The Varieties of Pathways to Dysfluent Reading Comparing Subtypes of Children With Dyslexia at Letter, Word, and Connected Text Levels of Reading

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Comparing Subtypes of Children With Dyslexia at Letter, Word, and Connected Text Levels of Reading

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The majority of work on the double-deficit hypothesis (DDH) of dyslexia has been done at the letter and word levels of reading. Key research questions addressed in this study are (a) do readers with different subtypes of dyslexia display differences in fluency at particular reading levels (e.g., letter, word, and connected text)? and (b) do children with dyslexia identified by either low-achievement or ability–achievement discrepancy criteria show similar differences when classified by the DDH? To address these questions, the authors assessed a sample of 158 children with severe reading impairments in second and third grades on an extensive battery and classified them into three reader subtypes using the DDH. The results demonstrated that the three DDH subtypes exhibited differences in fluency at different levels of reading (letter, word, and connected text), underscoring the separate reading profiles of these subtypes and the different possible routes to dysfluency in reading disabilities. Furthermore, the results suggest that the different patterns among DDH subtypes are primarily driven by the ability–achievement discrepancy group. The implications of these findings are discussed for intervention, reading theory, and a more refined understanding of heterogeneity.

Keywords: *dyslexia; fluency; naming speed; phonological processing; connected-text; Double Deficit Hypothesis; classification; early identification/intervention*

The double-deficit hypothesis (DDH) of dyslexia rep- resents an evolving, theoretically driven approach to subtyping classification that incorporates two of the best studied characteristics of most readers with dyslexia— deficits in phonological processing and in the processes underlying naming speed (Wolf, 1999; Wolf et al., 2002). However, a recent review by Vukovic and Siegel (2006) has called into question the existence of a core deficit in naming speed for readers with dyslexia. This study examines the utility of the DDH framework for examining differences in an area less covered in the recent review, namely, potential differences of children classified by the DDH at the connected text level.

In ongoing research on cognitive development, there is a shift from a focus on identifying universals of development to an effort to describe and analyze both the observed variation in development and the underlying factors (Fischer & Pare-Blagoev, 2000; Fischer & Pipp, 1984). For example, Fischer and Pare-Blagoev proposed a *dynamic systems analysis* to illuminate the pluralistic and multidimensional nature of development. Such a dynamic systems approach begins with a

> recognition of the variability of human activity and seeks to identify and analyze patterns of stability and order within the variation. . . . The focus is important because variation has historically been typically regarded as noise due to experimenter or instrument error or random processes. (p. 850)

The characterization of individual differences is important not only in the study of typical cognitive development, but also in the study of less typical development. In the present study, we examine *group-based* differences based on a possible classification of readers with dyslexia at different reading levels, particularly in the less-studied area of reading fluency. The significance of this approach lies in its potential for illuminating multiple pathways to dysfluent connected text reading, with the implications of such findings for diagnosis and intervention. In the present study, we aimed (a) to examine multiple pathways to dysfluent reading in word-level and connected text reading for readers with dyslexia using a DDH framework; and (b) to examine patterns of dsyfluent reading in word-level and connected text reading using the DDH for children who are classified as having a reading disability for different etiological reasons: one group of children who were referred due to overall low achievement, and another group of children who were referred due to an ability–achievement gap.

Variation, Classification, and the DDH

From early 19th-century emphasis on visually based explanations of dyslexia to recent emphasis on phonologically based explanations, the history of reading disabilities research has seen a number of efforts to explain reading failure through parsimonious discrepancy models, or *single- deficit* models. In the past two decades, it has been well established that children with dyslexia often have difficulty with phonological processing. Specifically, children with dyslexia often fail to develop an awareness that words— both written and spoken—can be broken down into smaller units of sounds (e.g., Catts, 1996; Stanovich, 1991). Phonological processing has been suggested as the core and, in many cases, single deficit that children with reading disabilities face.

Although systematic research on the role of phonological processes in reading failure and intervention has proven highly predictive for many children, it has been insufficient in dealing with the heterogeneity of reading disabilities and the complexity of reading breakdown, particularly in the area of reading fluency (for a recent review, see Meyer & Felton, 1999; see also Breznitz & Share, 1992; Wolf & Katzir-Cohen, 2001).

The DDH does not attempt to explain all sources of reading failure but, rather, uses the two best known behavioral deficits as a first index of these underlying sources. More specifically, the DDH integrates the unidimensional view— in which a single core phonological deficit is the underlying mechanism in reading impairment—with a view in which the range of component processes that underlie naming speed are seen as an additional set of possible, disruptive factors. Wolf and Bowers (1999) explored several other potential hypotheses to explain the relationships between reading problems and a deficit in processes underlying rapid naming.

For example, Bowers and Wolf (1993; see also Katzir et al., 2006) described how a deficit in naming speed might be responsible for some—but not all—orthographic development and reading deficits. In this view, processes responsible for the slow recognition of multiple letters in common orthographic patterns adversely affect word identification, with concomitant effects on dysfluent reading and comprehension. Indeed, naming speed has been found to be related both to the *latency* in single- word and connected text reading (Bowers, Sunseth, & Golden, 1999; Bowers & Wolf, 1993) and to the effective- ness of practice in producing quick recognition of single words and text passages (Bowers et al., 1999; Levy, Bourassa, & Horn, 1999; Levy & Lysynchuk, 1997; Young & Bowers, 1995).

A recent review by Vukovic and Siegel (2006) called into question the validity of the DDH for classifying children with reading disabilities. Vukovic and Siegel claimed that inconsistencies in sample characterization, methods of classification, and violation of statistical para- meters make generalization of specific findings difficult. However, as represented in the review, a growing body of work now demonstrates that there are discrete groups of children with dyslexia who show single deficits in either naming speed or phonological processes or combined deficits in both areas (Badian, 1997; Carver, 1997; Compton & Carlisle, 1994; Kirby, Parrila, & Pfeiffer, 2003; Lovett, 1987; Lovett, Steinbach, & Frijters, 2000; Manis, Doi, & Bhadha, 2000; Manis, Seidenberg, & Doi, 1999; Wolf & Bowers, 1999). As shown in one study not cited in the review, children with both phonological *and* naming speed deficits were consistently found to possess the most severe problems in reading accuracy and reading comprehension— a finding that suggests a possible cumulative effect of multiple deficit sources (Kirby et al., 2003).

The review by Vukovic and Siegel (2006) did highlight, however, two major gaps in the study of the DDH. First, no studies to date have systematically compared the three subtypes on oral reading fluency and comprehension. Oral reading fluency allows for the comparison of the disruptive effects of individual deficits (e.g., naming speed or phono- logical processes) at the connected text reading level. Investigating differences at this level will illuminate the possible cumulative effects of combined deficits or, potentially, the effect of component-general processing speed impediments. Second, no study has directly compared different types of children with reading disabilities when they are segregated according to the DDH. Thus, children who are characterized as garden-variety poor readers and children who are identified as having discrepancy-based dyslexia need to be compared.

The DDH and Multiple Sources of Dysfluency

A major implication of the subtype analysis in the DDH is that there may be multiple pathways to reading break- down, and by extension, we hypothesize, to dysfluent reading (Wolf & Bowers, 1999, 2000). Meyer and Felton's (1999) review on reading fluency implied that a breakdown in fluent reading can happen at the sublexical, lexical, sentence, or higher conceptual integration levels. More recently, Berninger, Abbott, Billingsley, and Nagy (2001) argued that dysfluency can arise from deficits in efficiency, automaticity, or executive functions. Difficulties in efficiency would be evidenced in poor readers by accurate but slow performance; difficulties in automaticity would be characterized by many repetitions yet good monitoring; and difficulties in executive function would result in poor monitoring by readers of what they read.

Wolf and Katzir-Cohen (2001) integrated a developmental view of fluency with a componential view. In their definition, which is also used in this study, they referred to reading fluency as the product of the initial development of both accuracy and automaticity in the processes and systems that underlie reading at the levels of letters, words, and connected text. According to their definition, achieving reading fluency involves the successful integration of information from phonological, orthographic, semantic, syntactic, and morphological processes.

Taken together, Wolf and Katzir-Cohen's (2001), Berninger et al.'s (2001), and Meyer and Felton's (1999) conceptualizations of fluency reinforce the suggestion that there are different levels at work in fluency, particularly sublexical, word, and sentence levels, and that different systems are used in varying degrees at each level. Thus, whereas successful performance at each level is necessary for performance at the next level, such performance is not sufficient for advancement to the next level, because each level requires additional coordination and differentiation from the previous one (Kame'enui, Simmons, Good, & Harn, 2001). As the processes under- lying naming speed, which are serial in nature, are suggested to be important for the development of fluency, examining the DDH at the connected text level, which goes beyond single word processing to serial, sequential processing, promises to shed light on the potential existence of separate reader subgroups.

Garden-Variety Poor Readers Versus Ability–Achievement Discrepancy

A review of the literature on reading disabilities indicates cognitive differences between "garden-variety" poor readers and children with dyslexia outside of the word recognition module (i.e., these children differ in intelligence), but there is limited indication that the nature of processing *within* the word recognition module differs at all for poor readers with and without an IQ–achievement discrepancy. In fact, a number of studies have found no evidence that children with dyslexia and garden-variety poor readers are different in reading, mathematics, or spelling skills, or in other basic cognitive processes (e.g., Share, McGee, & Silva, 1989; Siegel, 1992, 2003; Stanovich, 1989; Stanovich & Siegel, 1994). Furthermore, Siegel (1993) has found that most of the variance in word reading is contributed by phonological processing, as measured by pseudoword reading. Based on these findings, Siegel (2003) has suggested identifying all children performing below the 20th or 25th percentile on phonological decoding as having a reading disability.

Although the field is shifting away from discrepancy models to low achievement–based identification models, the issue of a single parsimonious deficit should be reevaluated. Inevitably, in a process as complex as reading, a parsimonious explanation of reading difficulty such as phonological processing can never explain all sources of reading breakdown, with the result that some children elude diagnosis, classification, and treatment. This may be especially true for children who are only diagnosed on the basis of their low reading scores, because there may be multiple pathways that lead to low reading skills. Thus, the examination of potential sub- groups within this group could help tailor an appropriate intervention for them as well. In this research, we examine whether discrepancy versus garden-variety differences are found among groups of children with reading disabilities who are subtyped in ways other than IQ.

Within this context, and under the new definition of fluency proposed by Wolf and Katzir-Cohen (2001), the overarching question to be resolved becomes the following: From an *etiological* perspective, can different sub-types of dyslexia be characterized by specific patterns of fluency deficits at different reading levels, or is there a more universal path to dysfluent reading, manifested in all readers with dyslexia?

As a first step toward investigating these questions, this study focuses on the group-based differences using the DDH framework in the reading levels that lead to reading fluency, specifically:

1. Do children classified by the DDH differ on fluency at the letter, word, and connected text levels?
2. Do children identified by either low-achievement or ability–achievement discrepancy criteria show similar patterns of differences when classified by the DDH?

To address these questions, we subtyped the dyslexia populations in this study according to the DDH (Wolf & Bowers, 1999; Wolf et al., 2002)—a framework that acknowledges the importance of both accuracy and automaticity in reading performance. We then compared performance across fluency-based subtypes on letter, word, and connected text reading measures. We hypothesized that children with different DDH subtypes would differ from each other on the different reading levels leading to dysfluent reading: The children with phono- logical deficits would have more difficulty with accuracy, the children with shortcomings in the processes underlying naming speed would have more difficulties with rate, and the children with double deficits would have the most impairment on all measures. We also hypothesized that the differences would become more apparent as the tasks became more demanding at the connected text reading level. Finally, we hypothesized that different patterns might be more apparent among different subtypes in the ability–achievement discrepancy group than in the low-achievement group because children with overall low achievement, despite their DDH subtype classification, may not have disparate underlying deficits.

Method

Participants

Our 158 study participants were selected from a larger sample of 269 children with severe reading disabilities who participated in a 4-year, multisite treatment study funded by the National Institute of Child and Human Development (NICHD; Wolf et al., 2002). The NICHD researchers recruited participants from public and private schools in three large metropolitan areas (Boston, Atlanta, and Toronto). Classroom teachers referred students with observed difficulties in learning to read for participation in the intervention. All participants were screened for participation at either the end of first grade or the beginning of second grade. Inclusion criteria for the NICHD study required that the child's (a) primary language was English, (b) age fell between 6-4 and 8-6 at the time of initial testing, (c) hearing and vision were within typical limits, and (d) race was either European American or African American. Exclusion criteria included (a) a composite score on the *Kaufman Brief Intelligence Tests* (K-BIT; Kaufman & Kaufman, 1990) below 70, (b) a history of psychotic or other serious psychiatric or neurological illness, and (c) a vision or hearing impairment. Common comorbid disorders such as attention-deficit/hyperactivity disorder (ADHD) were allowed to covary naturally and did not serve as exclusionary criteria. Based on Morrison (see summary in Stevens, 1996), to control for IQ scores in the subsample used in this study, participants had to meet an additional criterion of a full scale composite score of 80 or above on the *Wechsler Intelligence Scale for Children*, third edition (WISC-III; Wechsler, 1991).

Selection Criteria and Subtype Classification

Full Sample

To guarantee a wide representation of poor readers in the intervention program, NICHD researchers selected children who met the criteria for either low achievement (LA) or regression-corrected ability–achievement discrepancy (AA) definitions of reading disability (Stanovich & Siegel, 1994). They included participants by the LA criteria if their composite K-BIT score was higher than 80 and their average achievement on multiple measures was equal to or less than a standard score of 85. They included participants under the AA criteria if their actual reading scores fell one or more standard errors of the estimate below their predicted scores (as determined by regressing obtained scores on intellectual ability to correct for their correlation). Achievement level was established on the Word Identification subtest of the *Woodcock Reading Mastery Test–Revised* (WRMT-R; Woodcock, 1987). Because findings from previous research indicated that in referred samples, reading dis- ability is more prevalent in boys than in girls, female students were preferentially included in this study. This served to increase the proportion of girls within the sample (Shaywitz, Shaywitz, Fletcher, & Escobar, 1990).

Table 1
Demographic Characteristics of the Full Sample

Variable	*n*	%
Gender		
Boys	87	55.10
Girls	71	44.90
Grade		
2	120	75.90
3	38	24.10
Race		
African American	69	43.70
European American	89	56.30

Note: $N = 158$.

For the present study, we identified a subsample of 158 children from the NICHD sample for whom we had complete data for all participant selection, subtyping, and most experimental variables. Our subsample included 87 boys and 71 girls, which dramatically minimized the gender gap. Three main considerations directed participant selection criteria and study design: generalizability, ability to evaluate diverse classification models of reading disability, and replicability. In the NICHD sample, researchers chose three main factors within a factorial design to increase diversity of children with developmental reading disabilities: socioeconomic status (SES), race, and intelligence (IQ). They derived SES from parental occupational and educational information using the Hollingshead SES index and characterized all children in the sample as either aver- age or low SES. The dyslexia sample in the present study included 69 African American children and 89 European American children. Children's demographic information is summarized in Table 1.

Researchers used the K-BIT Composite IQ score as a screening measure of intellectual ability in the NICHD sample. As described earlier, participant selection criteria for this study included a Full Scale IQ score on the WISC of 80 and above (see Table 2).

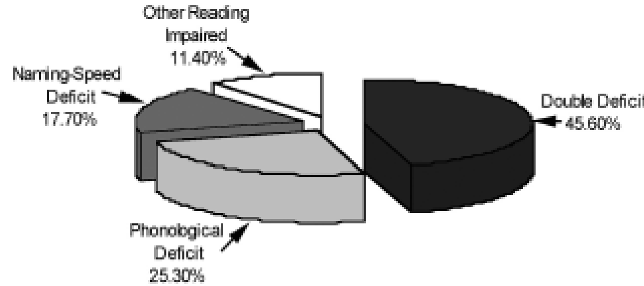
NICHD identified three subtypes of readers with dyslexia according to the classification framework of the DDH (Wolf et al., 2002). They characterized these subtypes respectively by phonological deficits, naming speed deficits, and a combination of both deficits (see Figure 1). In this study, we identified a phonological deficit (PD) if a child's score on the *Comprehensive Test of Phonological Processing* (CTOPP; Wagner, Torgesen, & Rashotte, 1999) Elision, but not Blending subtest (see Note 1) was at least 1 *SD* below age-normed expectations. We identified a naming speed deficit (NSD) if a child's rapid automatized naming (RAN) latency performance was more than 1 *SD* below age norms on the RAN Letter task. We classified children who met criteria for both phonological and naming speed deficits in a double- deficit (DD) subgroup. We characterized children who did not fit into any of these groups as having neither deficit, and we labeled them as having other reading impairment (ORI). The sample distribution according to the DDH framework can be seen in Figure 1.

Table 2
Means and Standard Deviations of Intelligence Measures for the Full Sample

Variable	*M*	*SD*	Range
Full Scale IQ	94.16	9.30	80–123
Picture IQ	96.66	10.74	75–125
Verbal IQ	93.10	10.30	70–124

Note: $N = 158$.

Figure 1
Composition of Double-Deficit Hypothesis Subgroups for the Full Sample



LA and AA Subgroups

In addition to the criteria described earlier, in the sub- group analysis of the LA and AA groups, we used a more stringent criterion: we removed children whose WRMT-R Word Identification score was above 85, because preliminary analysis showed higher representation of children whose Word Identification score was higher than 85 in the LA group than in the AA group. The removal of children whose Word Identification score was within 1 *SD* ensured that the remaining children showed high impairment and were more comparable in their sight-word reading skills. This reduced the sample sizes to 73 children in the LA reading disability group and 39 children in AA reading disability group. Table 3 presents demographic information for the LA and AA groups. There was no significant difference in their socioeconomic status, $F(1, 111) = .08$, $p = .78$. Figures 2 and 3 show the composition of the DDH subtypes in the LA group and AA group, respectively. It is notable that DD is more highly represented in the AA group (63%) than in the LA group (41%).

Table 3
Demographic Characteristics of the Sample by Reading Disability Criterion Group

	LA[a]			AA[b]		
Variable	*n*	*M*	*SD*	*n*	*M*	*SD*
Gender						
Boys	18			42		
Girls	21			31		
Grade						
2	32			56		
3	7			17		
Race						
European American	18			44		
African American	21			29		
SES		34.11	10.92		34.92	11.92

Note: $N = 112$. LA = participants classified based on low-achievement criterion; AA = participants classified based on ability–achievement discrepancy criterion; SES = socioeconomic status.
a. $n = 39$.
b. $n = 73$.

Processing-Related Constructs and Measures

Cognitive Ability

To assess cognitive ability, we used the WISC-III, which is scaled for children ages 6 to 16 (Wechsler, 1991). This comprehensive measure of children's intellectual abilities is divided into two scales: a Verbal scale and a Nonverbal scale. The subtests that make up the Verbal scale include Information, Similarities, Arithmetic, Vocabulary, and Comprehension. The subtests that make up the Nonverbal scale include Picture Completion, Coding, Picture Arrangement, Block Design, and Object Assembly.

Figure 2
Composition of Double-Deficit Hypothesis Subgroups for the Low-Achievement Criterion

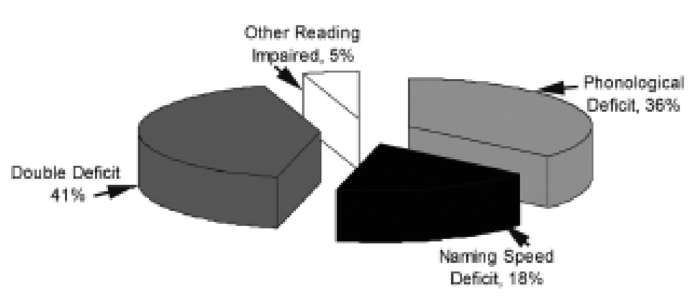
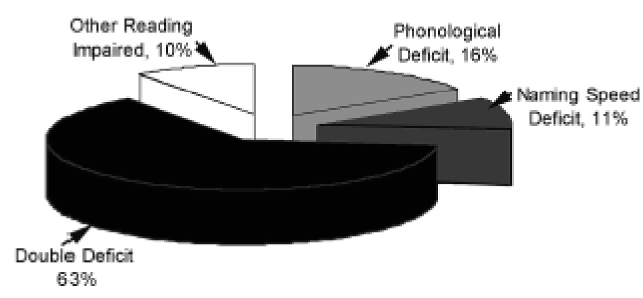


Figure 3
Composition of Double-Deficit Hypothesis Subgroups for the Ability–Achievement Discrepancy Criterion



Rapid Letter Naming

The Rapid Automatized Naming Test (RAN; Denckla & Rudel, 1976; Wolf, Bally, & Morris, 1986; Wolf & Denckla, 2005) comprises four subtests containing 50 stimuli each. The first three subtests, containing single category stimuli (Digits, Letters, and Objects, respectively), were used in this study. The stimuli in each sub- test are arranged randomly in a 10 × 5 matrix. The participant is required to name the stimuli in each subtest as quickly and accurately as possible. Speed and accuracy are measured. Standard scores (M = 100, SD = 15) are reported.

Phonological Awareness

We assessed phonological awareness using the CTOPP (Wagner et al., 1999). We used early versions of the Elision and Blending subtests, using the same stimuli with local norms. Z scores were used for both measures in this study. The Elision subtest requires the child to say a word produced by the experimenter and then repeat the word after deleting either a syllable or a phoneme specified by the experimenter, with the correct response forming a real word. The Blending subtest involves a series of orally presented isolated syllables or phonemes, which the child must blend together to form a word. The experimental version of these subtests was used in this study, along with preliminary norms.

Spelling Pattern Recognition

The Peabody Individual Achievement Test (PIAT; Markwardt, 1989) Spelling subtest was used to assess spelling. This task requires children to recognize letters by name or sound and to recognize standard spelling by choosing the correct spelling, from among four choices, of a word spoken by the examiner. It has 73 items and yields standard scores (M = 100, SD = 15).

Literacy Skill Measures

Decoding

The Word Attack subtest of the WRMT-R (Woodcock, 1987) assesses a child’s ability to apply grapheme– phoneme correspondence rules and word analysis skills to pronounce unfamiliar printed words (i.e., phonetically regular nonwords). Errors are recorded, and correct scores are standardized according to both grade and age norms (*M* = 100, *SD* = 15).

Word Reading

Two measures of word-level reading were used. The Word Identification subtest of the WRMT-R requires the participant to identify regular and irregular sight words within a 5-second limit per word. Standard scores are reported (M = 100, SD = 15).

An early version of the Test of Word Reading Efficiency (TOWRE; Torgesen, Wagner, & Rashotte, 1999) with local norms was used with the participants with dyslexia. This test contains 104 words of increasing difficulty arranged in four columns. The participant is required to read aloud as many words as possible within 45 seconds. Standard scores are reported (M = 100, SD = 15).

Connected Paragraph Reading

Two measures assessed connected text reading. The Gray Oral Reading Test (GORT; Wiederholt & Bryant, 1992) was used to assess paragraph comprehension (number of correct comprehension responses), reading accuracy (number of oral reading errors only for the oral reading paragraph), and reading time. All scores are reported as standard scores ranging from 0 to 20 (M = 10, SD = 3).

The Passage Comprehension subtest of the WRMT-R uses a cloze procedure that requires the participant to read sentences missing a word that is important to the meaning of the passage. Participants must supply a word that fits the meaning of each sentence or passage. Standard scores are reported (M = 100, SD = 15).

Table 4
Means and Standard Deviations of Word-Level and Connected Text–Level Reading Measures

Variable	*M*	*SD*	Range
Word level			
WRMT-R Word Identification[a]	79.68	10.31	45–113
WRMT-R Word Attack[a]	75.59	10.17	48–100
TOWRE[a]	67.84	9.78	34–97
Connected text level			
GORT Accuracy[b]	6.18	1.20	3–10
GORT Rate[b]	6.16	1.10	3–10
GORT Comprehension[c]	5.49	2.07	2–12
GORT Quotient[d]	76.43	12.08	55–130
WRMT-R Comprehension[a]	77.63	11.93	42–108

Note: WRMT-R = *Woodcock Reading Mastery Test–Revised* (Woodcock, 1987); TOWRE = *Test of Word Reading Efficiency* (Torgesen, Wagner, & Rashotte, 1999); GORT= *Gray Oral Reading Test* (Wiederholt & Bryant, 1992).
a. $n = 158$.
b. $n = 122$.
c. $n = 111$.
d. $n = 96$.

Results

The descriptive statistics on reading measures for the full sample are presented in Table 4. Not surprisingly, students' performance on the word-level and connected text–level reading measures was low—far below 1 *SD* of the norm. The students' performance in timed word reading (i.e., TOWRE) was particularly low—below 2 *SD*. It should be noted that many students had missing values on the GORT measures, most prominently in GORT Comprehension and Quotient. The inspection of the data showed that many students with double deficits tended to have missing values (28 out of 72; 39%). In this study, we excluded the missing values in the analysis, not imputing any values or replacing missing values with lowest observed values. The missing scores were systematic, not random, in that some of the GORT tasks were too challenging for many children to complete. Thus, from a measurement point of view, assigning a certain score would distort the true relationship when we did not have information on the children's performance on some of the GORT measures.

Table 5
Mean Intelligence and Symbol-Level Reading Performance Scores of Children by Reading Deficit Subtype

	NSD[a]		PD[b]		DD[c]				
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	η^2	Significance	Differences[d]
WISC-III									
Full Scale IQ	92.46	7.75	95.75	11.11	92.49	8.06		$F(2, 137) = 1.90$, $p = .15$	PD = NSD = DD
Picture IQ	91.21	10.28	98.40	11.91	96.93	9.80	.06	$F(2, 137) = 4.18$, $p = .02$	(PD = DD) > NSD
Verbal IQ	94.93	9.91	94.45	11.16	90.01	9.05	.05	$F(2, 137) = 3.88$, $p = .02$	(PD = NSD) > DD
RAN									
Objects	81.57	18.08	90.05	16.56	70.49	17.81	.20	$F(2, 137) = 16.65$, $p < .001$	PD > NSD > DD
Letters	64.32	16.68	92.85	12.05	50.36	17.87	.56	$F(2, 137) = 88.77$, $p < .001$	PD > NSD > DD
Digits	69.22	18.85	82.43	16.53	52.96	19.95	.32	$F(2, 136) = 32.54$, $p < .001$	PD > NSD > DD
CTOPP									
Blending	0.57	0.89	–0.74	1.15	–0.87	1.22	.20	$F(2, 135) = 16.36$, $p < .001$	NSD > (PD = DD)
Elision	–0.26	0.86	–1.77	0.46	–1.98	0.59	.54	$F(2, 136) = 78.46$, $p < .001$	NSD > (PD = DD)
PIAT									
Spelling	83.39	9.73	83.74	8.16	78.21	8.35	.09	$F(2, 136) = 6.85$, $p < .001$	(PD = NSD) > DD

Note: NSD = naming speed deficit; PD = phonological deficit; DD = double deficit; WISC-III = *Wechsler Intelligence Scale for Children* (3rd ed.; Wechsler, 1991); RAN = *Rapid Automatized Naming Test* (Denckla & Rudel, 1976; Wolf & Denckla, 2005); CTOPP = *Comprehensive Test of Phonological Processing* (Wagner, Torgesen, & Rashotte, 1999); PIAT = *Peabody Individual Achievement Test* (PIAT; Markwardt, 1989). Reported scores are standard scores, except for CTOPP, which used *z* scores.
a. $n = 28$.
b. $n = 40$.
c. $n = 72$.
d. The general linear hypothesis was used in all individual comparisons. Differences reported are significant at $p < .05$.

Subtyping Classifications

To explore whether the mean performance of the children in the three DDH subtypes (NSD, PD, and DD) differed significantly on different measures, we employed multiple regressions using general linear hypothesis (GLH) tests, instead of a univariate analysis of variance (ANOVA), because the estimates of the *p* values from post hoc tests in ANOVA tend to be unduly conservative, particularly when the sample size is small (see Note 2). For this analysis, we only included children who were classified as having NSD ($n = 28$), PD ($n = 40$), or DD ($n = 72$), and we excluded the ORI group ($n = 18$). Table 5 shows children's mean performance in intelligence measures, rapid naming, phonological awareness measures, and spelling pattern recognition by DDH subtypes.

All groups fell within the average IQ range for all IQ subscales, with no significant difference on Full Scale IQ. The PD group performed significantly higher than the DD group on the Verbal IQ subtask, but no statistical difference was observed in the Picture IQ. The DD group performed higher than the NSD group on Picture IQ, but the NSD group outperformed the DD group in Verbal IQ (for more descriptive analyses of IQ differences among subtypes, see O'Rourke, 2002).

On the symbol-level naming tasks, the PD group performed significantly higher than the NSD group, who in turn performed significantly higher than the DD group. On phonological measures (Elision and Blending), the NSD group performed significantly higher than both groups with a phonological deficit. The PD and the DD groups did not differ either on the Blending task or on the Elision task. Finally, the mean performance of the DD group was significantly lower than those of the PD and the NSD groups in the PIAT Spelling Recognition task.

Table 6 shows correlations between the measures in the study. The three RAN measures are fairly highly correlated with one another (*r*s > .61, *p*s < .001). Blending and Elision are moderately correlated with each other ($r = .55$, $p < .001$) but show differences in their relationships with word-level and connected text–level reading measures. Children's performance in the Elision task was significantly correlated with all the word-level reading measures and comprehension measures (WRMT-R and GORT) except GORT Accuracy, Rate, and Quotient. However, children's performance in the Blending task was significantly correlated only with Word Attack, but not with any other word-level or connected text–level reading measures (except for a marginally significant relation- ship with GORT Comprehension, $r = .17$, $p = .07$). Finally, all the word-level reading measures and connected text–level reading measures were significantly correlated with one another (rs > .33, ps < .001).

Research Question 1

To answer the first research question, "Do children classified by the DDH differ on fluency at the letter, word, and connected text levels?" we used GLH tests to examine whether there were differences among the three groups on the following measures: WRMT-R Word Identification, Word Attack, TOWRE, and WRMT-R Comprehension, and the four measures of the GORT. Effect sizes were found to be small to moderate (Cohen, Durant, & Cook, 1988; see Tables 7 and 8).

At the word level (see Table 7), the DD subtype performed significantly lower than the PD and the NSD sub- types on all the measures (WRMT-R Word Identification, Word Attack, and TOWRE). The children with NSD and PD were not significantly different from each other on Word Identification and Word Attack, but the PD subtype out- performed the NSD on word reading efficiency.

At the connected text level (see Table 8), the PD sub- type performed significantly better than the DD subtype on all the measures. The PD subtype did not differ from the NSD subtype on the comprehension measures (i.e., WRMT-R Comprehension and GORT Comprehension), but the PD subtype performed significantly higher than the NSD subtype on GORT accuracy and Rate. On the GORT Reading Quotient, the PD subtype outperformed the NSD and the DD sub- types, whereas the NSD subtype did not significantly differ from the DD subtype.

Table 6
Correlations Between Measures Used in the Study

Measure	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. RAN Objects	—															
2. RAN Letters	.61***	—														
3. RAN Digits	.62***	.81***	—													
4. CTOPP Blending	.07	.14	.23**	—												
5. CTOPP Elision	.10	.23**	.34***	.55***	—											
6. PIAT Spelling	.19*	.36*	.29*	.04	.15†	—										
7. Full Scale IQ	.08	.19*	.07	.24**	.12	.06	—									
8. Picture IQ	.08	.17*	.06	.02	–.07	–.01	.79***	—								
9. Verbal IQ	.05	.14	.06	.36***	.25**	.09	.82***	.30***	—							
10. WRMT-R Word Identification	.20*	.52***	.41***	.12	.30***	.70***	.17*	.06	.21**	—						
11. WRMT-R Word Attack	.17*	.40***	.27**	.29***	.40***	.41***	.15	–.004	.24**	.62***	—					
12. TOWRE	.28***	.57***	.43***	.12	.21*	.64***	.18*	.09	.19*	.78***	.55***	—				
13. WRMT-R Comprehension	.22**	.50***	.43***	.04	.22**	.50***	.21**	.15	.19*	.78***	.49***	.67***	—			
14. GORT Accuracy	.26**	.37***	.17	–.07	.05	.37***	.13	.10	.11	.61***	.46***	.59***	.50***	—		
15. GORT Reading Rate	.31**	.38***	.17	–.10	–.05	.35***	.20*	.17	.16	.63***	.41***	.57***	.52***	.89***	—	
16. GORT Comprehension	.32**	.42***	.38***	.17	.36***	.58***	.21*	.11	.23*	.51***	.46***	.60***	.42***	.38***	.33***	—
17. GORT Reading Quotient	.34**	.45***	.30*	–.07	.07	.62***	.11	.13	.05	.67***	.51***	.76***	.47***	.64***	.60***	.88***

Note: RAN = *Rapid Automatized Naming Test* (Denckla & Rudel, 1976; Wolf & Denckla, 2005); CTOPP = *Comprehensive Test of Phonological Processing* (Wagner, Torgesen, & Rashotte, 1999); PIAT = *Peabody Individual Achievement Test* (PIAT; Markwardt, 1989); WRMT-R = *Woodcock Reading Mastery Test–Revised* (Woodcock, 1987); TOWRE = *Test of Word Reading Efficiency* (Torgesen, Wagner, & Rashotte, 1999); GORT = *Gray Oral Reading Test* (Wiederholt & Bryant, 1992).

†$p = .06$. *$p < .05$. **$p < .01$. ***$p < .001$.

Table 7
Mean Word-Level Reading Performance Scores of Children by Reading Deficit Subtype

	NSD[a]		PD[b]		DD[c]				
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	η^2	Significance	Differences[d]
WRMT-R									
Word Identification	81.30	10.68	83.95	6.73	74.28	9.36	.20	$F(2, 136) = 16.65, p < .001$	(NSD = PD) > DD
Word Attack	78.48	9.89	76.25	8.73	71.17	8.57	.11	$F(2, 136) = 8.38, p < .001$	(NSD = PD) > DD
TOWRE	67.27	10.06	71.54	6.93	63.00	8.18	.17	$F(2, 137) = 13.96, p < .001$	PD > NSD > DD

Note: NSD = Naming Speed Deficit; PD = Phonological Deficit; DD = Double Deficit; WRMT-R = *Woodcock Reading Mastery Test–Revised* (Woodcock, 1987); TOWRE = *Test of Word Reading Efficiency* (Torgesen, Wagner, & Rashotte, 1999).

a. $n = 28$.

b. $n = 40$.

c. $n = 72$.

d. The general linear hypothesis was used in all individual comparisons. Differences reported are significant at $p < .05$.

Table 8
Mean Connected Text–Level Reading Performance Scores of Children by Reading Deficit Subtype

	NSD			PD			DD					
Variable	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	η^2	Significance	Differences[a]
WRMT-R Comprehension	28	77.96	11.17	40	82.88	8.52	72	72.24	11.85	.16	$F(2, 137) = 12.69, p < .001$	(PD = NSD) > DD
GORT Accuracy	22	5.61	1.47	35	6.60	0.85	49	5.86	0.91	.13	$F(2, 104) = 7.85, p = .001$	PD > (NSD = DD)
GORT Rate	22	5.70	1.40	35	6.54	0.82	49	5.88	0.88	.11	$F(2, 104) = 6.42, p = .002$	PD > (NSD = DD)
GORT Comprehension	21	5.86	2.08	31	5.81	1.64	44	4.45	1.56	.14	$F(2, 93) = 7.67, p = .001$	(PD = NSD) > DD
GORT Quotient	21	74.67	7.91	31	77.32	6.10	44	71.32	6.11	.14	$F(2, 93) = 7.82, p = .001$	PD > (NSD = DD)

Note: NSD = Naming Speed Deficit; PD = Phonological Deficit; DD = Double Deficit; WRMT-R = *Woodcock Reading Mastery Test–Revised* (Woodcock, 1987); GORT = *Gray Oral Reading Test* (Wiederholt & Bryant, 1992).
a. The general linear hypothesis was used in all individual comparisons. Differences reported are significant at $p < .05$.

Table 9
Means and Standard Deviations on Processing-Related and Reading-Related Measures by Reading Disability Criterion Group

	LA[a]			AA[b]				
Variable	*M*	*SD*	Range	*M*	*SD*	Range	Significance	Difference[c]
Processing-related measures								
WISC-III								
Full Scale IQ	88.08	4.90	81–97	96.36	8.38	80–119	$F(1, 110) = 32.12, p < .001$	LA < AA
Verbal IQ	87.72	7.50	74–104	94.26	8.89	78–114	$F(1, 110) = 15.28, p < .001$	LA < AA
Performance IQ	91.05	8.25	77–112	99.66	10.71	75–125	$F(1, 110) = 19.09, p < .001$	LA < AA
CTOPP								
Blending	−0.42	1.25	−3.09–2.79	−0.48	1.41	−3.09–3.38	$F(1, 110) = .07, p = .81$	LA = AA
Elision	−1.64	0.68	−3.15–0.40	−1.64	0.81	−3.15–0.35	$F(1, 110) = .00, p = .99$	LA = AA
RAN Letters	75.62	20.38	25–105	61.12	25.39	25–119	$F(1, 110) = 9.44, p = .003$	LA > AA
PIAT Spelling	81.66	7.89	62–97	78.26	9.09	56–105	$F(1, 110) = 3.79, p = .05$	LA > AA
Word-level reading measures								
WRMT-R								
Word Identification	81.03	3.51	71–85	72.33	8.87	45–92	$F(1, 109) = 34.50, p < .001$	LA > AA
Word Attack	75.28	7.42	53–88	71.53	9.84	48–91	$F(1, 110) = 4.33, p = .04$	LA > AA
TOWRE	67.69	5.21	56.5–80.5	63.26	9.60	34–85	$F(1, 110) = 7.16, p = .009$	LA > AA
Connected text reading measures								
WRMT-R Comprehension	78.38	7.86	56–91	71.53	11.60	42–92	$F(1, 110) = 10.85, p = .001$	LA > AA
GORT								
Accuracy	6.15	0.76	5–7	5.70	1.11	3–8	$F(1, 87) = 4.35, p = .04$	LA > AA
Rate	6.24	0.61	5–7	5.66	0.98	3–7	$F(1, 87) = 7.03, p = .003$	LA > AA
Comprehension	5.13	1.48	3–9	4.94	1.91	2–9	$F(1, 77) = .23, p = .64$	LA = AA
Quotient	72.20	8.95	67–85	74.17	4.58	55–112	$F(1, 77) = 1.24, p = .27$	LA = AA

Note: LA = Low-Achievement criterion group; AA = Ability–Achievement discrepancy criterion group; WISC-III = *Wechsler Intelligence Scale for Children* (3rd ed; Wechsler, 1991); CTOPP = *Comprehensive Test of Phonological Processing* (Wagner, Torgesen, & Rashotte, 1999); RAN = *Rapid Automatized Naming Test* (Denckla & Rudel, 1976; Wolf & Denckla, 2005); PIAT = *Peabody Individual Achievement Test* (PIAT; Markwardt, 1989); WRMT-R = *Woodcock Reading Mastery Test–Revised* (Woodcock, 1987); TOWRE = *Test of Word Reading Efficiency* (Torgesen, Wagner, & Rashotte, 1999); GORT= *Gray Oral Reading Test* (Wiederholt & Bryant, 1992).
a. $n = 39$; $n = 33$ for GORT Accuracy and Rate; $n = 30$ for GORT Comprehension and Quotient.
b. $n = 73$; $n = 56$ for GORT Accuracy and Rate; $n = 49$ for GORT Comprehension and Quotient.
c. Differences reported are significant at $p < .05$.

Research Question 2

To answer the second research question, "Do children identified by either low-achievement (LA) or ability–achievement discrepancy (AA) criteria show similar patterns of differences when classified by the DDH?" we investigated whether the differences among the deficit subtypes found in the previous section were true for children who were included in the study for different etiological reasons. Table 9 shows descriptive statistics on the measures for the LA and AA groups. The overall performance of the two groups was quite low on the majority of the measures, except for the intelligence measures, where the mean scores were close to the age norm average. As expected, the AA group showed significantly higher average cognitive performance on all measures than the LA group. However, the AA group had significantly lower scores than the LA group in all the other measures except phonological awareness tasks, GORT Comprehension, and GORT Quotient. The mean performance on the Blending task was within the average range for both groups, but their mean scores were very low in the Elision task—close to the fifth percentile. Also, the AA group's performance on RAN Letters and word reading efficiency was close to 2 *SD* below the age norm.

We conducted GLH tests again to compare the performance of the three DDH subgroups on different processes, word-level, and connected text reading measures within the LA and AA groups (see Tables 10–12). It should be noted that in some cases, the sample sizes were very small, so that the estimates may not be precise. As Table 10 shows, on the Elision task, the NSD subtype scored significantly higher than the PD and DD sub- types, but the PD subtype did not differ from the DD subtype for both the LA and AA criterion groups. Also, in RAN letter naming, the PD subtype scored significantly higher than the NSD and the DD subtypes, and the NSD subtype scored significantly higher than the DD subtype. Despite similar patterns in the Elision and RAN letter naming tasks, the LA and AA groups showed a different pattern in PIAT: In the LA group, the three sub- types were not different from each other in their mean spelling performance, but in the AA group, the PD sub- type scored significantly higher than the DD subtype.

Table 11 displays children's performance on the word-level reading tasks for the LA and AA groups. In the LA group, children of different subtypes did not differ from one another on WRMT-R Word Identification and Word Attack. On word reading efficiency, however, the PD subtype scored significantly higher than the DD subtype and marginally higher than the NSD subtype (p = .06), whereas the NSD subtype was not different from the DD subtype. Within the AA group, the NSD subtype was not significantly different from the DD sub- type on all three word reading measures, whereas the PD subtype scored significantly higher than the NSD sub- type on word identification and word reading efficiency.

Table 12 presents results on the connected text–level reading measures for the three DDH subtypes within the LA and AA groups. In the AA group, the PD subtype outperformed the DD subtype on all the connected text reading measures. The PD subtype did not differ from the NSD subtype, and the NSD subtype did not differ from the DD subtype on the comprehension measures. However, in the GORT Accuracy and GORT Rate tasks, the DD subtype outperformed the NSD subtype. In the LA group, there did not appear to be any consistent pattern. On GORT Comprehension, the children of the three deficit subtypes did not differ from one another in their performance, whereas on WRMT-R Comprehension, the PD subtype outperformed the DD subtype, and the NSD subtype marginally outperformed the DD subtype. On GORT Accuracy and Rate, the DD subtype outperformed the NSD subtype, whereas the PD did not differ from the DD subtype.

In summary, children in the AA group showed higher IQ scores but lower scores in the majority of process- related tasks and word-level and connected text–level reading measures, except for the phonological awareness tasks, GORT Comprehension, and GORT Quotient. The children in the three subtypes in the LA and AA groups showed similar patterns in elision and rapid letter naming, but a different pattern emerged in the spelling pat- tern recognition (PIAT). In the AA group, the PD subtype outperformed the DD subtype in PIAT, whereas no such difference was observed in the LA group. Furthermore, in the AA group, the PD subtype outperformed the DD subtype in all the word and connected text reading measures except Word Attack. Finally, the NSD subtype was not significantly different from the DD subtype in any of the word reading and connected text measures except GORT Accuracy and GORT Rate. In contrast, in the LA group, the three subtypes did not differ from each other in their performance in PIAT, Word Identification, Word Attack, or GORT comprehension. Interesting enough, the DD subtype also outperformed the NSD subtype in GORT Reading Rate.

Discussion

Subtype Classification

The classification of the students with severe reading impairment in the full sample into putative subtypes was consistent with previous results on the DDH. The results indicated that roughly 46% of the participants were categorized with double deficits in naming speed and phonology. Furthermore, approximately 25% of the sample could be classified as having a single phonological deficit, 18% had a single naming speed deficit, and 11% of the participants could not be classified into one of the DDH subtypes. In one of the few studies that have employed the DDH framework with populations with severe reading impairment, Lovett et al. (2000) found similar group ratios. Although several researchers have questioned the utility of a subtyping approach to reading (see O'Rourke, 2002, for a review), we believe that this study provides external validity to the DDH classification. After group member- ship had been established, the subtypes in this study differed in predictable ways on a set of variables that were not included in the generating of the subtypes.

Table 10
Mean Intelligence and Symbol-Level Reading Performance Scores of Children by Reading Deficit Subtype and Reading Disability Criterion Group

	LA								AA							
	NSD[a]		PD[b]		DD[c]				NSD[e]		PD[f]		DD[g]			
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	Significance	Differences[d]	*M*	*SD*	*M*	*SD*	*M*	*SD*	Significance	Differences[d]
WISC-III																
Full Scale IQ	87.86	6.39	88.00	4.84	88.00	4.64	$F(2, 34) = 0.002$, $p = .99$	NSD = PD = DD	94.75	8.08	104.58	9.08	93.63	6.92	$F(2, 63) = 10.30$, $p < .001$	PD > (NSD = DD)
Verbal IQ	94.86	7.13	89.57	6.82	83.38	5.63	$F(2, 34) = 8.65$, $p = .001$	(NSD = PD) > DD	92.13	9.67	99.25	9.84	91.98	7.67	$F(2, 63) = 3.73$, $p = .03$	PD > DD, PD = NSD, NSD = DD
Picture IQ	82.57	5.80	88.71	5.46	95.88	7.72	$F(2, 34) = 10.85$, $p < .001$	DD > NSD > PD		10.91	110.00	8.57	97.00	10.03	$F(2, 63) = 8.24$, $p = .001$	PD > (NSD = DD)
CTOPP																
Elision	−0.76	0.20	−1.76	0.45	−2.04	0.56	$F(2, 34) = 18.55$, $p < .001$	NSD > (PD = DD)	−0.52	0.40	−1.88	0.49	−1.95	0.59	$F(2, 63) = 22.92$, $p < .001$	NSD > (PD = DD)
Blending	0.19	0.43	−0.50	1.15	−0.75	1.30	$F(2, 34) = 1.69$, $p = .20$	NSD = PD = DD	0.99	1.06	−0.79	1.12	−0.86	1.28	$F(2, 63) = 7.79$, $p = .001$	NSD > (PD = DD)
RAN Letters	70.57	13.26	95.07	6.41	58.00	13.50	$F(2, 34) = 40.86$, $p < .001$	PD > NSD > DD	67.13	10.12	91.83	5.44	46.48	17.26	$F(2, 63) = 44.61$, $p < .001$	PD > NSD > DD
PIAT Spelling	82.86	7.40	82.15	8.35	80.63	8.57	$F(2, 34) = 0.22$, $p = .80$	NSD = PD = DD	78.38	11.94	83.83	8.21	75.24	6.73	$F(2, 63) = 5.97$, $p = .004$	PD > DD, PD = NSD, NSD = DD

Note: LA = Low-Achievement criterion group; AA = Ability–Achievement discrepancy criterion group; NSD = Naming Speed Deficit; PD = Phonological Deficit; DD = Double Deficit; WISC-III = *Wechsler Intelligence Scale for Children* (3rd ed.; Wechsler, 1991); CTOPP = *Comprehensive Test of Phonological Processing* (Wagner, Torgesen, & Rashotte, 1999); RAN = *Rapid Automatized Naming Test* (Denckla & Rudel, 1976; Wolf & Denckla, 2005); PIAT = *Peabody Individual Achievement Test* (PIAT; Markwardt, 1989).

a. $n = 7$.

b. $n = 14$.

c. $n = 16$.

d. Differences reported are significant at $p < .05$.

e. $n = 8$.

f. $n = 12$.

g. $n = 46$.

Table 11
Mean Word-Level Reading Performance Scores of Children by Reading Deficit Subtype and Reading Disability Criterion Group

	LA								AA							
	NSD[a]		PD[b]		DD[c]				NSD[e]		PD[f]		DD[g]			
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	Significance	Differences[d]	*M*	*SD*	*M*	*SD*	*M*	*SD*	Significance	Differences[d]
WRMT-R																
Word Identification	80.71	2.69	82.07	2.87	80.00	4.29	$F(2, 34) = 1.29$, $p = .29$	NSD = PD = DD	70.88	13.19	79.42	6.65	69.15	6.83	$F(2, 63) = 8.31$, $p = .001$	PD > (NSD = DD)
Word Attack	73.86	8.11	74.00	7.00	75.50	6.95	$F(2, 34) = 0.21$, $p = .81$	NSD = PD = DD	73.00	7.21	73.83	10.53	68.74	9.00	$F(2, 63) = 1.92$, $p = .16$	NSD = PD = DD
TOWRE	67.21	5.44	70.96	4.87	64.19	2.38	$F(2, 34) = 10.21$, $p < .001$	PD > (NSD = DD)[h]	60.25	12.80	68.25	5.27	60.18	7.54	$F(2, 63) = 5.00$, $p = .01$	PD > (NSD = DD)

Note: LA = Low-Achievement criterion group; AA = Ability–Achievement discrepancy criterion group; NSD = Naming Speed Deficit; PD = Phonological Deficit; DD = Double Deficit; WRMT-R = *Woodcock Reading Mastery Test–Revised* (Woodcock, 1987); TOWRE = *Test of Word Reading Efficiency* (Torgesen, Wagner, & Rashotte, 1999).

a. $n = 7$.

b. $n = 14$.

c. $n = 16$.

d. The general linear hypothesis was used in all individual comparisons. Differences reported are significant at $p < .05$.

e. $n = 8$.

f. $n = 12$.

g. $n = 46$.

h. PD > NSD at $p = .06$.

Table 12
Mean Connected Text–Level Reading Performance Scores of Children by Reading Deficit Subtype and Reading Disability Criterion Group

	LA											AA										
	NSD			PD			DD					NSD			PD			DD				
Variable	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	Significance	Differences[a]	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	Significance	Differences[a]
WRMT-R Comprehension	7	81.57	5.77	14	80.71	6.73	16	74.75	8.92	$F(2, 63) = 3.07$, $p = .06$	PD > DD, (NSD > DD)[b], PD = NSD	8	71	12.76	12	79	9.47	46	68.22	11.22	$F(2, 63) = 4.48$, $p = .02$	PD > DD, PD = NSD, NSD = DD
GORT																						
Accuracy	7	5.33	0.82	14	6.33	0.49	16	6.38	0.77	$F(2, 28) = 5.48$, $p = .01$	(PD = DD) > NSD	8	4.57	1.27	12	6.45	1.04	46	5.5	0.8	$F(2, 47) = 9.15$, $p < .001$	PD > DD > NSD
Rate	6	5.83	0.75	12	6.25	0.45	13	6.46	0.66	$F(2, 28) = 2.20$, $p = .13$	DD > NSD, NSD = PD, PD = DD	7	4.71	1.25	11	6.36	0.92	32	5.53	0.8	$F(2, 47) = 7.47$, $p = .002$	PD > DD > NSD
Comprehension	5	5.2	0.84	10	5.5	1.8	13	5.5	1.52	$F(2, 25) = 0.30$, $p = .75$	NSD = PD = DD	6	5.33	2.07	10	5.4	1.26	27	4.15	1.56	$F(2, 40) = 3.05$, $p = .06$	PD > DD, PD = NSD, NSD = DD
Quotient	5	71.8	2.95	10	75.3	4.92	13	74.85	4.78	$F(2, 25) = 1.05$, $p = .36$	(PD = DD) > NSD	6	70.33	9.2	10	75.3	5.56	27	69.07	5.99	$F(2, 40) = 3.48$, $p = .04$	PD > (NSD = DD)

Note: LA = low-achievement criterion group; AA = ability–achievement discrepancy criterion group; NSD = naming speed deficit; PD = phonological deficit; DD = double deficit; WRMT-R = Woodcock Reading Mastery Test–Revised (Woodcock, 1987); GORT = Gray Oral Reading Test (Wiederholt & Bryant, 1992). Lowest recorded scores are substituted for missing GORT scores.

a. The general linear hypothesis was used in all individual comparisons. Differences reported are significant at $p < .05$.

b. NSD > DD at $p = .06$.

Interesting enough, as Figures 2 and 3 show, the ratio of the DDH subgroups was different when segregated into LA and AA groups. The percentage of children in the PD category was double that of the NSD category for the LA group (36% vs. 18%), but the two categories claimed relatively similar proportions (11% vs. 16%) in the AA group. Furthermore, the proportion of the DD category was higher in the AA group (63%; 46 children) than in the LA group (41%; 16 children). These ratios suggest that these groups may have different literacy pro- files. Moreover, as phonological deficits are more highly correlated with Verbal IQ, it may be that the LA group's challenges reflect a more global language deficit and less of the processing speed deficit that is found in the AA group. The higher proportion of children with naming speed deficits (including double deficits) in the AA group suggests the existence of different etiologies for the shared reading difficulties of the two groups.

Differences on Categorization Measures

Consistent with previous studies (Lovett et al., 2000; Manis et al., 2000; O'Rourke, 2002; Wolf et al., 2000), in the full sample, the group with double deficits showed significantly more impairments on most measures. At the letter level, the PD category had relative strength in rapid letter naming, receiving a standard score within the average range. Interesting enough, no difference between the two single-deficit groups was found in object naming. Several studies have suggested that object naming differentiates individuals with ADHD from those with reading disabilities. Future error analysis of the RAN Letters task may reveal qualitative differences among the three groups.

Schatschneider, Carlson, Francis, Foorman, and Fletcher (2002) claimed that if a subtyping classification is based on predictor variables that are correlated with each other, the results from an analysis of variance could be substantially altered because, in this statistical frame- work, it is often assumed that the relevant factors are uncorrelated. In the case of phonological awareness and rapid naming, if the two are positively correlated, the group with the double deficit will have lower phonological awareness than the group with a single deficit in phonological awareness, and this may in turn imply that their lower scores can be explained in terms of their lower phonological skills.

Similar to Schatschneider et al. (2002), Katzir et al. (2006) found that rapid automatized naming correlated moderately with Elision in a sample of average-achieving readers in Grades 1 through 3. However, in the present sample of students with *severe reading impairment* in second and third grades, we found a very modest correlation between different RAN measures and Elision (*r*s = .10–.34) and with Blending (*r*s = .07–.23). Moreover, in this study, we found no significant differences between the PD and the DD subtypes on the Blending and Elision scores. We also found significant differences on RAN scores between the three subtypes, with the DD subtype showing the most impairment in naming speed. Thus, the DD children's low reading scores may not be explained solely by their low phonological skills, but rather by their deficits in both naming speed and phonology.

Schatschneider et al. (2002) suggested that a matched design would be difficult to accomplish, because it would be difficult to find children with very low phonological skills but average rapid naming scores. Furthermore, Vukovic and Siegel (2006) suggested that there appear to be only few individuals who have a naming speed deficit but intact phonological skills. In the present sample, how- ever, 90% of the children who had a single phonological deficit (n = 40) had a standard score of 90 or above on a rapid letter naming task (M = 92.85, SD = 12.05). On the other hand, children with a single naming speed deficit (n = 28) showed average phonological skills. Their z scores on two phonological measures were well within the average range (Elision, M = −0.26, SD = 0.86; Blending, M = 0.57, SD = 0.89). These findings lend support to a heterogeneous sample of readers in which a deficit in RAN at the level of the single naming speed group appears independently from phonological awareness, whereas for the children with the most profound reading problems, the more severe RAN scores are more typically found together with phonological deficits. In average-achieving children, who represent a more homogeneous group and do well on all reading and reading-related tasks, phonological awareness and naming speed are more highly correlated.

In sum, the results of the present study support the DDH as a valid framework for the investigation of distinct subtypes of children with reading disabilities. In future studies of the DDH, profile analysis of the ORI subgroup (showing neither deficit) may yield important clues about the ways in which additional cognitive and linguistic processes may be related to reading failure.

Differences Among DDH Subtypes

Our initial hypothesis—that DDH subtypes would differ from each other on the various reading levels and in the two reading process that lead to fluent reading—was partially confirmed. We found differences on all measures, but several predictions were *not* confirmed—specifically, that the DD children would show the most impairment on *all* measures, that the PD children would show more impairment on accuracy measures, and that the NSD children would show more impairment on rate measures.

Differences at the Word Level

Congruent with previous studies (e.g., Manis et al., 2000), the DD group showed the most impairment on all measures of word-level reading. This may suggest that the double deficit is more than the sum of the two single deficits and reflects a more severe deficit. Dissimilar from the findings by Wolf and Bowers (1999) and Manis et al. (2000), we found no significant differences between the PD and the NSD subtypes in any of the word-level measures. However, Manis et al. used the 25th percentile as the cutoff criterion, whereas we used 1 SD (16th percentile), so our results cannot be not directly compared. Similar to past findings, the PD children per- formed significantly better than the DD children on single-word reading efficiency. This finding is partially consistent with Bowers's (Bowers et al., 1999; Wolf & Bowers, 2000) proposal that slow naming speed interferes with the recognition and storage of orthographic patterns in printed words. The results suggest that the rapid retrieval of orthographic patterns is especially challenging for children with double deficits.

Differences at the Connected Text Level

The pattern that emerged for connected reading reflected a dissociation between reading rate and accuracy, on one hand, and reading comprehension, on the other hand. The NSD group performed significantly lower than the PD group on measures of rate and measures of accuracy. At first glance, these findings do not seem to be consistent with the DDH, which might predict that the NSD subtype would have a relative strength in accuracy (Wolf & Bowers, 2000). However, these data seem congruent with the temporal processing deficit hypothesis proposed by several researchers (see reviews by Farmer & Klein, 1995; Habib, 2000; Wolf & Bowers, 2000). One of the claims made by this line of research is that although students with dyslexia may not have difficulty in processing single, low-level stimuli, they have great difficulty in processing rapid, serially presented stimuli. As Wolf and Bowers (1999) speculated, naming speed "would represent at once both the effect of lower level processes on lexical retrieval and also a cause of further disruption of fluent reading" (p. 16). The findings from this study suggest that demanding serial processing in connected text reading from children with a naming speed deficit affects not only their speed of processing but also their accuracy. The multiple task demands of reading connected text may require more resources than the mere rule-governed word decoding for which NSD readers have a relative strength. Having to coordinate all the additional subprocesses involved in serial reading may be the central cause of their lower reading fluency scores.

The finding that the DD children in this study did not score lower than the NSD children on GORT Reading Rate does not refute the DDH. On the contrary, the majority of the children who did not complete the GORT task (and therefore were not included in the analyses) were from the DD group, implying that they actually have the most difficulty with this task. Future recoding of the existing data in a manner that will account for task completion will help illuminate this issue. It is of interest that although the NSD group showed more impairment than the PD group on accuracy and rate measures, the NSD group did not differ from the PD group on the comprehension measures. This finding may be explained by previous findings suggesting that the NSD group has a relative strength in Verbal IQ (O'Rourke, 2002). O'Rourke's (2002) profile analysis of the DDH on the WISC-III also helps to explain why the DD group, which had significantly lower IQ scores, performed at the lowest level on the GORT Comprehension task. An additional explanation would stipulate reading rate as causing more error-like behaviors on the GORT. If the NSD children indeed exhibited more pauses, repetitions, and self-corrections, these would have been scored as errors, making their accuracy scores lower. As these were not truly decoding errors but error-like behaviors that in fact enhanced their word retrieval, their comprehension would be higher than that of the DD children who made more genuine errors. A detailed error analysis for the different subtypes would provide important qualitative data and information on the nature of the errors that children make. An error analysis would also serve as an important clinical diagnostic measure and would help tailor intervention based on the type and quantity of errors made by a child.

Subtypes in the LA and AA Groups

Research comparing the cognitive and literacy profiles of LA and AA readers has attempted to answer the tough definitional questions about dyslexia that have persisted in the field for more than two decades (O'Rourke, 2002). One area of hypothesized differences between the two groups is on tasks that demand efficient and automatic processing of information. In this sample, we found a dissociation between performance on the WISC-III, which was lower for the LA group, and performance on all timed reading tasks, including RAN, on which the LA readers outperformed the AA group. This finding refutes the hypothesis that RAN can be explained by processing speed (Vukovic & Siegel, 2006). The AA group demonstrated a performance well within average on the general speed of processing as measured on the Performance IQ on the WISC-III. They also performed significantly higher than the LA group, who are typically characterized by slow general processing speed. Despite these differences, the AA group showed significantly more impairment than the LA group on the RAN. There was almost a full standard deviation difference in the mean of RAN Letters between the two groups. Moreover, whereas the percentage of children with single naming speed deficits in the LA group was similar to the one in the overall sample, there was a much higher percentage of children with single phonological deficits in the LA sample. Further research on the oral skills of this group is needed to under- stand the nature of their low reading scores.

The comparison of the results from the overall sample (where LA and AA are combined) and the separate analysis of the DDH subtypes within LA and AA shows that the results in the overall sample may have been driven by the AA group. The results of word reading skills in Tables 7 and 11 and connected text reading skills in Tables 8 and 12 show more similarities between the overall sample results and the results from the AA group. Specifically, in the overall sample and the AA group, the DD subtype's mean performance was significantly lower than that of the PD subtype in all word reading and connected text reading measures except word decoding (Word Attack), whereas in the LA group no such consistent pattern was observed. Furthermore, the results suggest that the deficit of the DD subtype in the AA group may be more severe than that of the DD subtype in the LA group: The DD subtype's performances in the AA group were consistently lower than those in the LA group on RAN Letters, PIAT Spelling, and all the word and connected text reading measures. It is possible that some of the inconsistent results in past literature have actually been due to the LA–AA distinction.

An interesting finding in the examination of the sub- types within the LA and the AA groups separately is that whereas children's mean performances showed the same pattern in the phonological awareness task (i.e., Elision) and the rapid naming task (i.e., RAN Letters), we noted a difference in orthographic processing (i.e., PIAT). In the LA group, the three DDH subtypes did not show differences in PIAT and some word and connected text reading measures. However, in the AA group, the PD subtype scored consistently higher in PIAT and all the word and connected text reading measures except Word Attack. This indicates that a critical starting point of divergence between children who are garden-variety poor readers and children with an ability–achievement discrepancy may be orthographic processing. These results suggest that the LA group is qualitatively different from the AA group in terms of the causes of reading failure but shows similar symptoms of reading failure (e.g., low performance in word reading). Therefore, different interventions may be required for garden-variety poor readers and for children with an ability–achievement discrepancy. Specifically, the subtypes within garden-variety poor readers may require differentiated, targeted emphasis on phonological awareness and rapid naming training depending on their subtype classification. However, the subtypes within garden-variety poor readers may not need differentiated training in orthographic processing. How- ever, some children in the ability–achievement discrepancy group (e.g., the NSD and the DD subtypes) may benefit from more targeted intervention in orthographic processing. More research is needed on specific profiles of children's expressive and receptive oral language skills for both groups.

Our findings suggest that different subgroups proceed via different paths to the same place—dysfluent reading. For the NSD group, deficits in reading rate beginning at the letter level and preceding through the sentence level may lead to deficits in accuracy, which lead to dysfluent read- ing. For the PD group, an opposite scenario may occur, in which deficits in accuracy may lead to deficits in reading rate, which again lead to dysfluent reading. For the DD group, both their reading rate and accuracy at each level, in conjunction with their lower verbal skills, will obstruct flu- ent reading development. This finding supports looking at reading rate as an independent variable, *causing* inaccura- cies, rather than as an outcome-dependent variable of inaccurate reading (Breznitz, 2006).

Teachers and clinicians basing their intervention plans on a composite measure like the GORT Reading Quotient will miss the complexity of the challenges that different children face. This is why developmentally appropriate reading rate scales should be developed to provide practitioners with useful assessment tools that— in combination with other existing materials—will pro- vide a more comprehensive picture of a student's reading profile. Only a multicomponent assessment can inform a well-rounded intervention that addresses the multiple sources of reading deficits. In other words, rather than merely focusing on one dimension of student responding (e.g., accuracy), intervention should target the multiple synchronic processes that are involved in reading.

Conclusion

As Coltheart and Jackson (1998) emphasized, applied studies of reading should differentiate outcome from cause: "Thus, we might have two children with comparable degrees of difficulty in learning to read, and with the same proximal cause of this difficulty, but with two very different distal causes" (p. 14). In the study of fluent reading, the proximal cause at the connected text level of reading should not be confused with different distal causes that may arise as early as the letter level for different groups of readers with dyslexia. Future studies should examine the differential contributions of synchronic processes for different groups of dyslexia.

With all the promising prospects of this line of research held in mind, a cautionary note should be added: Although component skill analyses provide a valuable source of data, this approach has several limitations (Levy & Carr, 1990). First, the analysis is limited by the tasks selected for inclusion in the test battery. This study focused on oral reading. Future studies should compare oral and silent reading to examine whether articulation has an effect on reading flu- ency. Second, in this study, the GORT's scoring system may have accounted for some of the differences between the DD and the NSD groups. Third, although we acknowledge that the sample sizes in the subtype analysis of the LA and AA groups were small, thus requiring caution in the interpretation, we believe that the results in the present study represent a revealing first step. A future study with a larger sample is warranted. Finally, different paths may exist in different orthographies (Ben Dror, Frost, & Bentin, 1995). Children reading in a regular orthography, such as Spanish, may encounter different reading difficulties than children reading in a complex orthography such as English.

This study provides a first step in the development of an interactive model of reading fluency. Much more work is necessary on the components suggested, mainly on the contribution of orthography, morphology, syntax, and semantics to fluent reading. Moreover, the interrelation- ships among the different components of the model at different phases in development remain unknown. More efforts to unravel the independent roles of each component, as well as the connections among them, will help researchers and practitioners devise better assessment and intervention tools for children who have difficulties in developing fluent reading. In sum, a comprehensive fluency battery that is theoretically based would be a valuable clinical tool to develop.

Notes

1. This decision was partly based on the finding that students' performance on the Blending and Elision tasks showed different patterns of relationships with word and connected text reading variables (see Table 5), and Elision was more highly associated with word and connected text reading measures. However, it should be noted that although only Elision was used as the criterion for the phonological deficit designation, there were only two children who would have been identified differently if Blending were also used as a criterion. Furthermore, the results based on the Elision subtest did not differ when Blending was also used as a criterion.

2. The results from general linear hypothesis (GLH) tests and analysis of variance (ANOVA) post hoc tests were almost identical for Research Question 1, but some discrepancies were noted for Research Question 2. For example, some differences in mean scores did not reach significance when using ANOVA post hoc tests, whereas they did when using GLH tests. In this article, we report the results from the GLH

tests. The results from the ANOVA post hoc tests are available on request.

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