DYSLEXIA AND THE DOUBLE DEFICIT HYPOTHESIS

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The double deficit hypothesis (Bowers and Wolf 1993) maintains that children with both phonological and naming-speed deficits will be poorer readers than children with just one or neither of these deficits. In the present study, we drew on this hypothesis to help understand why some children have a serious reading impairment. In addition, by adding an orthographic factor, we extended it to a triple deficit hypothesis. Participants were 90 children aged 6 to 10 years. Dyslexic children, whose reading was low for age and for expected level, garden-variety poor readers, reading-level matched younger children, and low verbal IQ good readers, were compared. The dyslexic group was significantly lower then the garden-variety poor readers and the low verbal IQ good readers on most measures, and lower than the younger group on phonological measures. Findings support the double deficit hypothesis of Bowers and Wolf, and also the triple deficit hypothesis. Most of the poorest readers, nearly all of whom qualified as dyslexic, had a double or triple deficit in phonological, naming-speed, and orthographic skills. Conclusions were that dyslexia results from an overload of deficits in skills related to reading, for which the child cannot easily compensate.

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An extensive body of research demonstrates that problems with phoneme awareness and nonword decoding are at the root of most cases of poor reading (Liberman and Shankweiler 1985; Rack, Snowling, and Olson 1992; Stanovich 1988, 1992). Success in reading is related to the degree to which learners are aware of the underlying phonological structure of words (Liberman and Shankweiler 1985). Although general cognitive factors, such as intelligence, vocabulary, and listening comprehension, predict early reading acquisition, phonological abilities are the most potent predictors (Stanovich 1992). In fact, the relationship of phoneme awareness to reading acquisition is so strong as to justify the assumption that the relationship is a causal one (Ball 1993; Stanovich 1992; Wagner and Torgesen 1987).

There is also convincing evidence that the rapid retrieval of the spoken referent for a visual stimulus, which is commonly measured through rapid serial naming tasks, is robustly related to reading skills and that naming-speed deficits are a major characteristic of poor readers (Bowers and Swanson 1991; Wolf 1991). Wolf (1991), drawing on her own research and that of others, stresses that there is an enduring relationship between continuous naming speed for alphnumeric stimuli and word recognition. Recently, McBride-Chang and Manis (1996) stressed the importance of naming speed in the early stages of word recognition. Although subsumed under the phonological processing category by Wagner and Torgesen (1987), phonological awareness and naming speed make unique contributions to reading (Bowers and Swanson 1991), and Bowers and Wolf (1993) make a strong plea for their independence.

Although a single deficit in either phonological awareness or naming speed may be associated with poor reading, a deficit in both of them is likely to lead to even more impaired reading (Wolf in press; Yap and van der Leij 1993). From their observations of the dire effects this combination of deficits could have on the development of reading skills, Wolf and Bowers (Bowers and Wolf 1993; Wolf in press) developed the "double deficit" hypothesis. According to the hypothesis, four groups of readers are predicted: Two single-deficit groups, a double-deficit group, and a no-deficit group. Wolf (in press) tested this hypothesis using fourth grade children and found that the double-deficit group was the most impaired on each of eight reading measures and that the two single deficit groups were more impaired than the no-deficit group, who were average readers. A recent study testing the double-deficit hypothesis supports the claims of Bowers and Wolf (1993) that the double deficit is a risk factor in disabled reading (McBride-Chang and Manis 1996), as both phonological awareness and naming speed were significantly associated with word reading for poor readers. For good readers, phonological awareness and verbal IQ were associated with variation in reading, but naming speed was not.

Although phonological awareness and naming speed account for much of the variance in reading skills, orthographic processing may also contribute, in at least some cases (Manis et al. 1990; Stanovich 1988, 1992). Phonological and orthographic skills make independent contributions in word recognition (Olson et al. 1994). Orthographic processing refers to the visual processing of letters and letter patterns into words and word parts (Bowers and Wolf 1993). Adams and Bruck (1993) argue that when orthographic images are unstable, the establishment of links to other processors (e.g., phonological, meaning) will be impeded. These authors maintain that many tasks used to assess phonological processing (e.g., nonword reading) necessarily depend on orthographic knowledge. The orthographic measure used in the present study tests recognition of the correct visual form of letters and numerals. If orthographic imagery for single letters is unstable, the formation of automatic orthographic-phonological connections will be impeded. Ehri (1992) maintains that in sight word reading letter-sound knowledge is needed to form a complete network of visual-phonological connections in lexical memory, and Berninger's (1990) model is similar. Others have also stressed the importance of orthographic-phonological connections in reading (Bowers and Wolf 1993).

If it is accepted that orthographic processing contributes to reading acquisition, the possibility arises that in some cases impaired reading may be associated with a triple deficit in phonological awareness, naming speed, and orthographic processing, rather than just with a double deficit, as defined by Wolf (in press). This hypothesis was investigated in the poor readers of this study.

Still other deficits may also contribute to poor reading. An obvious candidate is verbal IQ. However, some children with language deficits and low verbal intelligence learn to read spontaneously at an early age. These so-called hyperlexic children (Healy 1982) serve as a dramatic contrast to dyslexic children who are usually impaired in both word and nonword reading, in spite of adequate verbal intelligence. Healy concluded that hyperlexic children are successful at integrating phoneme-grapheme correspondences, as well as being able to read words through a visual matching-to-memory process. Hyperlexic children are exceptional, however. Low verbal ability is usually associated with relatively poor reading skills and most poor readers are of the "garden-variety" type, with reading at or near the level expected for their intellectual ability (Gough and Tunmer 1986; Stanovich 1988). Studies comparing dyslexic and garden-variety poor readers have tended to conclude that the two groups are more similar than different (e.g., Shaywitz et al. 1992), but the subject continues to be controversial.

In the present study, we attempted to answer the question of why dyslexic children (defined here as word recognition 1.5 standard deviations below the level expected for verbal intelligence) have difficulty learning to read by comparing their performance on phonological, naming speed, and orthographic tasks with that of three well-defined groups. Comparison groups included: (1) good readers of low verbal IQ, at least some of whom met Healy's (1982) criteria for hyperlexia; (2) garden-variety poor readers; and (3) normally developing readers who were two years younger. These younger children were included as a reading-level match for the dyslexic and garden-variety poor readers. Positive results with a reading-level match can help to establish which factors play a causal role in reading, although negative results are difficult to interpret (Goswami and Bryant 1989). As argued by Stanovich (1988), if dyslexic and garden-variety poor readers differ in skills underlying reading, it can be assumed that the two groups arrived at their similar reading levels by way of different routes. Good readers with low verbal IQ were included in the study to help clarify which skills are significant in reading acquisition.

METHOD

PARTICIPANTS

Participants were 90 children (56 boys, 34 girls) aged 6 to 10 years who met criteria for one of the groups described below. All children had been referred for evaluations in one school district, or were followed up because of early high risk status. Many of these high-risk children were normal readers at follow-up. Most of the participants were of lower-middle or middle socioeconomic status.

Study group criteria were based on verbal IQ and word reading. Reading status was defined by word reading because of the consensus that dyslexia is characterized by difficulties in single word decoding (Lyon 1995). Word reading was tested by the Word Identification subtest of the Woodcock Reading Mastery Tests-Revised (Woodcock 1987). Expected reading level was calculated from verbal IQ, correcting for regression effects (Badian 1996). As the estimated correlation between verbal IQ and word reading is approximately .60 at grades 1 through 3, this correlation was included in the regression formula to calculate expected achievement (Woodcock 1987). Following guidelines from the American Guidance Service, the formula for expected achievement level is [100-(.6*100] + (.6*VIQ). Expected achievement levels for VIQs of 84, 100, and 115, would be 91, 100, 109. Characteristics of the four study groups, Dyslexic (DYS), Garden-Variety (G-V), Low Verbal IQ (LowVIQ), Younger (YGER), are given in table I.

The DYS, G-V, and YGER groups did not differ on raw word reading scores, but the LowVIQ group achieved significantly higher scores. All groups, however, differed in word reading standard scores. The two groups of poor readers (DYS, G-V) and the LowVIQ good readers were matched in age, but the YGER group was 2 years younger. The DYS group scored higher than the G-V group and both other groups in verbal IQ, but the Low VIQ and G-V groups did not differ. As in previous research (Badian 1996), 92 (30th percentile) was the upper limit for verbal IQ for G-V poor readers. The percentage of males in each group was: DYS, 67.9%, G-V, 65.7%, LowVIQ, 53.3%, YGER, 58.0%. All children in the G-V and LowVIQ groups were white, compared with 96.4 percent of the DYS group and 92 percent of the YGER group.

Groups were compared on the measures listed below.

MEASURES

Phonological Measures. Our first phonological measure was a nonword reading test, the *Word Attack* subtest from Woodcock (1987). Oral reading of nonwords is frequently used as a measure of phonological decoding ability (e.g., Olson et al. 1994; Rack, Snowling, and Olson 1992), and was the phonological measure used by Wolf (in press) to test her double-deficit hypothesis. From their review of many studies of nonword reading, Rack, Snowling, and Olson (1992) concluded that in dyslexia there is strong evidence for a specific deficit in the use of phonological processes in reading. Following Wolf (in press), a deficit in nonword reading in the present study was defined as a score at least one standard deviation below the mean, using age norms (Woodcock 1987). Raw scores were used in analyses.

TABLE I. GROUP CHARACTERISTICS OF CHILDREN DEFINED AS HAVING DYSLEXIA (DYS), GARDEN-VARIETY READING DISABILITY (G-V), LOW VERBAL INTELLIGENCE (LOW VIQ), OR AS BEING YOUNGER NORMAL READERS (YGER)

	GROUPS										
Discrepancy*	DYS (1) VIQ>85 RDG<85 >1.5 *SDs*		G-V (2) VIQ<92 RDG<85 <1 *SD*		LowVIQ (3) VIQ<85 RDG>90 >Expected		YGER (4) VIQ>85 RDG>100 >Expected		*F* (3,86)	*p*<	Post-hoc tests
n	28		23		15		24				
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*			
Age (years)	8.8	(0.7)	8.8	(0.7)	8.8	(0.7)	6.9	(0.4)	45.83	.0001	1=2=3>4
Verbal IQ	105.0	(11.1)	85.7	(4.2)	81.0	(3.9)	99.3	(10.1)	37.28	.0001	1>4>2=3
Performance IQ	103.4	(13.7)	95.3	(9.0)	94.0	(16.5)	102.0	(10.1)	3.18	.0281	1>2=3, 4>3
Full Scale IQ	104.5	(11.3)	89.2	(5.3)	85.8	(9.3)	100.1	(9.0)	20.15	.0001	1=4>2=3
Word Reading**	34.6	(12.9)	40.3	(9.2)	58.3	(8.9)	38.7	(14.5)	13.40	.0001	3>1=2=4
Word Reading***	75.3	(6.3)	82.0	(2.4)	100.6	(8.3)	109.9	(12.3)	94.76	.0001	4>3>2>1
Discrepancy*	-27.6	(5.5)	-9.4	(3.0)	11.7	(7.9)	10.6	(9.1)	187.60	.0001	3=4>2>1

*Discrepancy between expected and actual word reading standard scores; **Raw scores; ***Standard scores.

Our second phonological measure was a phoneme deletion task, the Test of Auditory Analysis Skills (TAAS, Rosner 1979): In the first three test items, the child deletes one syllable from a spoken word. The next ten items include deletion of initial or final phonemes from spoken words or deletion of one of two phonemes in a consonant blend. The TAAS was normed on six heterogeneous grade 1 through 3 classes ($n = 131$) in the same population as the study sample. Split-half reliability was 0.84. Raw scores were used in analyses.

Naming Speed. We relied on the Rapid Automatized Naming (*RAN*) of *Colors, Objects,* and *Numbers/Letters* from Denckla and Rudel (1974). The child names five different items repeated ten times at random displayed in a 5 x 10 format on each of four charts. Time taken to complete each chart determines the score. The Colors subtest had not been administered to five children. Because of the high correlation between them ($r = .91$), the Numbers and Letters subtests were combined to give an alphanumeric naming-speed score. Age norms of Denckla and Rudel (1974) were used. Following Wolf (in press), naming speed (time in seconds) that was at least one standard deviation slower than that expected for age defined a deficit in naming speed.

Orthographic Skill. To assess orthographic knowledge, we used the Jordan Left-Right Reversal Test (JL-RRT), Level I (Jordan 1980). In this edition of the JL-RRT, the child crosses out any incorrectly oriented upper case letters or numerals displayed in five rows. The array consists of 27 letters and 14 numerals. There are no time limits. When administered to a cohort of 131 children in early first grade (Badian unpublished data), the JL-RRT correlated significantly with later reading and spelling ($p < .0002$ to $.0001$). For the same group of children, it correlated significantly with a homophonic choice orthographic test (Which is the real word: gerl, girl, gurl?), administered in mid-first grade ($p < .0001$) and more highly than with two phonological tests. The JL-RRT also predicted reading in children aged 6 to 8 years who were followed up after 2 years (Badian 1993). In the present study, an error score at least one standard deviation more than that expected for age (Jordan 1980 norms) defined a deficit.

Verbal Intelligence. We used the Wechsler Intelligence Scale for Children-Revised or Third Edition (WISC-R: Wechsler 1974 or WISC-III. Wechsler 1991). The Wechsler Preschool and Primary Scale of Intelligence-Revised (WPPSI-R: Wechsler 1989) had been administered to two younger children. All subtests were administered and scored following standard procedures.

PROCEDURES

The Wechsler intelligence test, the TAAS, the RAN subtests, and the JL-RRT were administered individually to all participants by the same school psychologist in a quiet room in their school building during two or three sessions, in most cases over a period of no more than two to three weeks. Woodcock (1987) Word Identification and Word Attack subtests were administered during that time either by the school psychologist or by a certified special education teacher.

Group differences on the phonological, naming-speed, and orthographic measures listed above were analyzed by means of analysis of variance (ANOVA) and post-hoc tests (Duncan's Multiple Range Test). The only gender difference was on RAN Colors, with boys faster. As boys in all groups were faster than girls, and the groups did not differ significantly in gender ratios, gender was not a factor in the analyses.

RESULTS

Means and standard deviations on the phonological, naming-speed, and orthographic measures are given for each group in table II. As the naming-speed scores are given as time taken in seconds, and the orthographic test results as the number of errors, lower scores indicate better performance. ANOVA and post-hoc analyses of between-group differences are also given in table II.

HOW DO GARDEN-VARIETY POOR READERS DIFFER FROM OTHER GROUPS OF READERS?

In keeping with the large body of research implicating nonword decoding in specific reading disability (Rack, Snowling, and Olson 1992), the DYS group could read significantly fewer nonwords than all other groups, despite being matched on word recognition with the G-V group, despite higher intelligence than the G-V and LowVIQ groups, and despite being two years older and just as intelligent as the YGER group. The phoneme deletion task proved to be less sensitive to individual differences. Although the DYS poor readers displayed less phoneme awareness than the YGER normal readers matched on word recognition, differences between DYS and G-V and LowVIQ groups failed to reach significance. We attribute this to the abbreviated nature of the phoneme task employed.

TABLE II. GROUP MEAN RAW SCORES ON PHONOLOGICAL, NAMING-SPEED, AND ORTHOGRAPHIC TESTS FOR CHILDREN DEFINED AS HAVING DYSLEXIA (DYS), GARDEN-VARIETY READING DISABILITY (G-V), LOW VERBAL INTELLIGENCE (LOW VIQ), OR AS BEING YOUNGER NORMAL READERS (YGER)

	GROUPS										
	DYS (1)		G-V (2)		LowVIQ (3)		YGER (4)		F (3,86)	$p<$	Post-hoc tests
Phonological*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*			
Nonword Reading	9.6	(7.4)	14.9	(4.4)	26.5	(8.9)	17.5	(8.1)	18.22	.0001	3>2=4>1
TAAS (max = 13)	7.6	(3.1)	8.2	(2.4)	9.2	(3.0)	9.5	(2.5)	2.52	.0630	4>1
Naming-Speed**											
RAN Colors	59.2	(17.8)	50.1	(8.1)	48.5	(12.2)	53.3	(11.5)	2.82	.0443	2=3>1
RAN Objects	77.3	(18.6)	72.8	(16.9)	62.7	(14.2)	72.6	(16.8)	2.40	.0736	3>1
RAN Nos/Letters	41.7	(11.3)	35.2	(7.7)	30.0	(5.3)	38.8	(6.8)	6.73	.0004	3>1=4, 2>1
Orthographic***											
Jordan L-RRT	5.0	(3.6)	1.7	(1.5)	1.3	(1.9)	4.2	(2.9)	9.15	.0001	2=3>1=4

*Number correct. **Time in seconds. ***Number of errors. TAAS = Test of Auditory Analysis Skills. L-RRT = Left-Right Reversal Test.

Although the DYS children were significantly slower than the LowVIQ and G-V groups in sequential naming of colors and alphanumeric characters, they were not significantly slower than the YGER controls. A similar pattern emerged on the orthographic task. There it was also the case that dyslexic children made more errors than age-matched LowVIQ and G-V groups, but were not more error-prone than the younger reading level controls.

In sum, children with a sizable discrepancy between reading and verbal IQ displayed more difficulties with phonological decoding, rapid-naming, and orthographic processing than did equivalently poor readers of lower IQ or good readers of lower IQ. This suggests that the disparity implicates difficulties specific to reading. When compared to younger normal readers, dyslexic readers displayed the usual deficit in phoneme awareness and nonword decoding; they did not, however, perform worse in naming-speed or orthographic processing, suggesting these tasks may include an important developmental factor.

It should be pointed out that among children of lower VIQ, the significantly higher word recognition scores of the LowVIQ good readers were associated only with nonword decoding; low IQ poor readers (G-V group) were not worse than IQ-matched good readers on naming speed, orthographic processing, or phoneme awareness. This strengthens the argument that it is not absolute reading level, but the discrepancy between reading and intelligence that indicates more than a simple delay in reading progress.

Although the DYS and G-V poor readers did not differ significantly on mean raw word reading scores, the DYS children were signficantly lower in reading standard scores, as well as in the size of the discrepancy from expected reading level, and more than half of the DYS group children had a lower reading standard score than any child in the G-V group. In an attempt to determine whether the lower scores of the DYS group in phonological decoding, naming-speed, and orthographic processing were associated with severity of reading deficit or discrepancy from IQ, multiple regression analyses were computed for poor readers, good readers, and the total group. Performance on the phonological, naming-speed, and orthographic variables was predicted from reading standard scores and then the discrepancy from expected reading level was entered into the analysis to see if it added any further variance.

For the total group, reading accounted for 78% of the variance and the discrepancy accounted for only a further 2.5% For poor readers (G-V and DYS) considered separately, the discrepancy added 7% to the 56% attributed to reading, and for good readers (LowVIQ and YGER), it accounted for an additional 15.6% of the variance. That is, for poor readers, a larger discrepancy between verbal IQ and reading tended to be associated with poorer performance on the experimental measures, independent of absolute reading level. Conversely, among good readers, the higher they were reading above expected level, the more likely they were to do well on phonological, naming-speed, and orthographic tasks.

Multiple regression analyses were also carried out to examine the question of independent risk factors associated with a discrepancy. Mentioned here are those variables that accounted for a significant amount of variance ($p < .05$). With discrepancy as the dependent variable, age was forced into the equation first, followed by the phonological, naming-speed, and orthographic variables in a stepwise procedure. For poor readers, age accounted for 4% of the variance, nonword decoding for an additional 25%, and the orthographic measure for 9%. For good readers, age accounted for 2% of the variance, phoneme deletion for 27%, color naming speed for 11%, alphanumeric naming speed for 10%, and nonword decoding for 9%. For the total group, age accounted for 20%, nonword decoding for 49%, and alphanumeric naming speed for 2%. These results confirm that phonemic awareness and naming speed are important factors in the development of good reading in the first school years, whereas reading below expected level is associated with poor phonological decoding skills and, in at least some cases, with poor orthographic processing.

DOUBLE AND TRIPLE DEFICITS IN RELATION TO GROUP STATUS

To test the hypothesis that impaired reading may be associated with double or triple deficits in phonological decoding, serial naming-speed, and orthographic processing, the number and percentage of children in each reading group with phonological (P), naming-speed (N), and orthographic (O) deficits was determined. A deficit was defined as a score at least one standard deviation below that expected for age level on nonword decoding (phonological), on letter-naming speed, or on the orthographic task (JL-RRT). Definitions of phonological and naming-speed deficits follow Wolf's (in press) criteria. Numbers and percentages of children in each group with deficits (PNO, PN, PO, NO, P, N, O, None) are shown in table III. Eleven times more DYS

TABLE III. PERCENTAGES OF CHILDREN WITH PHONOLOGICAL (P), NAMING-SPEED (N), AND ORTHOGRAPHIC (O) DEFICITS IN FOUR DISCREPANCY-DEFINED READER GROUPS

	GROUPS							
	DYS		G-V		LowVIQ		YGER	
DEFICITS	*n*	%	*n*	%	*n*	%	*n*	%
PNO	14	50.0	1	4.5	0	0	0	0
PN	5	17.9	5	22.7	0	0	0	0
PO	0	0	2	9.1	0	0	0	0
NO	5	17.9	1	4.5	1	6.7	2	8.3
P	2	7.1	2	9.1	2	13.3	0	0
N	0	0	4	18.2	0	0	2	8.3
O	2	7.1	1	4.5	1	6.7	5	20.8
NONE	0	0	6	27.3	11	73.3	15	62.5
TOTAL	28		22*		15		24	

*One G-V subject could not be classified because of missing data.

DYS = Dyslexic, G-V = Garden-variety poor reader, LowVIQ = Normal readers with low verbal intelligence, YGER = Younger normal readers.

than G-V children had a triple deficit. Every child in the DYS group had at least one deficit, compared with 63% of the G-V group. No good reader had a triple deficit and only 7 to 8% had two deficits. In the DYS group 75% had a nonword decoding deficit, 86% had a naming-speed deficit, 68% had both, and 75% had an orthographic deficit. By contrast, despite their much lower verbal IQ, only half or fewer of the G-V poor readers had a phonological or naming-speed deficit, suggesting it is reading and not intelligence that is related to these scores.

DOUBLE AND TRIPLE DEFICITS IN RELATION TO READING LEVEL

Because it is so difficult to disentangle size of discrepancy from severity of reading impairment, poor readers (DYS + G-V) were regrouped on the basis of reading standard scores (< 80 compared to 80-85). Better readers (LowVIQ + YGER) were also divided into two reading level groups (90-105 versus > 106). The number of children at each reading level with triple, double, single, or no deficits was then determined.

The number of deficits in relation to word reading standard scores is shown in figure 1 for more and less impaired poor readers and for good readers at two levels. More impaired poor readers were 8 times more likely to have a triple deficit than the less

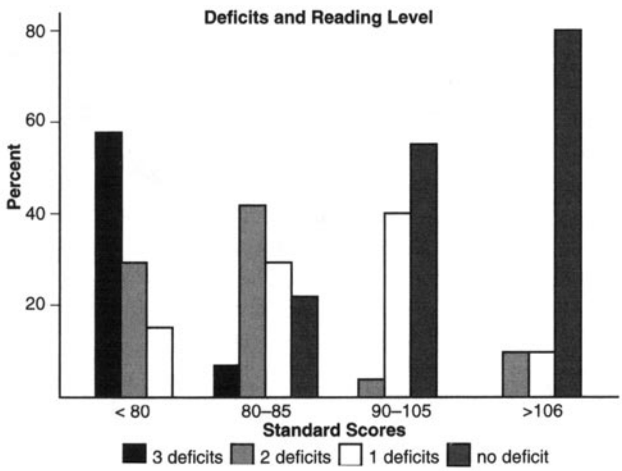

Figure 1. *Grouped by reading standard score, the percentages of children with 3, 2, 1, or no deficits in phonological processing, naming-speed, and orthographic skills. Note that all children with a standard score < 80 have at least one deficit, and no child with a standard score > 90 has 3 deficits.*

impaired (57%, 7%). The percentage of children with no deficit increased dramatically at each reading level: from 0% at < 80, to 22% at 80–85, to 55% at 90–105, to 79% at > 106.

To test the possibility that low verbal IQ may be an additional deficit affecting reading, the verbal IQ of the more and less impaired poor readers was examined. Mean verbal IQ was 98.7 (*SD* 9.4) in more impaired readers and 94.1 (*SD* 15.3) in less impaired readers. The difference was insignificant: $F(1,49) = 1.64$. For all poor readers, there was a significant correlation between verbal IQ and number of deficits ($r = .32$, $p < .03$). This suggests that when verbal IQ is higher, reading is likely to be impaired only when there are several underlying deficits.

Further analyses were carried out in an attempt to tease apart the issues of severity of reading impairment and the size of the discrepancy between verbal IQ and reading, and how they relate to phonological, naming-speed, and orthographic deficits. For good readers, there was an insignificant correlation between discrepancy and the number of deficits: $r = -.186$. For poor readers, the correlation was –.563, $p < .0001$, indicating that the larger the discrepancy, the greater the number of deficits. Because the DYS children achieved lower reading standard scores than the G-V children, the preponderance of deficits in the DYS group could be attributed to greater reading impairment. Subsets of children from the two groups were, therefore, compared. The ten closest matches on age and reading standard scores were selected. The two groups of ten children did not differ in reading (DYS: *M* 80, *SD* 3.9; G-V: *M* 81.7, *SD* 3.2), or age (*M* = 9.0 years in each group, *SD* 1.0 to 1.2), but the DYS group was 25 points higher in Verbal IQ (DYS *M* 111.4, *SD* 4.9; G-V *M* 86.0, *SD* 4.3). The subset of DYS children was above the mean of the total DYS group in Verbal IQ and reading, but the G-V subset closely matched their own total group means. Despite identical reading standard scores, 40% of the DYS subset had a triple deficit, compared with none of the G-V group. Ninety percent of the DYS subset had at least two deficits, compared with 50% of the G-V group. Deficit profiles of the two subsets were similar to those of the total groups from which they were drawn. These findings suggest that a sizable discrepancy between IQ and reading is associated with multiple deficits in nonword decoding, naming-speed, and orthographic processing independently of degree of reading impairment.

DISCUSSION

DIFFERENCES IN PHONOLOGICAL, NAMING-SPEED, AND ORTHOGRAPHIC SKILLS IN FOUR GROUPS OF READERS

In an attempt to understand why some children have unexpected difficulty learning to read, dyslexic children were compared to garden-variety poor readers, and both were compared with two groups of good readers.

On nonword reading, which is frequently used as a measure of phonological processing ability (e.g., Olson et al. 1989; Wolf in press), the dyslexic children were more impaired than all other groups. They were also significantly lower than the reading-level (R-L) matched younger children on the other phonological measure (phoneme deletion). The lower score of the dyslexic children on this measure demonstrates that their poor reading is associated with a specific phonological deficit and is not just a developmental lag, confirming numerous similar findings (Wagner and Torgesen 1987). Caution is needed, however, in drawing such an inference from the dylexic children's lower scores in nonword reading, as their poor reading of both words and nonwords may in turn result from the deficit in phonological awareness. In contrast to the dyslexic group, the garden-variety poor readers did not differ from the R-L match on either phonological task, suggesting that the poor reading of the garden-variety group could be categorized as a developmental lag. That is, these poor readers of lower verbal IQ were developing normally in reading, but at a slower than average rate. Results are consistent with the conclusions of Rack, Snowling, and Olson (1992) that, after equating for level of word recognition, verbally able poor readers tend to have weaker phonological skills.

Naming speed is an important factor in the development of reading skills (McBride-Chang and Manis 1996; Vellutino and Scanlon 1989). McBride-Chang and Manis (1996) stress that naming speed is critical for unskilled readers, who must rely on both knowledge of speech sounds and speed of symbol processing to identify printed words. In this study, the slower naming speed of the dyslexic poor readers, in comparison to the garden-variety group, suggests that this deficit also contributed to their reading difficulties. The lack of difference in naming speed between the dyslexic and R-L matched groups could be interpreted as evidence for a developmental lag in naming speed. Speed in naming visual stimuli develops rapidly during the early school years (Kail and Hall 1994). Kail and Hall found that age-related change in speed of processing was linked to more rapid naming, which was linked to word reading, and in turn to reading comprehension.

Findings for the orthographic measure are more difficult to interpret. Experiential factors, such as exposure to print, have been shown to play a major role in orthographic processing (Cunningham and Stanovich 1990; Olson et al. 1989). The simple orthographic measure used in this study has been found to predict later reading and spelling (Badian 1993) and to correlate significantly with a homophonic choice orthographic test (Badian unpublished data). A low score for age on the orthographic task as the sole deficit was observed more frequently among the R-L matched younger children than among either group of poor readers, suggesting an experiential effect, and possibly also reflecting the early high-risk status of many of the younger good readers. Although an impairment only in orthographic skills, as measured here, does not appear to be a significant risk factor for poor reading, a high percentage of dyslexic children had a low orthographic score, in most cases in combination with other deficits. Their poor orthographic skills may have impeded the development of visual-phonological connections in lexical memory (Ehri 1992). The garden-variety group made significantly fewer errors on the orthographic measure than either the dyslexic or R-L matched good readers. Although the longer years of experience with print may explain the garden-variety group's superiority in relation to the younger good readers, it does not account for the difference between the garden-variety and dyslexic groups, as the educational experience of the two groups was similar. The difference between them in orthographic processing could be interpreted as evidence that the two groups reached equivalent reading levels by way of different routes (Stanovich 1988).

This study included a group of good readers with low verbal IQ as an age-matched contrast group for both the dyslexic and the garden-variety poor readers. An analysis of the strengths of these children may help clarify the factors critical in reading development. Like the garden-variety poor readers, the low verbal IQ good readers were superior to the dyslexic group in nonword reading, naming speed, and orthographic knowledge. Their strengths in these skills indicate that they are more important factors in reading success than verbal IQ. For the poor readers (dyslexic plus garden-variety) there was a zero correlation between verbal IQ and reading ($r = -0.08$). With regard to reading, the very much higher verbal IQ of the dyslexic group was no match for the superior phonological, naming-speed, and orthographic skills of the low verbal IQ good readers. The only measure on which the low verbal IQ good readers were superior to the garden-variety poor readers, from whom they did not differ in verbal IQ, was nonword decoding. The fact that good and poor readers of low verbal IQ differed only in nonword decoding again points to the importance of phonological processing in word reading. The phoneme deletion task had limitations, as it failed to show a difference between the three groups of older children. Further research on differences between these groups of children is needed using longer and more sensitive phoneme deletion tasks, such as the original Auditory Analysis Test (Rosner and Simon 1971).

THE DOUBLE (OR TRIPLE?) DEFICIT HYPOTHESIS

Wolf (in press) has demonstrated that children with a double deficit in phonological processing (nonword decoding) and naming speed have more serious reading problems than children with a single (i.e., phonological or naming-speed) deficit, who, in turn, are more impaired than children with no deficit. In this study the double deficit hypothesis (Bowers and Wolf 1993; Wolf in press) was extended to a triple deficit, by including an orthographic factor, and differences between good and poor readers in the number of deficits were examined. Wolf (in press) was followed in defining phonological and naming-speed deficits.

The hypothesis that there is an association between the number of deficits and degree of reading impairment was supported. When poor readers were divided into more and less impaired groups, the more impaired readers were more likely to have a triple deficit and also a double phonological/naming-speed deficit, although the two groups did not differ in verbal IQ. By contrast, no good reader had a triple deficit or a double phonological/naming-speed deficit. Mean reading scores of the total sample showed an inverse relationship between reading level and number of deficits.

The association of more impaired reading with a triple deficit in phonological, naming-speed, and orthographic skills was very striking. As most of the more impaired readers (91%) belonged to the dyslexic group, an attempt was made to disentangle the issues of reading impairment and a discrepancy between IQ and reading. The two issues are confounded because more severely impaired reading tends to be associated with a larger discrepancy. A comparison of subsets of dyslexic and garden-variety poor readers matched in reading standard scores and age revealed deficit profiles very similar to those observed in the total dyslexic and garden-variety groups. This finding leads to the conclusion that a discrepancy is associated with multiple deficits in phonological, naming-speed, and orthographic skills, independently of reading level. It is reasonable to assume that a serious reading impairment in children of at least average verbal intelligence results from an overload of deficits in skills related to reading. Because of their phonological deficits, dyslexic children have difficulty learning to read through the phonological route; they also have difficulty learning to read through the visual-orthographic route because of problems with orthographic pattern recognition and with quick retrieval of names of visual stimuli.

CONCLUSIONS

The findings of this study support the claim of Wolf and Bowers (Bowers and Wolf 1993; Wolf in press) that children with a double deficit in nonword decoding and naming speed are more impaired readers than those with a single or no deficit, because they have few compensatory mechanisms to fall back on. The majority of the seriously impaired readers in this study also had a third orthographic deficit. Although the orthographic measure made an independent contribution in predicting a discrepancy between intelligence and reading for poor readers, we have insufficient evidence that it constitutes a distinct risk factor. For good readers, phoneme awareness, naming-speed, and nonword decoding were independent contributors. Further research is needed to investigate whether multiple deficits are associated with more serious reading impairment, irrespective of intelligence level, or are a specific characteristic of poor readers meeting discrepancy criteria for dyslexia.

References

Adams, M. J., and Bruck, M. 1993. Word recognition: The interface of educational policies and scientific research. *Reading and Writing: An Interdisciplinary Journal* 5: 113–39.

Badian, N. A. 1993. Predicting reading progress in children receiving special help. *Annals of Dyslexia* 43:90–109.

Badian, N. A. 1996. Dyslexia: A validation of the concept at two age levels. *Journal of Learning Disabilities* 29:102–12.

Ball, E. W. 1993. Phonological awareness: What's important and to whom? *Reading and Writing: An Interdisciplinary Journal* 5:141–59.

Berninger, V. W. 1990. Multiple orthographic codes: Key to alternative methodologies for developing orthographic-phonological connections underlying word identification. *School Psychology Review* 19:518–33.

Bowers, P. G., and Swanson, L. B. 1991. Naming speed deficits in reading disability: Multiple measures of a singular process. *Journal of Experimental Child Psychology* 51:195–219.

Bowers, P. G., and Wolf, M. 1993. Theoretical links among naming speed, precise timing mechanisms and orthographic skill in dyslexia. *Reading and Writing: An Interdisciplinary Journal* 5:69–85.

Cunningham, A. E., and Stanovich, K. E. 1990. Assessing print exposure and orthographic processing skill in children: A quick measure of reading experience. *Journal of Educational Psychology* 82:733–40.

Denckla, M. B., and Rudel, R. 1974. Rapid "automatized" naming of pictured objects, colors, letters and numbers by normal children. *Cortex* 10:186–202.

Ehri, L. C. 1992. Reconceptualizing the development of sight word reading and its relationship to recoding. In *Reading Acquisition*, eds. P. B. Gough, L. C. Ehri, and R. Treiman. Hillsdale, NJ: Lawrence Erlbaum Associates.

Goswami, U., and Bryant, P. 1989. The interpretation of studies using the reading level design. *Journal of Reading Behavior* 21:413–24.

Gough, P. B., and Tunmer, W. E. 1986. Decoding, reading, and reading disability. *Remedial and Special Education* 7:6–10.

Healy, J. M. 1982. The enigma of hyperlexia. *Reading Research Quarterly* 17:319–38.

Jordan, B. T. 1980. *Jordan Left-Right Reversal Test*. Novato, CA: Academic Therapy.

Kail, R., and Hall, L. K. 1994. Processing speed, naming speed, and reading. *Developmental Psychology* 30:949–54.

Liberman, I. Y., and Shankweiler, D. 1985. Phonology and the problems of learning to read and write. *Remedial and Special Education* 6:8–17.

Lyon, G. R. 1995. Toward a definition of dyslexia. *Annals of Dyslexia* 45:3–27.
Manis, F. R., Szeszulski, P. A., Holt, L. T., and Graves, K. 1990. Variation in component word recognition and spelling skills among dyslexic children and normal readers. In *Reading and its Development: Component Skills Approaches*, eds. T. H. Carr and B. A. Levy. San Diego: Academic Press.
McBride-Chang, C., and Manis, F. R. 1996. Structural invariance in the associations of naming speed, phonological awareness, and verbal reasoning in good and poor readers: A test of the double deficit hypothesis. *Reading and Writing: An Interdisciplinary Journal* 8:323–39.
Olson, R. K., Wise, B., Conners, F., Rack, J., and Fulker, D. 1989. Specific deficits in component reading and language skills: Genetic and environmental influences. *Journal of Learning Disabilities* 22:339–48.
Olson, R., Forsberg, H., Wise, B., and Rack, J. 1994. Measurement of word recognition, orthographic, and phonological skills. In *Frames of Reference for the Assessment of Learning Disabilities: New Views on Measurement Issues*, ed. G. R. Lyon. Baltimore, MD: Paul Brookes Publishing Co.
Rack, J. P., Snowling, M. J., and Olson, R. K. 1992. The nonword reading deficit in developmental dyslexia: A review. *Reading Research Quarterly* 27:29–53.
Rosner, J. 1979. *Helping Children Overcome Learning Difficulties*. New York: Walker.
Rosner, J., and Simon, D.P. 1971. The Auditory Analysis Test: An initial report. *Journal of Learning Disabilities* 4:384–92.
Shaywitz, B. A., Fletcher, J. M., Holahan, J., and Shaywitz, S. E. 1992. Discrepancy compared to low achievement definitions of reading disability: Results from the Connecticut longitudinal study. *Journal of Learning Disabilities* 25:639–48.
Stanovich, K. E. 1988. Explaining the differences between the dyslexic and the garden-variety poor reader: The phonological-core variable-difference model. *Journal of Learning Disabilities* 21:590–604, 612.
Stanovich, K. E. 1992. Speculations on the causes and consequences of individual differences in early reading acquisition. In *Reading Acquisition*, eds. P. B. Gough, L. C. Ehri, and R. Treiman. Hillsdale, NJ: Lawrence Erlbaum Associates.
Vellutino, F. R., and Scanlon, D. M. 1989. Some prerequisites for interpreting results from reading level matched designs. *Journal of Reading Behavior* 21:361–85.
Wagner, R. K., and Torgesen, J. K. 1987. The nature of phonological processing and its causal role in the acquisition of reading skills. *Psychological Bulletin* 101:192–212.
Wechsler, D. 1974. *Wechsler Intelligence Scale for Children-Revised*. New York: Psychological Corporation.
Wechsler, D. 1989. *Wechsler Preschool and Primary Scale of Intelligence-Revised*. San Antonio, TX: Psychological Corporation.
Wechsler, D. 1991. *Wechsler Intelligence Scale for Children-Third Edition*. San Antonio, TX: Psychological Corporation.
Wolf, M. 1991. Naming speed and reading: The contributions of the cognitive neurosciences. *Reading Research Quarterly* 26:123–41.
Wolf, M. In press. A provisional, integrative account of phonological and naming-speed deficits in dyslexia: Implications for diagnosis and intervention. In *Cognitive and Linguistic Foundations of Reading Acquisition: Implications for Intervention Research*, ed. B. Blachman. Hillsdale, NJ: Lawrence Erlbaum Associates.
Woodcock, R. W. 1987. *Woodcock Reading Mastery Tests-Revised*. Circle Pines, MN: American Guidance Service.
Yap, R., and van der Leij, A. 1993. Word processing in dyslexics: An automatic decoding deficit? *Reading and Writing: An Interdisciplinary Journal* 5:261–79.

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