologic skills. The test required the experimenter to pronounce pairs of words; the child had to produce 2 new words by transposing the first consonants of the 2 words (luna [moon]-dente [tooth] → duna [dune]-lente [lens]). Eighteen pairs of either 2 or 3-syllable words were presented. Both accuracy and response time were scored. One point was given for each word correctly produced (maximum score = 36). Using a stopwatch, the experimenter measured the time (in s) the child needed before uttering the 2 words (up to a 90 s time limit). Both scores were converted to z values with reference to a sample of 141 children with an age between 8 and 14 years.[33]

Phonemic Fluency

Phonemic fluency was measured with a test[34] requiring the child to produce as many words as possible beginning with a given phoneme within 1 minute. Three trials (with phonemes /f/, /p/, and /l/) were given. The score was the total number of words produced, converted to z scores, with reference to a group of 116 normal children with an age between 8 and 14 years.

RAN and Visual Search Skills

We used a RAN and a Cancellation test.[35] For both tests, stimuli were matrices of colors, objects or digits. In each condition, 5 different stimuli were presented. The colors were presented in small 1 by 1 cm squares; they were black, blue (RGB 51-102-255), red (RGB 221-8-6), yellow (RGB 252-243-5), or green (RGB 31-183-20). The objects were line drawings of a hand, a train, a star, a pear, and a dog. The dog, train, and pear were generated with Cairo font (size 24); the star with Monotype Sorts font (size 36); and the hand with Windings font (size 48). We used the digits 2, 4, 6, 7, and 9, generated with Helvetica font (size 24). There were 10 rows of 5 stimuli in each matrix for a total of 50 stimuli. We generated 2 different matrices for each condition.

In the RAN test, the child was requested to name each stimulus in the matrix as quickly and as accurately as possible. In the Cancellation test, the child was requested to cancel 1 of the 5 stimuli as quickly and as accurately as possible. The targets to be cancelled were the green square, the star, and the number 7 for the color, object, and digit conditions, respectively.

Stimuli were placed on a flat surface at ca. 40 cm from the child. A practice trial with a small (25 stimuli) matrix was run for each condition. Time to complete the task was measured separately for each matrix using a stopwatch. In the RAN test, the dependent measure was the mean time in seconds/syllable. This measure was adopted because the stimuli in the various conditions varied slightly for number of syllables (either 1 or 2). Naming errors were also measured. In the Cancellation test, the dependent measure was the mean time in seconds/item. Cancellation errors (either omissions or false positives) were also measured. For both tests, raw scores were converted to z scores according to reference data for Italian children.[35]

Data Analysis

Mean performances of dyslexics on the various tests were examined both as raw data and as z scores. Raw data are presented to illustrate the absolute performance level of Italian dyslexic children (note, however, that these data partly depend on the age composition of the sample). Z Score data allowed evaluating the degree of impairment in the various conditions with respect to age-matched reference data. This is particularly important in conditions in which levels vary in terms of general difficulty. In fact, if conditions involving different basic difficulties are used to compare pathologic versus "normal" groups of subjects, it is expected the most difficult conditions should produce larger differences in the less proficient group. This is well known as the overadditivity effect (for a discussion see Faust et al[36]).

Comparisons between the 2 groups were carried out on the z scores using ANOVAs with group as unrepeated factor. Depending on the test, other repeated measures were considered, for example, type of stimulus when considering reading (or writing) words and nonwords. As the 2 groups were different in nonverbal intelligence the analyses were replicated using intelligence quotient as covariate. The results of these analyses were identical to those of the original. Consequently, only the former analyses will be presented.

RESULTS

Reading and Writing

Reading Speed and Accuracy

Mean performances on the reading and spelling tests are presented in Table 1 as raw data and as z scores. The children made relatively few word reading errors (ca. 10%); however, this is pathologic compared with the performances of Italian normal readers who, by this age, read almost flawlessly. They made more nonword reading errors, a difficult condition also for proficient readers. Their reading speed was severely impaired as well; the children read little more than 1 syllable per second in the case of words (and less for nonwords); this was less than half the speed of 10-year-old children who read on average 3 syllables per second.[28]

Z Score data (right side of the table) allowed evaluating the degree of impairment in the various conditions with respect to age-matched reference data. An inspection of the table indicates that both groups were severely impaired in word and nonword reading compared with the normative sample. The deficit was more severe for speed than for accuracy and for words than for nonwords.

An ANOVA with group (noLD, LD) as unrepeated factor and type of stimulus (words, nonwords) and type of measure (accuracy, speed) as repeated factors was performed on z scores. The analysis showed a type of stimulus main effect ($F_{(1,35)} = 11.37$, $P < 0.005$): word reading performance (-5.32) was lower than nonword reading performance (-3.70). The type of measure effect

TABLE 1. Mean (and SD) Performance of Dyslexics With (LD) and Without (noLD) a History of LD on Reading and Spelling Tests

	Raw Scores Mean (SD)		z Scores Mean (SD)	
	noLD	LD	noLD	LD
Reading				
Words (% of errors)	8.2 (7.7)	12.5 (10.7)	− 2.52 (2.64)	− 5.38 (5.61)
Nonwords (% of errors)	25.6 (13.3)	28.3 (11.5)	− 2.11 (1.55)	− 2.66 (1.91)
Words (syllables/s)	1.26 (0.67)	1.30 (0.53)	− 6.04 (4.10)	− 7.36 (7.61)
Nonwords (syllables/s)	0.87 (0.40)	0.97 (0.37)	− 4.82 (3.54)	− 5.21 (5.98)
Text comprehension (% of correct responses)	69.4 (21.4)	52.8 (25.8)	− 0.07 (0.80)	− 1.01 (1.10)
Writing				
Words (% of errors)	14.2 (16.3)	15.4 (13.9)	− 4.01 (6.29)	− 4.35 (3.92)
Nonwords (% of errors)	14.4 (12.1)	22.9 (20.7)	− 0.33 (1.38)	− 1.15 (1.93)

was reliable ($F_{(1,35)} = 11.38$, $P < 0.005$): children were more impaired for speed (− 5.86) than for accuracy (− 3.17). The group effect was not significant ($F_{(1,35)} = 1.44$, NS). No interaction was significant.

Reading Comprehension

Reading comprehension was only mildly affected in LD children and was normal in noLD children (Table 1).

On average, the LD group scored significantly lower ($z = -1.01$) than the noLD group ($z = -0.07$; $F_{(1,33)} = 8.54$, $P < 0.01$).

Writing

Children made several errors in writing to dictation, with little absolute difference between words and nonwords (see last 2 rows of Table 1). With reference to normative data, word writing performance was much more impaired than nonword performance (see last 2 rows of Table 1).

An ANOVA with group (noLD, LD) as unrepeated factor and type of stimulus (words, nonwords) as repeated factor showed a type of stimulus main effect ($F_{(1,32)} = 14.97$, $P < 0.001$): word writing performance ($z = -4.17$) was more affected than nonword writing performance ($z = -0.74$). The main group effect and the group by type of stimulus interaction were not significant.

Comments

Children were severely impaired both in single word and nonword reading. However, the deficit was more apparent for words than for nonwords and for speed than for accuracy. This pattern is consistent with previous evidence indicating that the nonword reading deficit, often reported among English-speaking children, is not pathognomonic of Italian dyslexics (eg, Zoccolotti et al,[20] Judica et al[21]). A parallel deficit was present in writing, confirming a tendency already reported for Italian children.[24] Also in this case, nonword writing was not specifically affected compared with word writing. Overall, as a group the children seemed more impaired in lexical than sublexical functioning for both reading and writing. By and large, the presence of a previous LD did not affect reading and writing decoding skills.

In the sample as a whole, only a mild deficit was present in reading comprehension. Therefore, if enough time is provided, the child can reach a reasonable understanding of the text; this finding confirms previous observations in Italian dyslexics.[20,21] However, LD children performed more poorly than noLD children. The present data suggest that a mild deficit in reading comprehension may be the outcome of a previous oral language problem.

Phonologic Skills

As a group, noLD children showed a low average performance: on most tests they scored within one standard deviation of the mean (Table 2). By contrast, LD children seemed more impaired and scored lower than one standard deviation on all tests except the Phonemic Fluency test. Percentages of children with a performance below the –1.5 z score are also presented in Table 2. Despite some between-test variability, it is apparent that only a minority of noLD children were impaired and that the LD children were more frequently affected.

As for verbal working memory, an ANOVA with group (noLD, LD) as unrepeated factor and type of measure (HF-short, HF-long, Ph-sim, and Ph-dissim words) as repeated factors was performed on the z scores data. The analysis showed a group main effect ($F_{(1,30)} = 7.39$, $P < 0.01$): LD children performed worse (− 1.38) than noLD children (− 0.76). The type of stimulus main effect was reliable ($F_{(3,90)} = 7.93$, $P < 0.001$). Tukey a posteriori comparisons revealed that recalling HF-short words (− 0.73) was less impaired than recalling either Ph-dissim words (− 1.20) and Ph-sim words (− 1.48; both $P < 0.05$); moreover, recalling HF-long words (− 0.86) proved better than recalling Ph-sim words ($P < 0.05$). The group by type of stimulus interaction was not significant.

In the Spoonerism test, an ANOVA on the z scores with group (noLD, LD) as unrepeated factor and type of measure (accuracy, speed) as repeated factor indicated a group main effect ($F_{(1,30)} = 6.15$, $P < 0.05$): LD children performed worse (− 1.81) than noLD children (− 0.79). The type of measure factor and the group by type of measure interaction were not significant.

No difference was present in the case of the Phonemic Fluency test ($F_{(1,31)} = 2.49$, NS).

TABLE 2. Mean (and SD) Performance of Dyslexics With (LD) and Without (noLD) a History of LD on the Various Phonological Tests

	noLD			LD		
	Mean	SD	%	Mean	SD	%
Verbal Working Memory						
HF-short words*	−0.38	1.05	9	−1.09	1.14	31
HF-long words†	−0.65	0.92	19	−1.07	0.88	50
Ph-sim words‡	−1.24	0.79	40	−1.73	0.99	77
Ph-dissim words§	−0.77	0.93	14	−1.63	0.99	50
Spoonerism test						
Correct responses	−0.94	1.33	43	−2.04	1.99	50
Speed	−0.65	0.92	19	−1.59	1.25	45
Phonemic fluency	−0.63	0.91	11	−1.02	0.81	33

Data are z scores based on age-matched reference data. Percentages of children with z scores lower than -1.5 are also shown. The 2 groups did not differ on phonemic fluency; the main group effect was significant for both the Verbal Working Memory and Spoonerism Test, indicating poorer performance for LD children; no group by condition interaction was present for either test (see text for more details).

*HF-short words = high frequency, 2-syllable words.

†HF-long words = high-frequency, 4-syllable words.

‡Ph-sim words = low-frequency, phonologically similar, 2-syllable words.

§Ph-dissim words = low-frequency, phonologically dissimilar, 2-syllable words.

Comments

The pathologic performance on phonologic processing tests was influenced by the presence of a previous LD. LD children performed significantly worse than noLD children on verbal working memory and spoonerism tests.

Working memory tasks and phonemic fluency have also been conceptualized as tapping executive functions. However, it is unlikely that the performance in these tasks was significantly influenced by the presence of deficits in executive functions in our children. In fact, phonemic fluency was only mildly affected in our sample, whereas the working memory task mainly stressed coding and maintenance of phonologic information rather than overloading the executive system.

The finding that noLD children were only mildly affected in phonologic processing tasks indicates that, at least in a subgroup of Italian dyslexic children, reading disabilities may occur in the absence of clear phonologic working memory and metaphonologic deficits.

Cancellation and Naming Tests

Accuracy on the Cancellation test was high for both groups of dyslexics. In the noLD group, errors were 0.22%, 0.25%, and 0.04% for the color, object, and digit conditions, respectively. In the LD group, these figures were 0.37%, 0.63%, and 0.12%. RAN test performance was also quite high. The noLD dyslexics made 0.30%, 0.13%, and 0.22% errors in the color, object, and digit conditions, respectively. LD readers made 1.00%, 0.50%, and 0.31% errors. Consequently, for both tests statistical comparisons were restricted to speed measures.

Mean performances (in z scores) on the RAN and Cancellation tests are presented in Table 3 together with the percentage of children who scored pathologically in each condition (ie, children with z scores below -1.5). Both groups were relatively spared on the Cancellation test, but the noLD group performed slightly worse than the LD group. Inspection of individual data revealed that 1 of the 2 noLD children with a diagnosis of ADHD scored quite poorly on this test ($z = -6.43$, -6.79, and

TABLE 3. Mean (and SD) Performance of Dyslexics With (LD) and Without (noLD) a History of LD on the Cancellation and Naming Tests

	noLD			LD		
	Mean	SD	%	Mean	SD	%
Cancellation test						
Colours	−0.89	1.92	23	−0.08	0.99	7
Objects	−1.10	2.02	36	−0.11	0.69	0
Digits	−0.82	1.67	23	−0.04	1.19	7
Naming test						
Colours	−2.00	1.92	54	−2.85	3.36	50
Objects	−1.99	2.26	41	−3.22	3.30	57
Digits	−4.57	3.43	77	−7.78	7.60	71

Data are z scores based on age-matched reference data. Percentages of children with z scores lower than -1.5 are also shown. Note the higher proportion of impaired performances in the Naming as compared to the Cancellation test. No group main effect or group by condition interaction was present for Cancellation and Naming tests (see text for more details).

-3.88 for the color, object and digit condition, respectively). The other 2 children with ADHD (1 noLD and 1 LD) had scores that were compatible with the means of their group. By contrast, the 2 groups were severely affected on the RAN test in terms of mean performance and percentage of impaired children. The deficit seemed more marked for the digit condition.

For the Cancellation test, an ANOVA with group (noLD, LD) as unrepeated factor and type of stimulus (colors, objects, digits) as repeated factor was performed (*z* scores). No main effect or interaction was reliable. A similar ANOVA was performed for the RAN test. The analysis showed a type of stimulus main effect ($F_{(2,68)} = 24.25$, $P < 0.001$). Tukey a posteriori comparisons, revealed that digit naming performance (-6.17) was more impaired than color (-2.42) and object performance (-2.60; in both cases $P < 0.05$), which did not differ from each other. The group main effect and the group by type of stimulus interaction were not significant.

Comments

The children's ability to search visually for a target was spared. This finding is consistent with what is reported in other studies using the RAN procedure (eg, Wimmer et al[37]). However, the noLD group had fairly low scores on this test. As the cancellation measures may load on an attentional factor, this result may be influenced by the presence of ADHD among noLD children. The association between ADHD and low performance in this task was, however, not consistent: out of the 3 children with ADHD in the entire sample, only 1 child (noLD group) had an impaired performance, whereas the other 2 children with ADHD (one in the noLD and the other in the LD group) did not show a selective deficit. This observation is compatible with the inconsistent results found in studies on selective attention deficits in individuals with ADHD (eg, Young and Gudjonsson,[38] Fisher et al,[39] Huang-Pollock et al[40]).

A speed deficit was apparent in the RAN test. Severe slowness in RAN was present in both groups in terms of both mean performance and percentage of children performing pathologically. These observations are consistent with several other studies showing that RAN is selectively affected in dyslexic children in both opaque and transparent orthographies (for a review see Wolf and Bowers[19]).

Summary of Results

We can summarize our results in 3 main outcomes:

First, for some tests there was a clear impairment as compared with reference normative data, but no reliable difference between noLD and LD children. Clearly, this was the case for the reading of words and nonwords. Both groups of children were also severely impaired in writing, particularly in the case of words. Finally, both groups were quite affected on the Naming tests.

Second, there were cases in which the LD children were more affected than the noLD children. This was true for the Reading comprehension test and for 2 out 3 measures of phonologic skills. On these tests, the performance of noLD children was either normal or only marginally affected in comparison with normative data.

Third, both groups showed a largely spared visual search performance.

DISCUSSION

In the present study, we investigated phonologic and RAN abilities in Italian dyslexic children. Not all children in our sample had phonologic processing deficits, but most of those who did had a history of LD. LD children were impaired in phonologic tasks involving working memory and metaphonologic skills. The deficient working memory abilities found in our group of LD dyslexics may be a residual sign of their early language impairment, supporting the view that a working memory deficit is a typical marker of language impairment often persisting in children in whom language problems have resolved.[41] The lower performance of LD children compared with NoLD children on a complex metaphonologic task such as spoonerism, which requires that items be temporarily maintained in a phonologic code, may have been exacerbated by their reduced working memory abilities. Children with a negative history of language development scored in the average range on most phonologic tasks. This finding indicates that dyslexia can occur in the absence of clear phonologic impairment in a language with shallow orthography such as Italian. In contrast, a recent study by Ramus and colleagues[42] comparing English dyslexics across several different cognitive tasks demonstrated that the most significant cognitive problem, shared by all individuals in the sample, was a specific phonologic deficit. A different picture emerges from our study. Indeed, if phonologic processing deficits were the core symptom also of Italian dyslexics, we should expect all dyslexics to have phonologic processing deficits and those with weaker phonologic abilities to be more impaired in reading and writing skills. Neither prediction was confirmed. Indeed, in our study a phonologic impairment was not the common marker of all dyslexics. Moreover, dyslexic children with and without phonologic processing deficits were equally impaired in reading and writing and had a similar behavioral profile. In reading, both groups were more affected in speed than in accuracy. Further, they did not show a more severe deficit in nonword reading than in word reading, as has been reported in other studies on Italian dyslexic children.[20,21] This pattern of errors was confirmed for spelling, consistently with recent observations by Angelelli et al.[24]

A between group difference was detected in text comprehension, with LD scoring significantly lower than noLD children. This difference may be a consequence of the early LD of our LD dyslexics, as suggested by studies on literacy outcomes in preschool children with SLI (Bishop and Snowling[5]) showing that poor comprehension of written material is the most prominent feature of literacy development in this clinical population. In a pioneering prospective study, Bishop and Adams[6] found that the frequency of comprehension problems in a group of school-aged children who had been diagnosed as language impaired in preschool years was significantly above predictions in the normal population. On the other side, only a few of the children in the same sample (8%) met the diagnostic criteria for specific decoding difficulties in reading. Weak decoding skills in SLI children have also been reported in other studies.[41,43] However, it should be noted that in many studies children with previous language impairment do not meet the diagnostic criteria for dyslexia because they are often only slightly impaired in reading decoding parameters (accuracy and/or speed). Thus, theories that view SLI and dyslexia on a continuum (eg, Tallal et al[4]) sharing common phonologic processing deficits are not unequivocally supported by longitudinal studies of SLI children.

Our data on language development of dyslexic children are necessarily retrospective because the children were referred to us for assessment of literacy problems at school age. We tried to maximize reliability by obtaining information from parents in a clinical interview and in a semistructured questionnaire, independently rated by 2 experts in developmental speech and language pathology. However, we are aware that this approach has limitations, particularly in terms of obtaining detailed information about the types of language problems encountered previously. Nevertheless, it seems erroneous to disregard retrospective information on language development when evaluating dyslexic children simply because direct information is unavailable. By contrast, we propose that such information may be useful in studying the cognitive problems underlying dyslexia and might help to differentiate deficits associated with dyslexia from those that cause dyslexia. Comparing dyslexic children with and without a previous history of LD allowed us to demonstrate that verbal working memory and metaphonologic deficits are not the only cause of dyslexia in Italian, as many dyslexic children in our sample (mostly in the noLD group) had adequate phonologic processing skills. Therefore, it seems that phonologic deficits may not represent a specific marker of the reading deficit in Italian dyslexics, but could be a residual disability of a subset of dyslexics mainly associated with a previous LD.

The relationship between the cognitive and the behavioral level of dyslexia has been long debated.[44] One might speculate that phonologic problems interfere with the construction of correct mappings between phonology and orthography affecting development of the phonologic route of reading. Thus, we should expect LD children to perform worse on tasks requiring sublexical procedures (nonword decoding) that rely more on segmental operations. On the contrary, both LD and noLD children were less impaired in the use of sublexical than lexical procedures, as shown by the fact that, compared with normal readers, nonword reading was not more affected than word reading. The prevalent reliance on the sublexical procedure in Italian dyslexic children has been reported both in the case of reading[20,21] and spelling[24] deficits. The reliability of grapheme-phoneme correspondences facilitates the acquisition of phonologic recoding and phoneme awareness both in normal and in dyslexic children with phonologic impairment.

A deficit on a task requiring the rapid naming of visual targets was found in both groups of children and did not seem to be influenced by the presence of phonologic deficits because LD children were just as slow on the RAN test as noLD children.

Our data seem coherent with Wolf and Bowers'[19] "double deficit" hypothesis, which states that "phonologic deficits and processes underlying naming speed are separable sources of reading dysfunction" (p. 416). According to our results, deficits in both domains may characterize children with a previous LD who do not show a significantly more compromised reading performance than children without a previous LD and a single deficit in rapid naming. The influence of phonologic factors in reading Italian, a language with consistent orthography, may be reduced as compared with languages with inconsistent orthographies and more complex phonologic structures. In the latter case, the combined presence of phonologic and RAN deficits leads to more profound reading impairments compared with those found in children with a single delay. In our sample of dyslexics the weight of a RAN deficit seems prominent: it is the most frequent deficit and the one shared by children with and without a previous language delay. This cognitive pattern may be consistent with the main difficulty of Italian dyslexics in developing a direct route in processing written words; a specific link, in fact, has been shown between performance on RAN tests and direct access to the orthographic lexicon.[17]

There is a heated debate in the literature on which components of the RAN task are critically involved in dyslexia. According to some authors, the processes involved in RAN entail a phonologic dimension different from that required in metaphonologic and working memory tasks; RAN tasks may tap speeded retrieval of phonologic codes from long-term storage[45] rather than require phonologic fine-grained representations. Other nonphonologic explanations of the naming speed deficit in reading may involve visual search processes, automatization of name retrieval and precisely timed integration between visual and lexical codes.[19] In our study, the control condition involving only the visual search component of the task allowed us to demonstrate that visual search difficulties were not responsible for the RAN deficit. In fact, the majority of the dyslexics performed like the controls on the cancellation task, which did not require verbalization of targets.

Overall, reading deficits in regular orthographies may stem from difficulty in automatizing orthographic processing. Although this dimension seems relevant in the case of both opaque and transparent orthographies (for a review see Wolf and Bowers[19]), it may well be the most pathognomonic sign of reading deficiency in languages with regular orthographies where reading speed deficits are prominent.[13,20,21]

ACKNOWLEDGMENTS

The authors thank the dyslexic children who underwent long testing sessions and their parents for helpful cooperation. The authors are also grateful to Silvia Volterrani for collecting some of the spoonerism data and also to Michela del Viva and Roberta Igliozzi for providing some normative data for the phonemic fluency task.

REFERENCES

1. Stanovich KE, Siegel LS. Phenotypic performance profile of reading-disabled children: a regression-based test of the phonological core variable-difference model. *J Edu Psychol*. 1994;86:24–53.
2. Snowling NJ. *Dyslexia*. 2nd ed. Oxford: Blackwell; 2000.
3. Haynes C, Naidoo S. *Children With Specific Speech and Language Impairment. Clinics in Developmental Medicine: Vol. 119*. London: MacKeith Press; 1991.
4. Tallal P, Allard L, Miller S, et al. Academic outcomes of language impaired children. In: Hulme C, Snowling M, eds. *Dyslexia: Biology, Cognition and Intervention*. London: Whurr; 1997:167–181.
5. Bishop DV, Snowling MJ. Developmental dyslexia and specific language impairment: same or different? *Phychol Bull*. 2004;130: 858–886.
6. Bishop DV, Adams C. A prospective study of the relationship between specific language impairment, phonological disorders and reading retardation. *J Child Psychol Psychiatry*. 1990;31: 1027–1050.
7. Catts HW. Early identification of dyslexia: evidence from a follow-up study of speech-language impaired children. *Ann Dyslexia*. 1991; 41:163–177.
8. Catts HW. The relationship between speech-language impairments and reading disabilities. *J Speech Hear Res*. 1993;36:948–958.
9. Bird J, Bishop DV, Freeman NH. Phonological awareness and literacy development in children with expressive phonological impairments. *J Speech Hear Res*. 1995;38:446–462.
10. Kamhi AG, Catts HW. Toward an understanding of developmental language and reading disorders. *J Speech Hear Disord*. 1986;51: 337–347.
11. Rutter M, Yule W. Neurological aspects of intellectual retardation and specific reading retardation. In: Rutter M, Tizard J, Whitmore K, eds. *Educational, Health and Behavior*. London: Longman; 1970:57–74.
12. Naidoo S. *Specific Dyslexia*. London: Pitman; 1972.
13. Wimmer H. Characteristics of developmental dyslexia in a regular writing system. *Appl Psycholinguist*. 1993;14:1–33.
14. Denckla M, Rudel RG. Rapid "automatized" naming (RAN): dyslexia differentiated from other learning disabilities. *Neuropsychologia*. 1976;14:471–479.
15. Ackerman PT, Dykman RA. Phonological processes, confrontational naming and immediate memory in dyslexia. *J Learn Disabil*. 1993;26:597–609.
16. Bowers PG. Tracing symbol naming speed's unique contributions to reading disabilities over time. *Reading Writ Interdisciplinary J*. 1995;7:189–216.
17. Manis FR, Doi LM, Bhadha B. Naming speed, phonological awareness, and orthographic knowledge in second graders. *J Learn Disabil*. 2000;33:325–333.
18. Spring C, Davis JM. Relations of digit naming speed with three components of reading. *Appl Psycholinguist*. 1988;9:315–334.
19. Wolf M, Bowers PG. The double-deficit hypothesis for the developmental dyslexias. *J Edu Psychol*. 1999;91:415–438.
20. Zoccolotti P, De Luca M, Di Pace E, et al. Markers of developmental surface dyslexia in a language (Italian) with high grapheme-phoneme correspondence. *Appl Pyscholinguist*. 1999;20: 191–216.
21. Judica A, De Luca M, Spinelli D, et al. Training of developmental surface dyslexia improves reading performance and shortens eye fixation duration in reading. *Neuropsychol Rehabil*. 2002;2: 177–197.
22. Spinelli D, De Luca M, Di Filippo G, et al. Length effect in word naming in reading: role of reading experience and reading deficit in Italian readers. *Dev Neuropsychol*. 2005;27:217–235.
23. Zoccolotti P, De Luca M, Di Pace E, et al. Word length effect in early reading and in developmental dyslexia. *Brain Lang*. 2005;93: 369–373.
24. Angelelli P, Judica A, Spinelli D, et al. Characteristics of writing disorders in Italian dyslexic children. *Cogn Behavl Neurol*. 2004;1: 18–31.
25. Rack JP, Snowling MJ, Olson R. The nonword reading deficit in developmental dyslexia: a review. *Read Res Quart*. 1992;27:29–53.
26. American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders*. 4th ed. Washington DC: American Psychiatric Association; 1994.
27. Pruneti CA. Aggiornamento della standardizzazione italiana del test delle Matrici Progressive Colorate di Raven (CPM). *Bollettino di Psicologia Applicata*. 1996;217:51–57.
28. Sartori G, Job R, Tressoldi PE. *Batteria per la Valutazione Della Dislessia e Della Disortografia Evolutiva*. Firenze: Organizzazioni Speciali; 1995.
29. Cornoldi C, Colpo G. *Prove di Lettura MT per la Scuola Elementare-2*. Manuale. Firenze: Organizzazioni Speciali; 1998.
30. Cornoldi C, Colpo G. *Nuove Prove di lettura MT per la Scuola Media Inferiore*. Manuale. Firenze: Organizzazioni Speciali; 1995.
31. Ferretti G, Brizzolara D, Casalini C. Phonological working-memory Test. Software produced within the research project "Neuropsicologia e Neurolinguistica" financed by Italian Ministry of Health, IRCCS Stella Maris, Pisa; 2003.
32. Marotta L, Trasciani M, Vicari S. *CMF. Valutazione Delle Competenze Metafonologiche*. Trento: Erickson; 2004.
33. Brizzolara D. Technical Report for Italian Ministry of Health, IRCCS Stella Maris; 2005.
34. Brizzolara D, Brovedani P, Tomaiolo F, et al. Technical report, Ricerca finalizzata 1/95 Italian Ministry of Health, IRCCS Stella Maris; 1998.
35. Di Filippo G, Brizzolara D, Chilosi A, et al. Rapid naming, not cancellation speed or articulation rate, predicts reading in an orthographically regular language (Italian). *Child Neuropsychol*. 2005;11:349–361.
36. Faust ME, Balota DA, Spieler DH, et al. Individual differences in information-processing rate and amount: implications for group differences in response latency. *Psychol Bull*. 1999;125:777–799.
37. Wimmer H, Mayringer H, Landerl K. Poor reading: a deficit in skill-automatization or a phonological deficit? *Sci Stud Reading*. 1998;2:321–340.
38. Young S, Gudjonsson GH. Neuropsychological correlates of the YAQ-S and YAQ-I self- and informant-reported ADHD symptomatology, emotional and social problems and delinquent behaviour. *Br J Clin Psychol*. 2005;44:47–57.
39. Fischer M, Barkley RA, Smallish L, et al. Executive functioning in hyperactive children as young adults: attention, inhibition, response perseveration, and the impact of comorbidity. *Dev Neuropsycol*. 2005;27:107–133.
40. Huang-Pollock CL, Nigg JT, Carr TH. Deficient attention is hard to find: applying the perceptual load model of selective attention to attention deficit hyperactivity disorder subtypes. *J Child Psychol Psychiatry*. 2005;46:1211–1218.
41. Stothard SE, Snowling MJ, Bishop DVM, et al. Language impaired preschoolers: a follow-up into adolescence. *J Speech Lang Hear Res*. 1998;41:407–418.
42. Ramus F, Rosen S, Dakin S, et al. Theories of developmental dyslexia: insights from a multiple case study of dyslexic adults. *Brain*. 2003;126:841–865.
43. Catts HW, Fey ME, Tomblin JB, et al. A longitudinal investigation of reading outcomes in children with language impairments. *J Speech Lang Hear Res*. 2002;45:1142–1157.
44. Frith U. Paradoxes in the definition of dyslexia. *Dyslexia*. 1999;5: 192–214.
45. Wagner RK, Torgesen Jk, Laughon PL, et al. Development of young readers' phonological processing abilities. *J Edul Psychol*. 1993;85:83–103.

