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THE WORD CHAIN TEST: A SHORT COLLECTIVE SCREENING FOR IDENTIFICATION OF CHILDREN AT RISK FOR READING DISABILITIES

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Currently, no short collective screening measure effectively assesses silent word decoding skills in Italian primary and secondary school children. Jacobson (1995) described a test of silent words recognition, called Word Chain Test (WCT), which appeared a valid method for detecting children with reading difficulties. The aim of the present study was to validate an Italian version of the WCT. In Study 1, we presented normative data in a sample of 1,154 children from Grade 1 to Grade 8, and measured both concurrent validity and internal consistency. We calculated a word recognition index (WRI) which, controlling for visuospatial and speed factors, seemed to provide a good assessment of the word recognition ability. In Study 2, we evaluated whether the WCT could discriminate a clinically identified population of children with dyslexia from typical children. Advantages and recommendations on the use of the WCT by teachers were discussed.

Key words: Silent word recognition; Collective screening; Word Chain Test validation; Reading disorder.

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Clinical experts and academics usually agree that early identification of reading disabilities is vital to offer children the correct support (Snowling, 2013). To obtain maximum benefit from intervention, children with dyslexia need to be identified early (Cavanaugh, Kim, Wanzek, & Vaughn, 2004; Torgesen, 2002; Vellutino, Scanlon, Small, & Fanuele, 2006). Thus, the main goal of the present study was to validate an Italian version of the Word Chain Test (WCT; Jacobson, 1995). It is a short screening measure that effectively assesses silent word reading skills and that, differently from the majority of other Italian instruments available, which require individual assessment, allows a collective assessment.

In the past, most studies focused on oral reading fluency (ORF) rather than silent reading fluency (SRF; Fuchs, Fuchs, Hosp, & Jenkins, 2001; Hasbrouck & Tindal, 2006), because ORF is the primary reading mode (Kim, Wagner, & Foster, 2011; van den Boer, van Bergen, & de Jong, 2014). Surprisingly, little

attention has been paid to SRF, in spite of its being the dominant reading mode in junior high and high school, and for leisure reading (van den Boer et al., 2014). Some studies report that ORF correctly classified about 75% of participating students in Grade 4 passing high-stakes tests, leaving about one-fourth of the students classified incorrectly (McGlinchey & Hixson, 2004; Stage & Jacobsen, 2001).

A recent study conducted by Ciuffo and colleagues (2017) investigated SRF in typically developing students aged 14-23 and revealed that the ability to read silently tended to increase up to the last years of University, and it may be considered the most rapid and efficient reading mode. A study conducted by Gagliano and colleagues (2015) validated an SRF test for adults that consisted of a short text used as an indicator of silent reading fluency (syllables/second). In order to assess their ability to read without skipping lines or words, the readers were asked to do something (e.g., "knock twice on the table now"), to say something (e.g., "say the word 'ginger' aloud, please"), or to touch one of the three tokens of different colors placed in front of them. These authors, comparing adults with developmental dyslexia and typical readers, found a discrepancy between oral and silent reading speed improvement: in skilled readers, silent reading speed increased significantly more than in dyslexic ones (Gagliano et al., 2015). Despite the SRF appears important for discriminating students with reading disabilities and typical readers, to our knowledge no-one has thoroughly investigated the development of silent word reading in children with dyslexia and few instruments are to date available for testing this ability in children. Given that administering tests of ORF individually is time-consuming, assessments of silent reading fluency may be useful for collectively, and thus more quickly, identifying both older and younger students with reading difficulties and monitoring their progress (Denton et al., 2011).

Measures for the Assessment of Silent Word Reading in Children

Longitudinal studies have demonstrated that oral language skills, print awareness, phonological awareness, rapid naming, and visual-spatial attention are significant predictors of reading abilities in kindergarten and beginning of first grade (Catts, Fey, Zhang, & Tomblin, 1999; de Jong & van der Leij, 2003; Franceschini, Gori, Ruffino, Pedrolli, & Facoetti, 2012; Phillips, Lonigan, & Wyatt, 2009; Schatschneider, Fletcher, Francis, Carlson, & Foorman, 2004; Wagner, Torgesen, & Rashotte, 1994). According to Hatcher, Snowling, and Griffiths (2002), the best predictors in higher education are nonword reading, spelling, digit span, and writing speed, whereas Harrison and Nichols (2005) claimed that the assessment tests which best detect reading disabilities are the one-minute reading test, phonemic segmentation, two-minute spelling, nonsense reading, and one-minute writing.

Many screening tools are available worldwide to identify reading and spelling disorders (Fawcett & Nicolson, 1995; Good, Kaminski, Smith, Simmons, Kame'enui, & Wallin, 2003; Lonigan, Wagner, Torgesen, & Rashotte, 2007; Scortichini, Gasperini, Scorza, Boni, & Stella, 2015; Torgesen & Bryant, 2004; Torgesen, Wagner, & Rashotte, 1999). However, many screening batteries consist of additional subsets and are, therefore, time-consuming and difficult to administer collectively (Compton et al., 2010). Moreover, most screening procedures designed for early identification of children at risk for reading problems have rarely focused on silent word recognition.

In the Italian context, nearly all the screening tests currently in use are about 10 minutes long or require individual administration which may prevent their widespread use. In addition, most Italian screening procedures are designed for kindergarten and primary school only. In Italy, word decoding abilities are currently assessed in primary and secondary grades with tests requiring the students to read aloud a selected list

of words, or a selected list of nonwords, or a text. These lists are taken from standardized tests, the most widely used of which were introduced and illustrated by Sartori, Job, and Tressoldi (1995, 2007). The MT battery by Cornoldi and Colpo (1986; 1998) is the most efficient and reliable psychometric tool assessing reading speed and accuracy, widely used in clinical practice. Recently in Italy, Morlini, Stella, and Scorza (2014, 2015) proposed a new screening procedure (SPILLO), which identifies primary school children with slow literacy development. The screening requires students to read a selected text for exactly one minute. This reading procedure was designed by Nicolson and Fawcett (1997) and is frequently used in research to measure reading performance in both children and adults (Nicolson & Fawcett, 1997; Willburger & Landerl, 2009). The results confirm that SPILLO is an excellent screening test that identifies effectively poor and good readers. The reliability of this procedure, as measured by the percentage of variance explained by the first two factors, is 99%. The SPILLO screening test is simple, accurate, and cost-efficient; even teachers with no particular psychometric experience can easily manage it because scoring and recording mistakes are computer-assisted. However, teachers seem to prefer group tasks, which are considered more cost-efficient and time-saving. For this reason, the silent reading fluency assessment may be a useful tool to identify students with reading disabilities.

Four standardized measures of silent reading fluency are available: the Test of Silent Contextual Reading Fluency (TOSCRF; Hammill, Wiederholt, & Allen, 2006), the Test of Silent Word Reading Fluency, second edition (TOSWRF-2; Mather, Hammill, Allen, & Roberts, 2004), the WCT by Jacobson (1995), and the Prove Zero Test (Bellocchi, Bonifacci, Lami, & Manfredini, 2014). The TOSCRF is a text with no separations between words and no punctuation or spaces between sentences; the task is to draw lines to separate words. In the TOSWRF-2 (Mather et al., 2004) students are presented with a string of words with no spaces separating them; the task is to draw lines separating the terms, and the score is the number of words correctly identified in three minutes. The Prove Zero Test (Bellocchi et al., 2014) is to date the only screening measure assessessing SRF in Italian children; however, this measure includes silent text reading (but not silent word reading) and is available only for primary school children. The WCT (Jacobson, 1995) is a quick, simple, and collective screening procedure that seems to reliably identify primary and secondary school children with poor silent word decoding abilities. It is a five-minute group test commonly used in the classroom (Jacobson, 1995). Compared to the TOSWRF-2 the WCT allows to control for the visuospatial and phonological components involved in the WCT, using the Letter Chain Test (LCT; Zanzurino & Stella, 2009). Furthermore, one of the strongest points of this screening is the production of a word recognition index (WRI), which allows us to control for the speed factor and thus to provide a "purer" estimation of the word recognition abilities. The study by Jacobson (1995) revealed that a low WRI combined with low results at word chain recognition appeared to be a quick and reliable indication of dyslexia; it is therefore advisable to administer Jacobson's test to Italian children.

A previous study (Scorza, Boni, Scortichini, Morlini, & Stella, 2015) adapted the WCT to Italian primary school children. The novel contribution of the present study is to extend the validation to a larger sample of primary school children and to junior high school children for whom silent reading becomes the dominant reading mode (van den Boer et al., 2014). In addition to the previous study by Scorza and colleagues (2015), the present work also analyzes the WRI (Jacobson, 1995) and compares WCT scores and WRI values of children with dyslexia to those of typically developing children.

Specifically, in the first study reported here, 1,154 Italian children were evaluated on WCT (Jacobson, 1995) by primary and junior high school teachers. This procedure allowed us to collect information on the distribution of scores on the WCT in Italian primary (Grades 1-5) and junior high (Grades 6-8) school children and to confirm the validity of the WCT as a screening tool for silent word recognition difficulties.

In the second study, we examined the performance on WCT of children with clinically-identified dyslexia and non-dyslexic children and we analyzed whether the WCT was able to discriminate this clinical population from typically developing children.

The study met ethical guidelines for human subjects' protections, including adherence to the legal requirements of the country, and received formal approval by the local Research Ethical Committee of the University of Modena and Reggio Emilia.

STUDY 1

In Study 1, we conducted a cross-sectional investigation of the normal performance on the WCT in children from Grade 1 to Grade 8. Consistent with Jacobson's (1995) study, we expected word decoding ability to increase regularly from Grade 1 to Grade 8 and assumed that the months of formal education could predict performance on the WCT. Additionally, we calculated the WRI and produced normative threshold values for it in Italian children, because a low WRI combined with poor results in the WCT has proved to be a reliable method of identifying children with dyslexia (Jacobson, 1995). Finally, we investigated whether the performance on the WCT and the WRI values, at all school grades, correlated with the reading time/speed and accuracy assessed with two widely used Italian standardized tests (Battery for the Evaluation of Developmental Dyslexia and Dysorthography — DDE2, Sartori et al., 1995, 2007; MT Reading Test, Cornoldi & Colpo, 1998, 2012). We postulated close relationships between the scores of the new screening measure and those of the standardized test. Because the WCT is a time task, the strongest associations were expected between WCT, WRI, and time/speed variables on the DDE2/MT tests, thus, high concurrent validity of the WCT was probable. Internal consistency was also estimated.

METHOD

Participants

This study involved 1,154, recruited between February 2014 and May 2016, from primary and secondary schools in Northern, Central, and Southern Italy. Teachers were nominated by the schools contacted by the authors. They were invited to collaborate in this study, and only those willing to take part received a copy of the WCT and the associated instructions. The children's parents gave informed written consent for participation in the study, data analysis, and data publication.

The WCT and the reading standardized tests were administered during the month of February to children in Grades 2 (n = 168), 3 (n = 160), 4 (n = 198), 5 (n = 138), 6 (n = 155), 7 (n = 109), and 8 (n = 111). Children in Grade 1 (n = 115) were tested in May in order to achieve a more uniform reading level at the end of the first year of formal teaching. Given the regularity of Italian orthography, by the end of the first year of primary school, 90% of the children can read (Cossu, 1999) and reading automaticity has been nearly achieved (Scorza, Boni, Zanzurino, et al., 2015). Participants' stratification according to school grade (months of formal education) is reported in Table 1.

Children were included if they met the following criteria: (a) they spoke Italian as their first language; (b) they did not have any indication of neurological, visual, or hearing impairment; (c) they did not

have any indication of intellectual disabilities; (d) they received adequate schooling (i.e. regular school attendance), as reported by teachers.

TABLE 1
Socio-demographic characteristics of the sample

School grades	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8	Total
Number of children	115	168	160	198	138	155	109	111	1,154
Months of formal education	8	14	23	32	41	50	59	68	-

Procedure

The design of the WCT required teachers to familiarize themselves with the test. During this familiarization phase, teachers administered the test to each other and scored it together with an expert examiner. After this preliminary work, the WCT was administered collectively to children in the classroom by the teachers. Teachers reported that the instructions for the WCT were easy to understand, and they did not find any difficulties in administering the test.

During the same week, the standardized DDE2 and MT reading tests were administered individually to all children by an expert examiner. Each child was evaluated in a quiet room of the school in a session lasting approximately 20 minutes.

The Word Chain Test (WCT)

The WCT is a Swedish screening test consisting of orthographic segmentation of words. In the present study, the WCT was partially modified, in compliance with Jacobson's (1995) original version, to be adapted to the Italian population.

The Italian WCT consisted of 48 "word chains," each including three words without interword spaces. The words were selected from Burani and colleagues' database (Burani, Barca, & Arduino, 2001), available on the website https://link.springer.com/article/10.3758%2FBF03195599#SupplementaryMaterial, following Rinaldi and colleagues' criteria (Rinaldi, Barca, & Burani, 2004) and Marconi and colleagues' criteria (Marconi, Ott, Pesenti, Ratti, & Tavella, 1993) for frequency and imageability. Thirty-six were high frequency-high imageability words, 36 were high frequency-low imageability words, 36 were low frequency-high imageability words, and 36 were low frequency-low imageability words. Each chain consisted of two two-syllable words and one four-syllable word arranged in random order (e.g., "tartarugamercefilo, ortogaralucertola, pratocaramellatuta"). The test included a total of 144 words. The word chains were printed in lowercase form, Bookman Old Style font, size 12.

All children received the test sheet and a pencil and were instructed by the teachers to draw a line to separate the words as quickly and accurately as possible (e.g., "tartaruga/merce/filo, orto/gara/lucertola, prato/caramella/tuta"). Before actual testing, all children took a sample test. Teachers did not provide any feedback during the test, which lasted 180 seconds and was then interrupted. As Jacobson (1995) suggested, speed results reflected the child's word decoding level; many young children had to pronounce each letter

before they could identify the words, whereas older children seemed to have immediate lexical access based on rapid recognition of the orthographic patterns. Performance is expressed as the number of correctly recognized words. Scoring was carried out by an expert examiner.

In accordance with Jacobson's (1995) original version, the WCT was preceded by a task called LCT, the main purpose of which was to control for the visuospatial components involved in the WCT. Given that the LCT is a test of letter recognition, many of its original features were retained. The LCT involved the same demand characteristics as the WCT — scanning letter sequences and pencil markings. It consisted of 92 "letter chains," each composed by a sequence of 10 letters without interletter spaces. Each letter chain contained two pairs of identical letters (e.g., "kvsstthoa, ipnnlddzxq, fvhhyjtts"). The test included a total of 184 pairs of identical letters. The letter chains were printed in Bookman Old Style font, size 12 and, unlike Jacobson's LCT, in lowercase.

All children received the test sheet and were instructed by the teacher to separate the double letters (two in each chain) with a pencil mark (e.g., "kvs/st/thoa, ipn/nld/dzxq, fvh/hyjt/ts"). Children were asked to solve the task as quickly and accurately as possible. Before actual testing, all children took a sample test. Teachers did not provide any feedback during the test, which lasted 90 seconds and was then interrupted. Performance is expressed as the number of correctly marked double letters. Scoring was carried out by an expert examiner. Total testing time (WCT and LCT) was 4.5 minutes.

Word Recognition Index (WRI)

As suggested by Jacobson (1995), a discrepancy between WCT and LCT scores, that is, poor scores on WCT versus normal scores on LCT, could be the expression of word recognition problems. Jacobson suggested the following formula to calculate the WRI:

$$\text{WRI} = 100 * (\text{WCT score} - \text{LCT score}) / \text{LCT score}$$

in which the WCT score is the number (raw score) of correctly recognized words and the LCT score is the number (raw score) of correctly marked double letters. The testing time is 100 percent longer in the WCT (3 minutes) than in the LCT (1.5 minute). A child that obtains the maximum score in the WCT theoretically should have a 100 percent score in the WCT, which means a WRI of 100. By contrast, young children or children with dyslexia could have a WRI below zero. This index allows us to control for the speed factor and, consequently, could provide a better estimation of word decoding ability.

Standardized Reading Tests

Battery for the Evaluation of Developmental Dyslexia and Dysorthography (DDE2; Sartori et al., 1995, 2007). This tool is a widely used diagnostic test in Italy. It consists of five subtests for the evaluation of oral reading (single grapheme identification, lexical decision task, words reading, nonwords reading, and identification of homophones) and three subtests for the evaluation of writing (words dictation, nonwords dictation, and sentences with homophone words dictation). The subtests selected for the present study were words reading and nonwords reading. In the first one, the child was asked to read a list of words and in the second a list of nonwords. Each child was asked to read aloud as quickly and accurately as possible. The

procedure required the examiner to time the performance and record the mistakes without interrupting the child. The time requested for administering the subtests depended on the child's ability and was around 10 minutes. For each subtest, the time (in seconds) and the number of incorrect pronunciations (errors) in reading the list of stimuli were scored.

MT Reading Test (Cornoldi & Colpo, 1998, 2012). The MT test is a psychometrically valid Italian instrument that measures oral reading speed and accuracy and consists of a series of texts for all grades. The child was asked to read aloud as quickly and accurately as possible the text chosen according to his or her school grade. The examiner was not allowed to intervene when the child made a mistake, but only if he or she skipped a line. During the test, the examiner timed the reading and recorded the mistakes. After 4 minutes, if the child had not finished yet, the examiner interrupted the task. Number of syllables per second (speed) and number of words misread (errors) were scored.

These instruments (DDE2, MT) obtained good reliability (test-retest correlation above.85) and concurrent and predictive validity scores.

Results

Cross-Sectional Evaluation of the WCT

All statistical analyses were carried out using SPSS 21.0 for Windows with an α level of .05. Descriptive data for WCT and LCT scores are presented in Table 2. The analysis of these data revealed that the ability of word decoding steadily improved from Grade 1 to Grade 8. The results of the LCT also showed progress from the youngest to the oldest children. Comparing these data, the performance increase on the WCT across the school grades appeared different from the performance increase on the LCT. On the WCT, the word recognition ability continued to steadily increase from Grade 1 to Grade 8, whereas the performance increase on LCT was much smaller.

To determine the extent to which months of formal education correlated with the performance on WCT and LCT, two linear regressions were carried out, with months of formal education as possible predictor for WCT and LCT accuracy scores. As Table 3 indicates, the linear regression model with months of formal education as possible predictor for WCT scores captured a significant amount of variance in WCT scores — $R^2 = .68$; $F(1,1153) = 2453.55$, $p < .001$. The months of formal education were a significant predictor of WCT scores ($\beta = .83$, $p < .001$). These findings reveal that for every additional month of formal education there is a corresponding increase of 1.78 points in the mean WCT score (*B* value; see Table 3).

With regard to the second linear regression (see Table 3), the months of formal education capture a smaller amount of variance in LCT scores — $R^2 = .35$; $F(1,1153) = 616.21$, $p < .001$. The months of formal education are a significant predictor of LCT scores ($\beta = .59$, $p < .001$). These findings reveal that for every additional month of formal education there is a corresponding increase of 0.52 points in the mean LCT score (*B* value; see Table 3).

As for the second aim of the present study, we have calculated the WRI from Grade 1 to Grade 8. As Figure 1 shows, the WRI average value is negative in children of Grades 1 and 2. In Grade 2, the WRI average value is near zero, which means that the average scores in WCT and LCT are the same in these children. From Grade 3, the WRI average values are positive and increase evenly up to Grade 8.

TABLE 2
Descriptive analyses (mean, standard deviation, and range) of WCT scores (number of correctly recognized words), LCT scores (number of correctly marked double letters) from Grade 1 to Grade 8

School grades	Grade 1 (n = 115)		Grade 2 (n = 168)		Grade 3 (n = 160)		Grade 4 (n = 198)		Grade 5 (n = 138)		Grade 6 (n = 155)		Grade 7 (n = 109)		Grade 8 (n = 111)	
	M (*SD*)	Range	*M* (*SD*)	Range	*M* (*SD*)	Range	*M* (*SD*)	Range	*M* (*SD*)	Range	*M* (*SD*)	Range	*M* (*SD*)	Range	*M* (*SD*)	Range
WCT scores	20.06 (11.33)	0/52	37.48 (17.92)	0/91	57.26 (19.24)	13/119	79.96 (25.55)	17/144	91.95 (25.20)	29/144	99.48 (29.13)	30/144	117.65 (24.55)	54/144	131.89 (18.26)	64/144
LCT scores	35.50 (11.09)	12/79	43.63 (12.07)	17/102	48.24 (11.39)	10/75	55.21 (12.23)	24/120	57.57 (13.68)	24/102	61.66 (15.14)	12/122	66.12 (15.18)	32/112	68.49 (14.70)	32/106

Note. WCT = Word Chain Test; LCT = Letter Chain Test.

TABLE 3
Summary of two linear regression analyses for WCT and LCT scores, respectively, with months of formal education as explicative variable, in the whole sample

Regression for WCT scores				
Independent variables	Regression coefficient *B* [90% CI]	β	*p* <	Adjusted R^2
Months of formal education	1.78 [1.75/1.82]	.83	.001	.68
Intercept	14.42 [12.98/15.85]	-	.001	
Regression for LCT scores				
Independent variables	Regression coefficient *B* [90% CI]	β	*p* <	Adjusted R^2
Months of formal education	0.52 [0.50/0.54]	.59	.001	.35
Intercept	35.84 [35.01/36.67]	-	.001	

Note. *p* value for inclusion in the model was set at .10; CI = 90% confidence interval; WCT = Word Chain Test; LCT = Letter Chain Test.

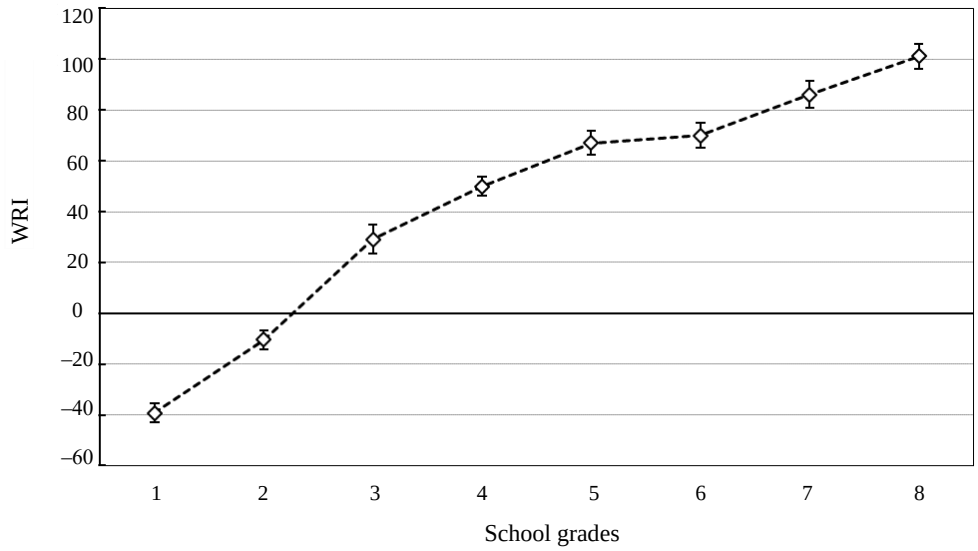

FIGURE 1
WRI values (means and standard errors) as a function of school grades (from Grade 1 to Grade 8). The figure shows a peak enhancement on WRI values between Grade 1 and Grade 3. From Grade 3, the WRI average values increase evenly up to Grade 8. WRI = word recognition index.

Concurrent Validity with Standardized Reading Measure

To determine the extent to which WCT scores correlated with children's performance on the DDE2 subtests and MT test, a series of Spearman's correlations were conducted. Close negative associations existed between WCT scores and both time and errors in the DDE2 subtest, in children of Grades 1 to 5. Children of Grades 6 and 7 showed close negative associations between WCT scores and the time variable in the DDE2 words subtest. Children in Grade 8 did not present any close correlation between WCT scores and time and errors on DDE2 words subtest (see Table 4).

As for the correlation analysis between WRI values and DDE2 word subtest scores, results showed close negative associations between WRI values and both time and errors in the DDE2 word subtest, in children from Grades 1 to 5. In the subsequent grades, only children in Grade 7 revealed one close correlation between WRI values and time in the DDE2 word subtest (Table 4).

Regarding the DDE2 nonword reading subtest (time and errors variables), there were close negative associations between WCT scores and both time and errors in the DDE2 nonword subtest in children from Grades 1 to 5. Children of Grades 6 and 7 showed close and negative associations between WCT scores and the time variable in DDE2 nonwords subtest. In children in Grade 8, there were no close correlations between WCT scores and time and errors on DDE2 nonwords subtest (see Table 5).

With reference to the associations between WRI values and DDE2 nonword subtest scores, results revealed close negative associations between WRI values and both time and errors in the DDE2 nonword subtest in children from Grades 1 to 5, except for the error variable in Grades 2 and 5, which did not strongly correlate with the WRI values. Children in Grades 7 and 8 showed close negative correlations between WRI values and time in the DDE2 nonwords subtest (Table 5).

Considering the MT Test (speed and errors variables), children of all grades showed close positive associations between WCT scores and speed on the MT Test. Close and negative associations existed

between WCT scores and error variables on the MT Test in children of Grades 1, 3, and 7 (see Table 6). As to the correlation analysis between WRI values and MT scores, results indicated close positive associations between WRI values and speed in the MT Test in children of all grades, except for Grade 8. Close and negative associations existed between WRI values and error variables in the MT test in children of Grades 1, 3, and 8 (Table 6).

A further analysis was conducted to examine the discriminative power of the WCT in detecting impaired readers. Prior to conducting this analysis, data were checked to determine whether WCT scores and WRI values were normally distributed, using the Kolmogorov-Smirnov test. To define the thresholds, medians and percentiles were used instead of means and standard deviations, due to the nonnormality of the variables (Morlini et al., 2015). Basic thresholds (cutoffs) for both WCT scores and WRI values were set at the 15th percentile, which is a common practical cutoff for screening measures (Geary, Bailey, & Hoard, 2009). The cutoff values for each school grade are presented in Table 7. Children that scored below the cutoff value on WCT and/or on WRI were classified as at risk for reading impairment. Impaired readers from Grade 2 to Grade 8 were identified using the DDE2 standardized test. A child was classified as impaired reader when his/her performance was two standard deviations (*SD*) below the mean in at least two of the four DDE2 variables: time on word, errors on word, time on nonwords, and errors on nonword. This analysis revealed that 53 out of 1,039 children (5.10%) showed reading impairment. Of these 53 children, 36 (68%) were detected by WCT, that is, they demonstrated a performance below the 15th percentile on WCT and/or on WRI. Because the WCT is a time task, this test was replicated considering the "speed dyslexics" only. Time performances falling within two standard deviations (*SD*) below the mean in both the DDE2 word and nonword subtests were considered impaired. This analysis revealed that 22 out of 1,039 children (2.12%) exhibited reading time impairment. Of these 22 children, 19 (86%) were detected by WCT.

Internal Consistency

An exploratory factor analysis was performed on the correlation matrix (obtained from the values of all variables in all grades), using the Principal Components (PC), to investigate the multivariate relationships among the variables used in the standardized tests and in the screening procedures. The Kaiser-Meyer-Olkin test measured sampling adequacy for the analysis (KMO = .81) and Bartlett's test of sphericity indicated that correlations between variables were sufficiently large for PC, $\chi^2(28) = 7276.94$, $p < .001$. The PC analysis showed the presence of two main latent orthogonal factors. The first factor was highly correlated with the variables measuring time/speed (WCT scores, LCT scores, DDE2 word reading time, DDE2 nonword reading time, MT text speed). The eigenvalue of this factor was equal to 4.57, and the percentage of explained variance was 57.12%. The second factor was highly correlated with variables measuring accuracy (DDE2 word reading errors, DDE2 nonword reading errors, MT text errors). The eigenvalue of this factor was 1.38, and the percentage of explained variance was 17.30%. The orthogonal rotation using Varimax did not improve the percentage of variance explained by the first two factors. Drawing from these results, we estimated the degree to which the first set of variables measured a single one-dimensional latent variable (the reading speed). Selecting variables with positive pairwise correlations (WCT scores, MT text speed), we estimated the internal consistency of these variables by means of Cronbach α coefficient (Cronbach, 1951), and obtained $\alpha = .92$. According to the literature, values ranging from .70 to .95 are considered more adequate for this parameter (De Vet, Terwee, Mokkink, & Knol, 2011).

TABLE 4

Spearman's correlations between WCT scores, WRI values, and DDE2 words reading subtest scores (time and errors variables) for each school grade

School grades	Grade 1 (*n* = 115)		Grade 2 (*n* = 168)		Grade 3 (*n* = 160)		Grade 4 (*n* = 198)		Grade 5 (*n* = 138)		Grade 6 (*n* = 155)		Grade 7 (*n* = 109)		Grade 8 (*n* = 111)	
	DDE2 words		DDE2 words		DDE2 words		DDE2 words		DDE2 words		DDE2 words		DDE2 words		DDE2 words	
	Time	Errors	Time	Errors	Time	Errors	Time	Errors	Time	Errors	Time	Errors	Time	Errors	Time	Errors
	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s
WCT scores	**–.77****	**–.68****	**–.62****	**–.54****	**–.66****	**–.46****	**–.72****	**–.58****	**–.67****	**–.47****	**–.51****	–.32**	**–.63****	–.30**	–.32**	–.28**
WRI values	**–.61****	**–.59****	**–.56****	**–.43****	**–.59****	**–.53****	**–.60****	**–.52****	**–.52****	**–.47****	–.36**	–.34**	**–.50****	–.28**	–.36**	–.23*

Note. Significant correlations representing a medium or large effect are in bold. WCT = Word Chain Test; WRI = word recognition index; DDE2 words = words reading subtest of the Battery for the Evaluation of Developmental Dyslexia and Dysorthography.

*p < .05. **p < .01.

TABLE 5

Spearman's correlations between WCT scores, WRI values, and DDE2 nonwords reading subtest scores (time and errors variables) for each school grade

School grades	Grade 1 (*n* = 115)		Grade 2 (*n* = 168)		Grade 3 (*n* = 160)		Grade 4 (*n* = 198)		Grade 5 (*n* = 138)		Grade 6 (*n* = 155)		Grade 7 (*n* = 109)		Grade 8 (*n* = 111)	
	DDE2 nonwords		DDE2 nonwords		DDE2 nonwords		DDE2 nonwords		DDE2 nonwords		DDE2 nonwords		DDE2 nonwords		DDE2 nonwords	
	Time	Errors	Time	Errors	Time	Errors	Time	Errors	Time	Errors	Time	Errors	Time	Errors	Time	Errors
	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s
WCT scores	**–.70****	**–.56****	**–.52****	–.39**	**–.59****	**–.43****	**–.65****	**–.43****	**–.58****	**–.45****	**–.45****	–.40**	**–.59****	–.29**	–.28**	–.14
WRI values	**–.53****	**–.46****	**–.46****	–.29**	**–.50****	**–.49****	**–.55****	**–.47****	**–.55****	–.29**	–.35**	–.27**	**–.47****	–.28**	**–.42****	–.18

Note. Significant correlations representing a medium or large effect are in bold. WCT = Word Chain Test; WRI = word recognition index; DDE2 words = words reading subtest of the Battery for the Evaluation of Developmental Dyslexia and Dysorthography.

*p < .05. **p < .01.

TPM Vol. 26, No. 1, March 2019
5-27

TABLE 6

Spearman's correlations between WCT scores, WRI values, and MT Test scores (speed and errors variables) for each school grade

School grades	Grade 1 (*n* = 115)		Grade 2 (*n* = 168)		Grade 3 (*n* = 160)		Grade 4 (*n* = 198)		Grade 5 (*n* = 138)		Grade 6 (*n* = 155)		Grade 7 (*n* = 109)		Grade 8 (*n* = 111)	
	MT Test		MT Test		MT Test		MT Test		MT Test		MT Test		MT Test		MT Test	
	Speed	Errors	Speed	Errors	Speed	Errors	Speed	Errors	Speed	Errors	Speed	Errors	Speed	Errors	Speed	Errors
	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s	*r*s
WCT scores	**.78****	**–.62****	**.63****	–.36**	**.65****	**–.45****	**.71****	–.36**	**.68****	–.30**	**.54****	–.36**	**.71****	**–.42****	**.47****	–.33**
WRI values	**.63****	**–.56****	**.52****	–.28**	**.58****	**–.46****	**.57****	–.31**	**.44****	–.24**	**.40****	–.31**	**.54****	–.31**	.36**	**–.43****

Note. Significant correlations representing a medium or large effect are in bold. WCT = Word Chain Test; WRI = Word Recognition Index; MT = MT reading Test.
**p* < .05. ***p* < .01.

TABLE 7
Basic thresholds (cutoff values) set at the 15th percentile both for WCT score and WRI value for each school grade

	WCT cutoffs (15th percentile)	WRI cutoffs (15th percentile)
Grade 1	7.00	–79.25
Grade 2	19.00	–58.14
Grade 3	39.00	–19.61
Grade 4	54.00	–2.00
Grade 5	68.00	6.67
Grade 6	68.00	5.00
Grade 7	87.00	34.48
Grade 8	114.00	56.45

Note. WCT = Word Chain Test; WRI = word recognition index.

DISCUSSION

In the present study, the WCT created by Jacobson (1995) for Swedish children was adapted for Italian children from Grade 1 to Grade 8, to develop an objective screening procedure identifying Italian children with silent word reading difficulties. In primary and secondary education in Italy, there is an increasing need for quick and effective screening procedures for dyslexia. Full diagnostic assessment is typically a costly and time-consuming process, and a screening system may be useful to determine whether a full assessment would be appropriate. Although dyslexia is one of the most common neurobehavioral disorders affecting children, it is largely underestimated in Italy to date. Barbiero and colleagues (2012) carried out three consecutive levels of screening: the first two at school, and the last one at the Health Services. In a sample of 1,357 children aged 8-10 years, they found that two out of three children with dyslexia had not been previously diagnosed with the disorder. We believe that the excessive length and the individual administration of the available Italian screenings are the two major flaws that may prevent the widespread use of these tests by teachers.

Additionally, few screening procedures target silent words reading in primary and secondary school children. As suggested by Bellocchi (2011), primary school children with reading difficulties show lower silent reading fluency than their typically developing peers do. The only Italian screening assessing silent words reading provides normative data only for children in Grades 1 and 2 (Bellocchi, 2011). Thus, dyslexia may not be recognized in children aged 8-10 years when the disorder should already have been clearly expressed and identified (Barbiero et al., 2012). The WCT is a screening procedure that could be easily used in the classroom with a testing time of 4.5 minutes. The WCT, with its focus on silent word decoding skill, seems to be a useful screening method for detecting children with reading problems.

Consistent with data on Swedish children, our results show that the ability to segment orthographic stimuli progresses regularly from the youngest to the oldest children. As shown by the regression analysis, the months of formal education predicted the performance on WCT, capturing a significant amount of variance in children's WCT scores. Because the WCT is a timed task, it may be assumed that the speed with which children silently read WCT words continues to develop from Grade 1 to Grade 8. This result is in line with other similar studies on silent reading speed in skilled high school and university students (Ciuffo et al.,

2017), which show that silent reading fluency continues to increase over time. As suggested by Wimmer (1993), in consistent languages, which are characterized by high grapheme-phoneme correspondence, the most reliable prognostic indicator of dyslexia is decoding speed ("speed dyslexia"). This consideration found evidence in some recent studies carried out on Italian children with dyslexia (Morlini et al., 2014; Tressoldi, Lorusso, Brenbati, & Donini, 2007; Tressoldi, Stella, & Faggella, 2001; Zonno, Scorza, Morlini, & Stella, 2016). For example, Tressoldi and colleagues administered the MT Test to children with and without dyslexia, and revealed a divergent development in reading speed, with a slower increase in children with dyslexia. Zonno and colleagues detected a minimal improvement in word reading speed in children with dyslexia between lower and upper grades of secondary school. Recently, other authors (Gagliano et al., 2015) focused on silent reading fluency and suggested that adults with dyslexia are less capable of improving their reading speed significantly, compared to skilled readers. In the light of these considerations, the WCT may be a screening procedure suitable to identify children with "silent speed dyslexia."

Another strong point of the WCT is the LCT, which provides additional information on the visuospatial components involved in the reading process. The performance on LCT increases very quickly during the first years of formal education and it is thereafter rather constant. In fact, letter decoding represents the simplest possible level of decoding skill, and letter learning appears to be prominent during the first two years of formal education. The results are in line with those of Jacobson's (1995) study, and these considerations can be extended to lower-case letter recognition. It is generally known that reading difficulties depending on visuospatial deficits are often brought to clinical attention later, probably due to lack of tests measuring visuospatial abilities (Cornoldi, Venneri, Marconato, Molin, & Montinari, 2003). Thus, there is a great need for new, straightforward, and easy-to-use instruments allowing early identification of reading problems associated with visuospatial difficulties in the classroom. Because the WCT includes a letters identification task, this new screening measure is a step in this direction. In fact, the screening presented here identifies children with poor scores on both the WCT and the LCT, which could indicate a low processing speed due to visual perception issues (Jacobson, 1995).

A particularly interesting contribution of this study is the WRI. Results showed a constant increase of the WRI from Grade 1 to 8. Specifically, we observed a peak enhancement on WRI values between Grades 1 and 3. In Grade 2, the WRI average value was near zero, which means that the average scores on the WCT and the LCT were the same in these children. After Grade 3, the WRI values evenly increased as an expression of the improvement of the word decoding skills. As suggested by Jacobson (1995), because the WRI formula controls for visuospatial and speed factors, it is reasonable to assume that WRI provides a "pure" estimation of the silent word recognition ability. As a result, a low score on WRI may indicate specific silent word decoding difficulties. Unlike Jacobson's study (1995), we did not find a flattening curve in secondary school grades. In fact, our results show that the WRI values continue to increase from Grade 6 to Grade 8. Interestingly, the WRI values in all secondary school grades are higher in Italian children than in Swedish ones. Specifically, the WRI for Italian children in Grade 6 increases to around 70, which coincides with the WRI value of Swedish college students; in Grade 7, the WRI increases to around 86 that is equivalent to the WRI value of Swedish students aged 20-25 years; in Grade 8, the WRI is even higher, that is, around 101. Therefore, the silent word reading skill, assessed using the WCT, seems to become automatic in Italian children as early as the secondary educational level, preceding the Swedish population. There is strong evidence that both orthographic (Goswami & Ziegler, 2005) and literacy experience/instruction influence performance on reading measures (Hogan, Catts, & Little, 2005; Mann & Wimmer, 2002). Accordingly, interpretation of these findings might depend on the differences in the orthographic features between Swedish and Italian written language or in the teaching strategies. Certainly, the WRI appears to be a perfect tool to detect possible silent word reading problems in Italian children.

This research reported preliminary data on the reliability and validity of the WCT in Italian children. The concurrent validity of the WCT was assessed by comparing WCT and WRI scores with the diagnostic tests widely used for the evaluation of reading skills in Italian children. Both WCT scores and WRI values closely correlated with the scores on the standardized tests, providing evidence for concurrent validity. Specifically, the closest relationships were found between the two screening scores and both time and errors in the DDE2 word reading subtest, from Grades 1 to 5. In Grades 6 and 7, the closest associations were the time variable of the DDE2 word reading subtest, whereas significant but not close relationships were found in Grade 8. An equivalent pattern of associations was found between WCT scores, WRI values, and DDE2 nonword reading subtest scores. Regarding the correlations between the scores of the two screenings and those of the MT Test, the closest relationships were found between WCT scores and MT speed parameter in all grades. In general, closer relationships were found in all school grades between the WCT/WRI scores and the time/speed variables of the standardized tests, rather than the error variables. In sum, the correlation analyses presented here show that the WCT could provide a valid screening measure for detecting silent word recognition problems in Italian children.

In addition to its concurrent validity, the WCT appears to have a good discriminative power in detecting impaired readers. A preliminary analysis showed that the WCT detected a high percentage (almost 90%) of children with time impairment at DDE2 reading standardized test. Certainly, the simple analysis carried out has some clear limitations and the results should be interpreted carefully. However, this preliminary analysis seems to demonstrate that with the use of an appropriate cutoff, the risk of false negatives is low (Cornoldi et al., 2003).

Furthermore, the present study has demonstrated the good internal consistency of the WCT. This gives evidence that the number of words recognized in silent mode in the WCT is a measure of the same feature calculated by the reading speed variables in the standardized tests. In summary, our results extend Jacobson's (1995) work and confirm that the WCT is a good instrument to detect reading problems in primary and secondary school children.

STUDY 2

The first aim of Study 2 was to examine the performance on WCT in a group of clinically identified children with dyslexia, comparing them with a control group. We expected children with dyslexia to exhibit poorer word recognition skills on WCT and lower WRI values, compared with the typically developing children group. The second aim was to evaluate whether the WCT was able to discriminate this clinical population by typically developing children.

METHOD

Participants and Procedure

Two groups of children were selected. Group 1 included 28 children with dyslexia, from Grades 3 to 8 of formal education. They were recruited from some schools taking part in Study 1 and diagnosed with dyslexia between the third class of primary school and the third class of secondary school. The medical diagnoses received comply with the diagnostic manual ICD-10 (World Health Organization, 1992; 2008) and the PANEL - Consensus Conference DSA (PARCC, 2011), in agreement with the discrepancy criterion

between reading ability and general intelligence. The children's parents gave informed written consent for participation in the study, data analysis, and data publication. The WCT was administered to all children with dyslexia by an expert examiner in a quiet room of the school. The WRI for each child was also calculated. For the detailed description of the WCT and WRI, see Study 1. Group 2 (control group) included 150 typically developing children, from Grade 3 to 8 of formal education (25 children per school grade), randomly selected from Study 1.

Results

All statistical analyses were carried out using SPSS 21.0 for Windows with an alpha level of .05. Prior to conducting analyses, data were checked for violation of normality assumptions using the Kolmogorov–Smirnov test. The WCT scores distribution and WRI values distribution were normal.

A *t* test was conducted to compare the two groups on educational level (months of formal education). In both groups, the mean of months of formal education was approximately 45 (dyslexics, $M = 45.18$, $SD = 14.80$; control group, $M = 45.50$, $SD = 15.42$). The two groups did not differ significantly on educational level, $t\ (176) < 1$, *ns*.

A series of analyses of variance (ANOVAs) were conducted to assess potential differences in WCT scores, LCT scores, and WRI values between children with dyslexia and the control group. Descriptive data for WCT scores, LCT scores, and WRI values are presented in Table 8. Scores on the WCT differed significantly between the two groups, with children with dyslexia performing more poorly than typically developing children (see Table 8). Relative to the control group, the children with dyslexia obtained significantly lower WRI values (see Table 8). No significant differences were found between the two groups on the LCT scores.

To determine the extent to which the children's performance on the WCT correlated with children status (dyslexics vs. nondyslexics), we conducted two logistic regression analyses: in the first, we used WCT scores and LCT scores as predictors (independent variables) and children status as outcome (dependent variable); in the second, we used WRI as predictor (independent variable) and children status as outcome (dependent variable).

A significant and close relationship emerged between WCT scores and children status (dyslexics vs. nondyslexics), exemplified by the change in odds of the outcome that resulted from a unit change in the WCT score (see Table 9). A significant, albeit less close relationship also emerged between LCT scores and children status (see Table 9). The second logistic regression analysis with the WRI value as predictor for children status (dyslexics vs. nondyslexics) showed a significant and close relationship between the predictor and the outcome, exemplified by the change in odds of the outcome that resulted from a unit change in the WRI value (see Table 10).

Discussion

The first major finding of Study 2 was that significantly less advanced silent word recognition abilities were observed in children with dyslexia, when compared to typically developing children, as assessed on WCT. With respect to typically developing children, significantly lower WRI values were also observed in children with dyslexia. The WRI appears very low in this clinical population; the WRI mean value of these children approximately corresponds to a normal WRI for children of Grade 2. Thus, children with dyslexia seem to have a slow processing speed in silent word recognition tasks, such as the WCT.

TABLE 8
WCT scores (number of correctly recognized words), LCT scores (number of correctly marked double letters), and WRI values in children with dyslexia and typically developing children

	Children with dyslexia (n = 28)			Control group (n = 150)			ANOVA		
	M	*SD*	Range	*M*	*SD*	Range	*F*	$p \leq$	η_p^2
WCT scores	61.71	31.15	13/126	98.64	34.09	29/144	28.40	**.001**	.14
LCT scores	63.11	12.77	43/84	58.39	13.17	32/102	3.06	.082	.02
WRI values	–4.36	42.50	–71.74/77.08	70.69	55.72	–47.27/237.50	45.75	**.001**	.21

Note. Significant results (*p*s) are in bold. WCT = Word Chain Test; LCT = Letter Chain Test; WRI = word recognition index.

TABLE 9
Summary of the multiple logistic regression analysis for children status (nondyslexics vs. dyslexics), with WCT scores and LCT scores as explicative variables, in the whole sample

Regression for children status (nondyslexics vs. dyslexics)			
Independent variables	Regression coefficient *B* (*SE*)	Odds Ratio [95% CI]	$p \leq$
WCT scores	0.06 (0.01)	1.06 [1.04, 1.08]	**.001**
LCT scores	–0.10 (0.02)	0.90 [0.86, 0.94]	**.001**
Intercept	3.42 (1.13)	-	**.002**

Note. Significant results (*p*s) are in bold. *SE* = standard error; CI = confidence interval; WCT = Word Chain Test; LCT = Letter Chain Test.

TABLE 10
Summary of the logistic regression analysis for children status (non-dyslexics vs. dyslexics), with WRI values as explicative variable, in the whole sample

Regression for children status (nondyslexics vs. dyslexics)			
Independent variables	Regression coefficient *B* (*SE*)	Odds Ratio [95% CI]	$p \leq$
WRI values	0.03 (0.01)	1.03 [1.02, 1.05]	**.001**
Intercept	0.73 (0.25)	-	**.004**

Note. Significant results (*p*s) are in bold. *SE* = standard error; CI = confidence interval; WRI = word recognition index.

A second contribution of Study 2 was that the WCT for Italian children can apparently discriminate a clinically identified population of children with dyslexia from typically developing children. In fact, the first regression analysis revealed that children's performance on WCT predicted their status (i.e., dyslexic or not). In other words, the model predicted that, if the WCT score (number of correctly recognized words) increased, the probability of being dyslexic decreased. The second regression analysis revealed that the WRI value also predicted children's status: If the WRI increased, the probability of being dyslexic decreased. Slightly inconsistent results were found with regard to LCT, and thus they should be considered cautiously. Consistent with Jacobson's (1995) results, the WCT and WRI appear more suitable to discriminate children with dyslexia from typically developing children, relative to LCT. A low score on WCT combined with a low WRI appears a reliable measure to identify children with silent reading problems. As has been documented, silent reading is the dominant reading mode in junior high school and high school (van den Boer et al., 2014) and it may be considered the most rapid and efficient reading mode (Ciuffo et al., 2017); moreover, the increase in silent reading speed was significantly lower in children with dyslexia when compared to skilled readers (Gagliano et al., 2015). Thus, this new screening measure that allows us to collectively assess silent reading abilities in Italian children could be very useful for detecting potential reading disabilities at school.

CONCLUSION

In contrast with the large and well-established pool of individual screening procedures available for early detection of affected children, no collective and quick instruments are available to teachers for early identification of silent word recognition difficulties in the classroom from Grade 1 to Grade 8. In this study, we attempted to offer an easy-to-use tool that may serve as a short and valid screening procedure. Consistent with data on Swedish children (Jacobson, 1995), a poor performance on the WCT combined with a low WRI value appear to provide a quick and reliable way to identify children at risk for reading difficulties.

Despite the successful validation results presented here, teachers and experimenters should be cautious when using screening tests such as the WCT for children evaluation or research purposes. Further studies are necessary to fully validate the WCT as an adequate screening tool. In particular, additional analyses need to be carried out to shed light on the validity of the WCT. The next step would be to examine the predictive validity of the WCT and the agreement rates between the WCT and the standardized tests in terms of sensitivity and specificity, within this sample of Italian children. Additionally, some recommendations concerning the use of WCT by teachers are required. A screening result is not comparable with the result of an accurate diagnostic assessment. The aim of a screening is not to formulate diagnoses but to identify a

population at risk that should take part in more specific assessments (Wood, Flowers, Meyers, & Hill, 2002). Notably, the WCT is a screening tool that intends to serve as a first or basic step in the detection of children with reading problems and, therefore, may result in false positives and false negatives. Teachers are required to carry out individual and more accurate examinations on children identified by the WCT as being at risk for reading disorders. Children not identified by the WCT but showing lower reading performance compared to their peers should also receive special attention.

Despite these limitations, the current findings provide preliminary support to the effectiveness of the WCT as a short, simple, and collective screening measure, suitable to identify Italian primary and secondary school children with dyslexia with a fair degree of precision and certainty. One strong point in the approach to validation in this study is the confirmation that a high percentage of children rated by the WCT and/or the WRI as having word recognition difficulties did indeed show a reading time deficit when individually tested for these abilities. Furthermore, Study 2 has demonstrated that the WCT is able to discriminate a clinically identified population of children with dyslexia from typically developing children.

Given its feasibility, the test can be periodically administered to monitor each student's progress and identify the students who are at risk and require extra help. Through the administration of this test after a given period, it is possible to verify whether a child's performance requires more specific individual examination and specific intervention, or whether the child has overcome the difficulty.

Literacy experience and instruction play a major role in the underpinnings of literacy development (Adams, 1990; Mann & Wimmer, 2002). Experience/instruction with the alphabet and sound-letter correspondence affects the skills tested with the screening instruments. This is clearly the case for measures involving letters and words recognition (Mann & Wimmer, 2002). Thus, teachers may decide to use this test to check the average reading skills of their class or to determine the level of some of their students with the aim of adopting teaching strategies based on their students' abilities.

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