Cognitive Functioning as Measured by the WISC-R:

Do Children with Learning Disabilities Have Distinctive Patterns of Performance?

Amedeo D'Angiulli and Linda S. Siegel

Abstract

Patterns of performance on the *Wechsler Intelligence Scale for Children–Revised* (WISC-R) have been proposed as useful tools for the identification of children with learning disabilities (LD). However, most of the studies of WISC-R patterns in children with LD have been plagued by the lack of a typically achieving comparison group, by failure to measure individual patterns, and by the lack of a precise definition of LD. In an attempt to address these flaws and to assess the presence of patterns of performance on the WISC-R, we examined data from 121 children with typical achievement (TA), 143 children with reading disabilities (RD), and 100 children with a specific arithmetic disability (AD), ages 6 to 16 years. The results indicated that the RD and AD groups had significantly lower scores than the TA group on all the Verbal IQ subtests. Many of the children with AD and RD showed a significant difference between Verbal and Performance IQ scores, but so did many of the typically achieving children. Although there were some children with LD who showed the predicted patterns, typically, 65% or more of the children with LD did not. Furthermore, a proportion of the TA group—generally not significantly smaller than that of the RD and AD groups—showed discrepancy patterns as well. Our results indicate that the patterns of performance on intelligence tests are not reliable enough for the diagnosis of LD in individual children. Therefore, it might be more profitable to base the detection of an individual's LD on patterns of achievement test scores.

It is often assumed that a learning disability may be diagnosed by significant variability (often referred to as *scatter*) in scores on the subtests of intelligence tests (e.g., Kaufman, 1981). The rationale for the analysis of scatter is that these patterns can be used to assess information processing deficits and have implications for instruction and remediation. In the present study, we address a critical question: Are there actually different patterns of performance on the *Wechsler Intelligence Scale for Children–Revised* (WISC-R; Wechsler, 1974) that can be used to reliably discriminate children with learning disabilities (LD) from typically achieving children?

To answer this question, we compared patterns of scores on achievement tests with patterns of IQ scores. As representative approaches based on patterns of IQ scores, we considered two variants of the discrepancy formula. One is the frequent, general assumption that there is a significant discrepancy between the Verbal and Performance IQ scores of children with LD, with Performance IQ > Verbal IQ. The other is a specific model by Bannatyne (1971), who proposed a factor scheme for the analysis of the WISC-R subtests. Bannatyne's proposed factors are as follows:

1. Spatial, composed of Picture Completion, Object Assembly, and Block Design subtest scores;
2. Conceptual, composed of Comprehension, Similarities, and Vocabulary subtest scores;
3. Knowledge, composed of Information, Arithmetic, and Vocabulary subtest scores; and
4. Sequential, composed of Digit Span, Picture Arrangement, and Coding subtest scores.

The hypothesis underlying Bannatyne's model is that in the children with LD, the Spatial factor (a relative strength) should be higher than the Sequential factor.

Before a pattern of scores can be used to identify a disability, one has to be sure that (a) the given disability has a well-defined and stable phenotypic performance profile, and (b) a certain pattern of test measures fits the specific performance phenotype associated with the disability. Unfortunately, at the state of the art, we have not achieved Step 1 yet.

No evidence exists that clearly relates patterns of performance on the WISC-R to learning disabilities in a systematic way. Over the past 30 years, it has become clear that there are two major clusters of learning difficulties. The most commonly known is reading disability (RD), sometimes called *dyslexia.* There is no difference in meaning between the terms *dyslexia* and *reading disability.* Another equally prevalent but less commonly known disability is *arithmetic (mathematics) disability* (AD), sometimes called *nonverbal learning disability, developmental output failure, writing–arithmetic disability,* or *visual–spatial disability.* Although there is admittedly some heterogeneity within them, these two major clusters of LD incorporate enough common and distinctive characteristics that it seems reasonable to consider them as two separate and specific categories.

Dyslexia involves difficulties with phonological processing, which includes knowing the relationship between letters and sounds. Over the years, a consensus has emerged that one core deficit in dyslexia is a severe difficulty with phonological processing (e.g., Rack, Snowling, & Olson, 1992; Siegel, 1993b; Siegel & Faux, 1989; Siegel & Ryan, 1988; Snowling, 1980; Stanovich, 1988a, 1988b). Most individuals with dyslexia also show problems in the area of memory and language (Siegel & Ryan, 1984, 1988; Snowling, 1980; Stanovich, 1988a, 1988b; Vellutino, 1978). Usually, individuals with dyslexia have spelling problems, but the presence of spelling difficulties without reading difficulties does not indicate dyslexia.

Individuals with developmental output failure or writing–arithmetic disability have difficulty with computational arithmetic and written language, typically in the absence of reading difficulties, although this disability can co-occur with dyslexia. Individuals with AD often have difficulties with spelling and problems with fine motor coordination, visual–spatial processing, and short-term and long-term memory (e.g., multiplication tables), but they usually have good oral language skills (Fletcher, 1985; Johnson & Mykelbust, 1967; Kinsbourne & Warrington, 1963; Kosc, 1974; Levine, Oberklaid, & Meltzer, 1981; Morrison & Siegel, 1991b; Rourke, 1991; Rourke & Finlayson, 1978; Shafrir & Siegel, 1994b; Siegel & Feldman, 1983; Siegel & Linder, 1984; Spellacy & Peter, 1978). Rourke and his associates (e.g., Rourke, Del Dotto, Rourke, & Casey, 1990; Rourke & Tsatsanis, 1996) have described a syndrome called *nonverbal learning disabilities* that is similar to writing–arithmetic disability. However, the operational definition of this learning disability is problematic; it is not clear how a diagnosis can be made. Often, individuals with a nonverbal learning disability have Verbal IQ scores significantly higher than their Performance IQ, but this discrepancy is neither necessary nor sufficient to make the diagnosis. Often, they have arithmetic scores lower than their reading scores, but the differences between these scores are not always significant (e.g., Rourke et al., 1990; for an extended discussion of the definitional issue and conceptualization of this disability, see Morrison & Siegel, 1991a).

There has been considerable debate about whether children with LD have distinctive patterns of performance on the WISC-R or its predecessor (WISC; Wechsler, 1999). Studies that have attempted to confirm the usefulness of the WISC-R as a diagnostic tool for LD have been fraught with methodological errors. To provide a valid test of the discrepancy formula, we now consider some major flaws of these studies and describe how we attempted to correct them in the present study.

A comprehensive review by Kavale and Forness (1984) indicated that there is little evidence for distinctive profiles of WISC and WISC-R scores for children with LD. Most of the studies included in their review did not consider the heterogeneity within the population of children with LD. Often, children with attention deficits but without reading, spelling, or arithmetic problems are included. As a result, the heterogeneity of the sample is further increased. The present study used common subtypes of LD defined by specific achievement difficulties in children without attention deficits.

Although there have been studies that have used WISC or WISC-R patterns to diagnose learning disabilities, most of these studies either have failed to find a difference between children with and without LD or have produced inconclusive evidence (see Rourke, 1998). One source of difficulty is the failure to adequately define learning disabilities. The definitional issues are very complex ones and have been reviewed by Fletcher (1992), Siegel (1989a, 1989b), Siegel and Heaven (1986), and Vellutino (1979). In the present study, we used the definition of LD based on work by Rourke (1991); Rourke and Tsatsanis (1996); Rourke and Finlayson (1978); Rourke et al. (1990); Siegel (1988a, 1988b, 1989a, 1989b, 1990a, 1991a, 1992, 1993a, 1994, 1998); and Siegel and Heaven (1986). In this conceptualization, LD is defined as a significant problem in reading or arithmetic. Provided that other exclusionary criteria apply (severe emotional problems, insufficient knowledge of the language, etc.), if an individual has a significantly low score compared to a peer on a reading or an arithmetic test, then that individual has a reading or arithmetic disability, respectively, and should therefore be considered an individual with a learning disability.

Another problem of previous studies is the failure to include children without learning disabilities as a comparison group. Before it can be concluded that a particular WISC-R pattern is uniquely characteristic of LD, it is important to demonstrate that typical children do not show a similar pattern. The use of the standardization sample as the comparison group does not solve the problem, because the standardization sample contains some unknown proportion of children with learning disabilities. Therefore, the present study included a comparison group of typically achieving (TA) children.

Finally, the analysis of what constitutes a *pattern* has been inadequate. It seems that a pattern should describe the scores of an individual, not the mean scores of a group. For example, the analyses regarding possible patterns should determine *how many* children with RD, as compared to typically achieving children, had Performance IQ scores significantly higher than their Verbal IQ scores, not what the *mean* Verbal and Performance IQ scores were of the RD group compared to the typically achieving children. Therefore, the present study included an analysis of how many individual cases in each group showed scores that fit a particular pattern predicted by the IQ-discrepancy definition.

In short, following our definition of LD, we first categorized children as typically achieving (TA), having arithmetic disabilities (AD), or having reading disabilities (RD) based on their scores on arithmetic and reading achievement tests. Then, we assessed how many children in each of the diagnosed groups fit the patterns of WISC-R scores predicted by two variants of the discrepancy formula, namely, the *verbal–performance discrepancy* scheme and the *Bannatyne factor* scheme.

The verbal–performance discrepancy scheme affords two main sets of predictions:

1. With respect to the means of the WISC-R scores, there should be a significant pattern TA > AD > RD in the Verbal IQ scale and in the Verbal subtests. However, in the Performance IQ scale and in the Performance subtests, the pattern should be as follows: RD ≥ AD ≥ TA.
2. With respect to individual IQ scale, RD and AD groups should show the pattern Performance IQ > Verbal IQ, whereas TA children should show the pattern Verbal IQ = Performance IQ.

The Bannatyne factor scheme predicts that the children with RD and AD should show the pattern Spatial > Verbal Conceptualization > Acquired Knowledge > Sequencing, or similarly the pattern Spatial > Verbal Conceptualization > Sequencing. Here too, TA children should show a more even distribution than that of the children with RD and AD.

Method

Tests

The following tests were administered: The *Wide Range Achievement Test* (WRAT) or *Wide Range Achievement Test–Revised* (WRAT-R; Jastak & Wilkinson, 1984) and the *Wechsler Intelligence Scale for Children–Revised* (WISC-R; Wechsler, 1974). Another set of tests was administered in addition to the WISC-R and WRAT tests; this set included the *Woodcock Reading Mastery Test–Revised* (WRMT-R) Word Attack subtest (Woodcock, 1987), the *Gilmore Oral Reading Test* Reading Comprehension subtest (Gilmore & Gilmore, 1968), the *Beery Development Test of Visual–Motor Integration* (VMI; Beery, 1982), and the *Peabody Picture Vocabulary Test–Revised* (PPVT-R; Dunn & Dunn, 1981). We included the WRMT-R Word Attack subtest to confirm that the individuals whom we diagnosed as having RD had a deficit in phonological processing (and to compare their phonological processing skills to the other groups'). Similarly, the Gilmore Reading Comprehension subtest was included to examine the differences and similarities in reading comprehension between groups. The PPVT-R was included as a measure of receptive vocabulary, and the VMI was added as a measure of visual–motor ability.

Participants

The participants were 364 children, ages 7 to 16, who had volunteered to be in a study of language and memory processes in children with and without learning disabilities. The children had been referred by schools and physicians. The children were required to have a Verbal IQ or Performance IQ or Full Scale IQ score higher than 80 to participate in the study. A child with a score below the 25th percentile on the WRAT-R Reading subscale was assigned to the RD group. A child with a score below the 25th percentile on the WRAT-R Arithmetic subscale and a score on the WRAT-R Reading subscale above the 30th percentile was assigned to the AD group. The TA children were required to have scores above the 30th percentile on the WRAT-R Reading, Spelling, and Arithmetic subscales.

Procedure and Preliminary Analysis

As a first step of this investigation, we assigned children to the TA, AD, or RD groups according to the scores that they attained on the WRAT or WRAT-R. The number of children per group and the mean age for each group are shown in Table 1. The mean scores for each group on the WRAT-R and the WISC-R are also shown in Table 1. Not surprisingly, the children with RD had significantly lower scores than all the other groups. Although their reading and spelling scores were in the average range, the children with AD had significantly lower arithmetic scores (by definition) than the typically achieving children. The scores on the WRAT-R Spelling subscale were significantly different for all the groups. Table 2 presents the mean scores for all groups in two other reading tests, word recognition (WRMT-R) and comprehension (Gilmore), confirming the pattern found for the WRAT-R measures. Both children with RD and children with AD had significantly lower scores than the TA group. Table 2 also presents mean scores on two additional measures—visual–motor coordination (VMI) and vocabulary (PPVT-R)—which once again confirm the patterns found for the WISC-R measures. These patterns indicate the presence of LD; they are consistent with those found by Fletcher (1992), Siegel and Ryan (1988), Siegel and Linder (1984), and Rourke and Finlayson (1978).

Comparisons between the groups in these and subsequent analyses are based on ANOVAs, and pairwise comparisons are based on Scheffé tests. The

RD and AD groups were significantly older than the TA group. When the sample was split into three age groups (i.e., 7–9, 10–12, and 13–16), the results were identical, so the analyses that are reported are for the total sample.

Results

Verbal–Performance Pattern Analysis

The mean scores of each group on the WISC-R and WRAT-R are shown in Table 1. The RD group had significantly lower full Verbal IQ and Performance IQ scores than the AD group, and the AD group had significantly lower scores than the TA group. The children with RD had consistently lower scores on all the Verbal subtests, and the children with AD had significantly higher scores than the RD group but significantly lower scores than the TA group.

The groups did not differ significantly on the Object Assembly, Picture Arrangement, or Mazes subtests of the Performance IQ scale. The RD group had significantly lower scores than the TA group and the AD group on the Block Design and Picture Completion subtests. Both the AD and RD groups had significantly lower scores on the Coding subtest than the TA group.

Table 3 shows the percentage of children in each group whose Verbal IQ scores were significantly higher (≥ 15 points) than their Performance IQ scores versus whose Performance IQ scores were significantly higher (≥ 15 points) than their Verbal IQ. Most of the children with LD did not show either pattern, and neither did the typically achieving children. An overall chi-

TABLE 1
Means and Standard Deviations on Intelligence and Achievement Scores by Group

	TA[a]		AD[b]		RD[c]	
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*
Age (months)	116.5	25.7	140.6	26.9	124.3	31.0
WISC-R						
Full Scale	105.3_p	14.6	96.5_q	11.9	91.1_r	13.3
Verbal	104.8_p	15.3	94.7_q	12.6	87.0_r	12.5
Vocabulary	11.3_p	3.5	9.4_q	2.7	8.1_r	2.5
Similarities	11.0_p	3.1	9.4_q	3.1	8.3_r	3.2
Comprehension	11.1_p	3.2	9.7_q	2.7	8.7_r	2.7
Information	10.4_p	2.9	9.0_q	2.3	7.5_r	2.6
Arithmetic	10.1_p	2.6	8.2_q	2.1	6.9_r	2.2
Digit span	9.6_p	2.5	8.4_q	2.6	6.8_r	2.6
Performance	105.2_p	14.3	99.6_q	13.8	97.4_r	15.7
Block design	10.8_p	3.3	9.8_p	3.0	9.5_q	3.4
Object assembly	10.7_p	3.0	10.7_p	3.0	10.4_p	3.1
Picture completion	11.4_p	2.9	10.7_p	2.7	10.3_q	3.1
Picture arrangement	11.4_p	2.5	10.5_p	3.1	10.6_p	3.4
Coding	9.4_p	3.0	8.1_q	3.0	7.3_q	3.2
Mazes	10.3_p	2.5	9.7_p	2.8	9.8_p	2.6
Estimated IQ	106.3_p	16.6	97.9_q	13.4	93.2_r	14.3
WRAT-R						
Reading	65.9_p	20.0	55.6_q	17.3	11.3_r	7.6
Spelling	58.2_p	22.6	38.4_q	22.4	10.9_r	9.4
Arithmetic	51.5_p	15.3	12.6_q	7.8	17.6_r	17.5

Note. Different subscripts indicate significant differences according to Scheffé tests. TA = typical achievement; AD = arithmetic disabilities; RD = reading disabilities; WISC-R = *Wechsler Intelligence Scale for Children–Revised* (Wechsler, 1974) scaled scores; WRAT-R = *Wide Range Achievement Test–Revised* (Jastak & Wilkinson, 1984) percentile scores.
[a]*n* = 121, 32.2% girls. [b]*n* = 100, 24.0% girls. [c]*n* = 143, 21.7% girls.

TABLE 2
Means and Standard Deviations on Additional Achievement Scores by Group

	TA[a]			AD[b]			RD[c]		
Measure	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*
WRMT-R	27	52.4_p	29.8	16	49.8_q	22.5	44	9.00_r	7.96
GORT	43	5.4_p	2.4	27	4.9_q	1.7	44	2.90_r	1.80
VMI	118	33.4_p	22.9	100	30.9_q	22.9	135	21.90_r	23.10
PPVT-R	95	109.4_p	15.9	83	104.3_q	15.9	102	98.20_r	14.60

Note. Different subscripts indicate significant differences according to Scheffé tests. TA = typical achievement; AD = arithmetic disabilities; RD = reading disabilities; WRMT-R = *Woodcock Reading Mastery Test–Revised* (Woodcock, 1987) Word Attack subtest, percentile scores; GORT = *Gilmore Oral Reading Test* (Gilmore & Gilmore, 1968) Reading Comprehension subtest, stanine scores; VMI = *Beery Developmental Test of Visual–Motor Integration* (Beery, 1982) percentile scores; PPVT-R = *Peabody Picture Vocabulary Test–Revised* (Dunn & Dunn, 1981) scaled scores.
[a]*n* = 121, 32.2% girls. [b]*n* = 100, 24.0% girls. [c]*n* = 143, 21.7% girls.

square test indicated a significant pattern for higher Verbal IQ, $\chi^2(2, N = 364) = 16.52$, $p < .0001$, and higher Performance IQ, $\chi^2(2, N = 364) = 10.59$, $p < .005$. TA children were more likely to show the Verbal IQ > Performance IQ pattern than children with RD, $\chi^2(2, N = 264) = 10.67$, $p < .001$, but there was no reliable difference in the comparisons between TA and AD groups or between AD and RD groups. Both the AD and RD groups were more likely to show the Performance IQ > Verbal IQ pattern than the TA group, $\chi^2(1, N = 221) = 5.02$, $p < .025$, and $\chi^2(1, N = 264) = 16.52$, $p < .0001$, respectively. However, there was no difference between the AD and RD groups in the likelihood of showing this discrepancy. Nonetheless, it is important to note that only 35% of the children with LD (AD or RD) showed a significantly higher Performance IQ than Verbal IQ, whereas 65% did not. It is also important to note that 13.2% of the typically achieving children showed this pattern as well.

To verify whether a profile analysis would be successful in correctly classifying the individual children, we conducted a priori planned comparisons of pairs of subtests based on subtraction of individual scaled scores (for discussion of this method, see Sattler, 1992). To obtain statistically accurate comparison values, we selected three Verbal and two Performance subtests. Instead of the mean Performance IQ or Verbal IQ scaled scores, we selected as reference subtests the Vocabulary and Block Design scores, because these two measures have the highest correlation with full Verbal IQ (.78) and Performance IQ (.68), respectively. To maximize the size of the difference between the individual scores, we subtracted the individual scores belonging to the subtests with the lowest mean scaled scores (Digit Span, Coding, and Arithmetic) from the individual scores of the reference subtests. A difference of 3 or more points from the child's subtest reference score determined whether a particular test was *significantly low* (see Kaufman, 1979). Table 4 shows the percentage of children in each group showing significantly low Digit Span scores (Vocabulary – Digit Span ≥ 3), significantly low Coding scores (Block Design – Coding ≥ 3), or significantly low Arithmetic scores (Vocabulary – Arithmetic ≥ 3).

TABLE 3
Percentage of Children Showing Significant Verbal–Performance IQ Discrepancies by Group

	%		
Discrepancy	**TA**	**AD**	**RD**
VIQ > PIQ			
Yes	14.9	9.0	3.5
No	85.1	91.0	96.5
PIQ > VIQ			
Yes	13.2	25.0	35.0
No	86.8	75.0	65.0

Note. TA = typical achievement; AD = arithmetic disabilities; RD = reading disabilities; VIQ = Verbal IQ; PIQ = Performance IQ.

TABLE 4
Percentage of Children Showing Significantly Low Scores on Digit Span, Coding, and Arithmetic Subtests by Group

	%		
Low score	**TA**	**AD**	**RD**
Digit Span			
Yes	42.9	35.0	36.2
No	57.1	65.0	63.8
Coding			
Yes	43.8	40.0	51.0
No	56.2	60.0	49.0
Arithmetic			
Yes	39.9	28.0	28.4
No	60.1	72.0	71.6

Note. TA = typical achievement; AD = arithmetic disabilities; RD = reading disabilities.

There was no difference among the three groups in the percentage of children with low Digit Span scores, $\chi^2(2, N = 364) = 1.77$, $p < .42$, and it should be noted that at least one third of the children in each group showed this pattern. There was no difference among the three groups in the percentage of children with low Coding scores, $\chi^2(2, N = 364) = 3.13$, $p < .21$, and it should be noted that at least 40% of the children in each group showed this pattern. There was no difference among the three groups in the percentage of children with low Arithmetic scores, $\chi^2(2, N = 364) = 1.23$, $p < .55$, and at least 25% of the children in each group showed this pattern.

It is possible that children who show particular patterns on the WISC-R will show differences in achievement-related cognitive processes. Within the TA, AD, and RD groups, there were no differences between the children who showed the Verbal IQ > Performance IQ pattern and those who did not show this pattern on any of the achievement measures (WRAT-R Reading, Spelling, and Arithmetic; WRMT-R Word Attack, Gilmore Reading Comprehension, VMI, or PPVT-R).

Comparisons between the groups that showed the Performance IQ > Verbal IQ pattern revealed no differences for the AD, RD, and TA groups, with two exceptions: TA and RD group children with higher Performance IQ scores had significantly higher VMI percentile scores (M = 49.87, SD = 22.25, vs. M = 30.99, SD = 23.73, for the TA group, $t[116] = 2.89$, $p < .004$; and M = 32.70, SD = 29.15, vs. M = 16.34, SD = 17.13, for the RD group, $t[133] = 4.10$, $p < .0001$) than other members of their respective groups without a discrepancy between their Verbal and Performance IQ scores.

In summary, our data show that

1. patterns based on the Verbal–Performance IQ discrepancy are not sufficiently reliable to discriminate between children with and without learning disabilities, and
2. the effects related to IQ discrepancies are statistically unimportant.

Bannatyne Factors Analysis

The Bannatyne (1974) factors were calculated as follows:

1. Spatial factor = Picture Completion + Block Design + Object Assembly
2. Verbal Conceptualization factor = Similarities + Vocabulary + Comprehension
3. Acquired Knowledge factor = Information + Arithmetic + Vocabulary
4. Sequencing factor = Arithmetic + Digit Span + Coding

The mean scores of each group on these factors are shown in Table 5. There was a significant difference on the Spatial factor scores among the three groups, $F(2, 352) = 4.5$, $p < .01$: the RD group had significantly lower scores than the TA group, but the AD group did not differ from either the TA or the RD group. There was a significant difference between all three groups on the Verbal Conceptualization factor, $F(2, 352) = 35.5$, $p < .00001$, with the TA group obtaining significantly higher scores than the AD group and with the AD group obtaining significantly higher scores than the RD group. There were significant differences between the groups on the Acquired Knowledge factor, $F(2, 352) = 63.1$, $p < .00001$; the TA group had significantly higher scores than the AD group, who had significantly higher scores than the RD group. There were significant differences between the three groups on the Sequential factor, $F(2, 352) = 58.5$, $p < .00001$. Again, the scores of the TA group were the highest; the AD group had significantly lower scores than the TA group but significantly higher scores than the RD group.

There is an expectation that the children with RD would have significantly higher scores on the Spatial factor. This was not detected in the analysis that focused simply on the comparisons between the single measures composing the Bannatyne factors; however, the difference between the Spatial and Conceptualization factors was significantly greater for the RD and AD groups than for the TA group. There were no differences among the three groups for any of the other differences between factors.

The expectation of the analyses using the Bannatyne factors is that children with learning disabilities will show the following pattern: Spatial > Verbal Conceptualization > Acquired Knowledge > Sequential. Table 6 shows the extent to which the performance of the children in the three groups fit this prediction. The only significant difference between groups was that the RD group was more likely to show this pattern than the TA group, $\chi^2(1, N = 264) = 8.6$, $p < .003$, but most children with LD (AD or RD) did not show this pattern.

Table 6 also shows the percentages of children in each group who showed the pattern Spatial > Verbal Conceptualization > Sequential. Again, the only significant difference was that the children with RD were significantly more likely to show this pattern than the TA group, $\chi^2 = 20.2$, df = 1, $p < .0004$, but most children with LD (AD or RD) did

TABLE 5
Means and Standard Deviations on Bannatyne Factors by Group

Bannatyne factor	TA[a] M	TA[a] SD	AD[b] M	AD[b] SD	RD[c] M	RD[c] SD
Spatial	32.9_p	7.8	31.3_p	6.6	30.2_q	7.4
Verbal conceptualization	33.3_p	8.7	28.6_q	7.3	25.1_r	7.1
Acquired knowledge	31.7_p	7.6	26.8_q	6.0	22.4_r	5.8
Sequential	29.0_p	6.0	24.9_q	5.5	21.0_r	6.0
Differences						
Δ spatial–conceptual	-0.4_p	8.5	2.7_q	7.4	5.1_q	7.3
Δ conceptual–sequential	4.2_p	8.6	3.7_p	7.7	4.0_p	6.2
Δ knowledge–sequential	2.6_p	6.2	1.9_p	6.4	1.4_p	4.7

Note. Different subscripts indicate significant differences according to Scheffé tests. TA = typical achievement; AD = arithmetic disabilities; RD = reading disabilities.
[a]n = 121, 32.2% girls. [b]n = 100, 24.0% girls. [c]n = 143, 21.7% girls.

TABLE 6
Percentage of Children Showing Various Bannatyne Patterns by Group

Pattern	% TA	% AD	% RD
SP > VC > AK > SQ			
Yes	10.3	16.0	25.4
No	89.7	84.0	74.6
SP > VC > SQ			
Yes	24.8	31.0	50.7
No	75.2	69.0	49.3

Note. TA = typical achievement; AD = arithmetic disabilities; RD = reading disabilities. Bannatyne factors: SP = spatial; VC = Verbal Conceptual; AK = Acquired Knowledge; SQ = Sequential.

not show this pattern, and almost 25% of the TA group did.

In short, it seems that the Bannatyne factor scheme does not represent a valid alternative to the verbal–performance discrepancy scheme. Our data suggest that both approaches are of limited diagnostic value.

Discussion

We have defined reading disability as a deficit related to linguistic skills that impairs typical reading. Consistent with this definition, our data showed that children with RD had significantly lower scores than their peers on tests that required expressive language skills, especially phonological processing. These results show that if the definition of RD as a deficit impairing a phonological processing module is adopted, then a specific reading disability can be identified by standardized word recognition and pseudoword reading tests. Naturally, these word recognition or pseudoword reading tests will be relatively insensitive to other processes that fit broader definitions of RD. For example, if we wanted to achieve a reliable identification of *reading comprehension disability,* it would be appropriate to use a specific standardized measure of reading comprehension. Nevertheless, our data did show a consistent pattern of results for the WRAT-R reading measures and the Gilmore comprehension test (cf. Table 1 to Table 2). How would these results fit the specificity assumption we are proposing? A possibility is that these results indicate that our children with RD had trouble in decoding single words, and their difficulty in word decoding influenced their comprehension of the sentences they were trying to read. In this case, the data suggest that the WRMT-R phonological processing measure did to some degree indicate a relationship between phonological deficits and difficulties in reading comprehension.

In contrast, the patterns of WISC-R scores failed to detect RD in most of the children with RD diagnosed with our criteria. Due to the way this study was designed, WRAT-R test scores necessarily provided a better alternative to the WISC-R, because these achievement tests were by definition assumed as the gold standard against which the WISC-R subtests were evaluated. Our main conclusion on the fallacies of using the verbal–performance discrepancy formula is that IQ fails where achievement scores work appropriately. It is important to point out that our data did not demonstrate that we adopted the best *definition* of learning disabilities. Rather, our findings confirmed that standardized word recognition and pseudoword reading tests are the best *measures* available on the basis of which one can identify reading disabilities; and this is independent of the specific operational definition of learning disabilities (e.g., cutoff criteria, regression methods) that is adopted. There are logical reasons to believe so. To make a diagnosis of reading or learning disabilities is to determine whether an individual meets specific criteria or not. Standardized, norm-referenced tests appear to be the best way to do this, because an individual is then compared with others of the same age. Diagnostic methods based on nonstandardized assessments can be used, but they do not provide normative information for comparison. With diagnostic methods based on nonstandardized or informal assessments, it is impossible to know whether an individual has made the number and type of errors that are *typical* or expected of his or her age. In brief, if one aims at detecting significant problems, as compared to a norm, the best logical choice is to use standardized achievement assessments.

It should be noted that although we excluded students with IQ scores below 80, the differentiation of average-IQ students with low achievement scores from students with low achievement and IQ scores lower than 80 can hardly be justified in light of the advances in LD research in the last 20 years. This is most evident in the case of reading disabilities. Several studies have demonstrated that the cognitive processes underlying word recognition are the same for below-average readers with low IQ and high IQ (Fletcher et al., 1994; Siegel, 1988, 1989a, 1989b, 1992; Stanovich & Siegel, 1994). Furthermore, there is no evidence that low-IQ and high-IQ below-average readers respond differently to treatment (Vellutino, Scanlon, & Lyon, 2000; Vellutino et al., 1996) and no evidence that the neuroanatomical impairments responsible for the reading deficits of these two groups are different (Stanovich, 1999). Therefore, achievement scores are still the most satisfactory measures for identifying reading and learning disabilities regardless of IQ level.

As our data clearly show, the failure of different patterns on the WISC-R test in the identification of LD extended to arithmetic disability—a deficit that has been much less frequently recognized as a distinct learning difficulty and that is much less frequently diagnosed as such. Children with AD have adequate word recognition skills but problems with eye–hand coordination, short-term memory, and some visual–spatial tasks (e.g., Bull & Johnston, 1997; Hitch & McAuley, 1991; Hitch & Towse, 1995; Morrison & Siegel, 1991a; Passolunghi, Cornoldi, & De Liberto, 1999; Siegel & Ryan, 1989a, 1989b). In our study, the children with AD had significantly lower Arithmetic, Coding, and Performance IQ scores. The WISC-R Arithmetic subtest has a significant short-term memory component, Coding requires short-term memory and eye–hand coordination, and the Performance IQ reflects a variety of visual–spatial skills. The children with AD had a lower Performance IQ; however, their scores on subtests related to spatial abilities (Block Design and Object Assembly) were not significantly different from the TA group's. One possible reason for this pattern of results is that children with AD were impaired not on the purest tests of spatial concepts but on those in which memory, attention, and speed were critical. It may also be that their difficulties related more to three-dimensional than to two-dimensional visual–spatial processing.

Indeed, a reconsideration of the results reported in Table 1 can explain the patterns based on group scores for both the AD and RD groups and show why they appear to be consistent across IQ levels. Conceptually, there appear to be three factors that are measured by some of the subtests. These factors are

1. Language, composed of Similarities and Vocabulary;
2. Spatial, composed of Block Design and Object Assembly; and
3. Memory/Attention, composed of Arithmetic, Digit Span, and Coding.

The children with RD had scores on the Language factor that were significantly lower than those of the other groups. The scores of the children with AD on this factor were also significantly lower than those obtained by the typically achieving children. None of the groups showed significantly different scores on the Spatial factor. The most significant differences emerged on the Memory/Attention factor. On this factor, children with RD had significantly lower scores than the other groups. The scores of the AD group were significantly lower than those of the typically achieving children, yet significantly higher than those obtained by the RD group. Thus, the pattern of WISC-R scores suggests that the locus of the AD group children's deficit was in memory, attention, and speed. Similarly, problems in reading seem to selectively affect the WISC-R subtests in which memory, attention (working memory), and language are the essential components. Spatial tasks are not affected, because these tasks can be carried out by using strategies supported by perception or perceptual knowledge (e.g., Shafrir & Siegel, 1994a).

These results are important for the definition of learning disabilities. Both children with RD and children with AD had significantly lower scores on subtests that tapped working memory or language. It is clear from these results that the performance of children with LD on the WISC-R cannot be conceptualized as an *unbiased* estimate of their intelligence. Rather, it should be considered as a global measure of potential that is negatively biased toward children with LD (AD or RD) because it penalizes children who have working memory and language difficulties.

Although the scores of the three groups of children were equivalent on the WISC-R Object Assembly, Picture Arrangement, and Mazes subscales, the scores on Picture Completion and Block Design of the RD group were significantly below those of the TA and AD groups. On the Coding subscale, both LD groups also had lower scores than the TA group, but they did not differ from each other. In all groups, the scaled scores on Picture Completion and Block Design were above average, and the differences found between groups in relation to these subscales were extremely small. However, the relatively low scores on Coding entered into the calculation of the Performance IQ of the LD groups and resulted in a spuriously low figure. It should be noted that Coding requires efficient eye–hand coordination skills and short-term memory, which are critical features of both AD and RD. Thus, the differences found in the Performance subscales most likely reflect weaknesses in these areas, which are more pronounced in children with RD than in children with AD. This interpretation is confirmed by the pattern of results found for the VMI, reported in Table 2.

There is a further confirmation of these hypotheses. The verbal–performance discrepancy patterns are not even consistently found in most individuals with LD and do occur in children with *no* learning disability. Consistent with our findings, Kaufman (1994) reported that a large proportion of the nondisabled population showed significant verbal–performance discrepancies and that a large percentage of students with LD did not show these significant discrepancies. Kaufman's and our own findings provide elements to question the very existence of verbal–performance discrepancy patterns, let alone their usefulness.

Similarly, the Bannatyne profile is of little diagnostic validity for *individual* children. The children with LD as a group have significantly different profiles, but it is important to note that many do *not* have this profile, and a significant number of typically achieving children also have this profile. Therefore, such a profile analysis cannot be useful in a diagnostic sense. Our results agree with the results of Decker and Corley (1984), who found that 28% of children with RD and 13% of children without RD fit the Bannatyne profile Spatial > Conceptualization > Sequential. Sattler (1992) reviewed a number of studies that invalidated the usefulness of the Bannatyne scheme for diagnosing not only learning disabilities but also other disabilities.

Bannatyne Acquired Knowledge factor scores seem consistently low in children with LD, suggesting that tests, including IQ tests, that have this factor as a component will underestimate the intelligence or potential of these children. Although it is not known exactly which critical factors interfere with the acquisition of knowledge (e.g., poor memory, lack of exposure due to reduced opportunities) in children with LD, conceivably reading can be considered one of the likely candidates. However, lack of knowledge should not be confused with general intelligence. For, example, what Bannatyne has defined as the Conceptual factor is composed of scores on Comprehension, Similarities, and Vocabulary. It should be noted that the children with RD had low scores on this factor, but because all these tests require expressive language skills and because the children with RD are deficient in these skills (for a review, see Siegel, 1985), it is not surprising that they have lower-than-average scores. However, in spite of the label for this factor, it should not be assumed that the children with RD have poor conceptual or problem-solving skills, but merely that their *verbal* skills are below average. Therefore, IQ test scores reflect their difficulties in various aspects of information processing. If IQ is conceptualized as a measure of potential, the scores of these children with LD will be spuriously low, because their information-processing problems will be reflected in these scores. Therefore, any scheme that attempts to define learning disabilities as a function of an IQ–achievement discrepancy contains a logical fallacy (i.e., circularity), because low scores on the IQ test are a *consequence,* not a cause, of the learning disability.

Achievement scores and IQ scores are not independent; any equation or definition that contains IQ–achievement discrepancy as a component is actually biased and will not identify some children who have low achievement and certain information-processing problems. A discrepancy definition is meaningful only if IQ scores and achievement scores are independent. If the discrepancy is used to indicate the presence of a learning disability, this assumes that IQ test scores are independent of achievement test scores, but they are not. Therefore, it seems logical that learning disability should be defined on the basis of a problem in school-related achievement, such as reading, writing, spelling, and arithmetic. As confirmed by this study, the WISC-R patterns of individual children do not appear to correlate very well with the patterns of achievement test deficits (see also Stanovich & Siegel, 1998). These findings suggest that IQ tests are not particularly useful for determining who has a learning disability, and findings from other studies suggest also that IQ test scores are not particularly useful for determining who will benefit the most from remediation (Vellutino et al., 1996; Vellutino et al., 2000). On the contrary, what emerges from this study is that the most appropriate measure for diagnosing a reading disability or an arithmetic disability appears to be the presence of significantly low scores on achievement tests.

It might be more profitable to concentrate research efforts on patterns of *achievement* scores rather than on patterns of IQ scores. In particular, the assessment of the performance of one individual in tests that measure skills in the area of word recognition and phonological processing (e.g., pseudoword reading) could be contrasted against the performance of the same individual in tests that measure arithmetic, visuomotor coordination, and spatial memory skills. For example, preliminary data from an ongoing investigation by one of our research teams (D'Angiulli, Lesaux, & Siegel, 2002) showed that distinctive patterns of relative differences in ability level on tests of spatial, arithmetic, and reading skills reliably and consistently identify children with AD and RD. These patterns differentiated the LD groups from TA children, who seemed to show rather uniform and average ability levels across the three types of cognitive operations. Thus, relative patterns of performance on standardized achievement tests can be used to identify specific processing deficits, increasing the confidence of the classification of learning disability subtypes. Furthermore, analyzing the components of areas such as reading, spelling, arithmetic, and writing might be particularly useful for providing appropriate remediation strategies for the specific difficulties that children encounter every day at school and that have, it seems, little to do with what IQ scores these children achieve.

In conclusion, we have provided further evidence that the IQ-discrepancy formula is not a useful diagnostic tool for learning disabilities, but that achievement test scores are. Hence, to maximize the chances to identify and understand learning disabilities and to design effective remediation strategies, we should focus on the study of patterns related to achievement tests.

ABOUT THE AUTHORS

Amedeo D'Angiulli, *PhD, is an assistant professor at the University of British Columbia. His research interests include imagery and nonverbal thinking in typical, blind, and visually impaired individuals; and reading, phonological processing, comprehension, and memory in bilingual children, children with English as a second language, and children with learning disabilities.* ***Linda S. Siegel,*** *PhD, is professor and Dorothy Lam Chair in Special Education at the University of British Columbia. Her interests include cognitive aspects of learning disabilities, early detection and remediation of learning disabilities, identification of children at risk for school failure, bilingual and multicultural education, and children with English as a second language (ESL). Address: Amedeo D'Angiulli, Behavioural Research Unit, Department of Pediatrics, University of British Columbia, 4480 Oak St., L408, Vancouver, British Columbia, Canada V6H 3V4; e-mail: amedeo@interchange.ubc.ca*

AUTHORS' NOTES

1. *This study was supported by a grant from the Natural Sciences and Engineering Research Council of Canada.*
2. *The authors wish to thank Norman Himel and Elizabeth Bredberg for help with the data analysis and Kim Kozuki for secretarial assistance.*

REFERENCES

Bannatyne, A. (1971). *Language, reading, and learning disabilities.* Springfield, IL: Thomas.

Bannatyne, A. (1974). Diagnosis: A note on recategorization of WISC scale scores. *Journal of Learning Disabilities, 7,* 272–273.

Beery, K. E. (1982). *Revisited administration, scoring, and teaching manual for the Developmental Test of Visual–Motor Integration.* Cleveland, OH: Modern Curriculum Press.

Bull, R., & Johnston, R. S. (1997). Children's arithmetical difficulties: Contributions from processing speed, item identification, and short-term memory. *Journal of Experimental Child Psychology, 65,* 1–24.

D'Angiulli, A., Lesaux, N. K., & Siegel, L. S. (2002). Arithmetic disability, dyslexia, and visual–spatial skills in adults [Abstract]. *Canadian Pschology, 43*(2), 99.

Decker, S. N., & Corley, R. P. (1984). Bannatyne's "genetic dyslexic" subtype: A validation study. *Psychology in the Schools, 21,* 300–304.

Dunn, L. M., & Dunn, L. M. (1981). *Peabody picture vocabulary test–Revised.* Circle Pines, MN: Academic Guidance Service.

Fletcher, J. M. (1985). Memory for verbal and nonverbal stimuli in learning disability subgroups: Analysis by selective reminders. *Journal of Educational Child Psychology, 40,* 244–259.

Fletcher, J. M. (1992). The validity of distinguishing children with language and learning disabilities according to discrepancies with IQ: Introduction to the special series. *Journal of Learning Disabilities, 25,* 546–548.

Fletcher, J. M., Shaywitz, S. E., Shankweiler, D., Katz, L., Liberman, I., Steubing, K., et al. (1994). Cognitive profiles of reading disability: Comparisons of discrepancy and low achievement definitions. *Journal of Educational Psychology, 85,* 1–18.

Gilmore, J. V., & Gilmore, E. C. (1968). *Gilmore oral reading test.* New York: Harcourt Brace Jovanovich.

Hitch, G. J., & McAuley, E. (1991). Working memory in children with specific arithmetical learning difficulties. *British Journal of Psychology, 3,* 375–386.

Hitch, G. J., & Towse, J. N. (1995). Working memory, what develops? In F. E. Weinert & W. Schneider (Eds.), *Memory performance and competencies: Issues in growth and development* (pp. 3–21). Mahwah, NJ: Erlbaum.

Jastak, S., & Wilkinson, G. S. (1984). *Wide range achievement test–Revised.* Wilmington, DE: Jastak Associates.

Johnson, D. J., & Mykelbust, H. R. (1967). *Learning disabilities: Education principles and practice.* New York: Grune & Stratton.

Kaufman, A. (1979). *Intelligent testing with the WISC-R.* New York: Wiley.

Kaufman, A. (1981). The WISC-R and learning disabilities assessment: State of the art. *Journal of Learning Disabilities, 14,* 520–526.

Kaufman, A. (1994). *Intelligent testing with the WISC-III.* New York: Wiley.

Kavale, K. A., & Forness, S. R. (1984). A meta-analysis of the validity of Wechsler Scale profiles and recategorizations: Patterns or parodies? *Learning Disability Quarterly, 7,* 136–156.

Kinsbourne, M., & Warrington, E. K. (1963). The developmental Gerstmann syndrome. *Archives of Neurology, 8,* 490–501.

Kosc, L. (1974). Developmental dyscalculia. *Journal of Learning Disabilities, 7,* 164–177.

Levine, M. D., Oberklaid, F., & Meltzer, L. (1981). Developmental output failure: A study of low productivity in school-aged children. *Pediatrics, 67,* 18–25.

Morrison, S. R., & Siegel, L. S. (1991a). Arithmetic disability: Theoretical considerations and empirical evidence for this subtype. In L. V. Feagans, E. J. Short, & L. Meltzer (Eds.), *Subtypes of learning disabilities: Theoretical perspectives and research* (pp. 189–208). Hillsdale, NJ: Erlbaum.

Morrison, S. R., & Siegel, L. S. (1991b). Learning disabilities: A critical review of definitional and assessment issues. In J. E. Obrzut & G. W. Hynd (Eds.), *Neuropsychological foundations of learning disabilities: A handbook of issues, methods, and practice* (pp. 79–97). San Diego: Academic Press.

Passolunghi, M. C., Cornoldi, C., & De Liberto, S. (1999). Working memory and intrusions of irrelevant information in a group of specific problem solvers. *Memory & Cognition, 5,* 779–790.

Rack, J. P., Snowling, M., & Olson, R. (1992). The nonword reading deficit in developmental dyslexia: A review. *Reading Research Quarterly, 27,* 28–53.

Rourke, B. P. (1991). Validation of learning disabilities subtypes: An overview. In B. P. Rourke (Ed.), *Neuropsychological validation of learning disability subtypes* (pp. 3–11). New York: Guilford.

Rourke, B. P. (1998). Significance of verbal–performance discrepancies for subtypes of children with learning disabilities: Opportunities for the WISC-III. In A. Pritiera & D. Saklofske (Eds.), *WISC-III, clinical use and interpretation* (pp. 139–156). San Diego: Academic Press.

Rourke, B. P., Del Dotto, J. E., Rourke, S. B., & Casey, J. E., (1990). Nonverbal learning disabilities: The syndrome and a case study. *Journal of School Psychology, 28,* 361–385.

Rourke, B. P., & Finlayson, M. A. J. (1978). Neuropsychological significance of variations in patterns of academic performance: Verbal and visual–spatial abilities. *Journal of Abnormal Child Psychology, 6,* 121–133.

Rourke, B. P., & Tsatsanis, K. D. (1996). Syndrome of nonverbal learning disabilities: Psycholinguistic assets and deficits. *Topics in Language Disorders, 16,* 30–34.

Sattler, J. M. (1992). *Assessment of children* (3rd ed.). San Diego: Author.

Shafrir, U., & Siegel, L. S. (1994a). Preference for visual scanning strategies versus phonological rehearsal in university students with reading disabilities. *Journal of Learning Disabilities, 27,* 583–588.

Shafrir, U., & Siegel, L. S. (1994b). Subtypes of learning disabilities in adolescents and adults. *Journal of Learning Disabilities, 27,* 123–134.

Siegel, L. S. (1985). Psycholinguistic aspects of reading disabilities. In L. S. Siegel & F. J. Morrison (Eds.), *Cognitive development in atypical children* (pp. 45–66). New York: Springer Verlag.

Siegel, L. S. (1988a). Evidence that IQ scores are irrelevant to the definition and analysis of reading disability. *Canadian Journal of Psychology, 42,* 202–215.

Siegel, L. S. (1988b). Definitional and theoretical issues and research on learning disabilities. *Journal of Learning Disabilities, 21,* 264–266.

Siegel, L. S. (1989a). IQ is irrelevant to the definition of learning disabilities. *Journal of Learning Disabilities, 22*, 469–478, 486.

Siegel, L. S. (1989b). Why we do not need intelligence test scores in the definition and analyses of learning disability. *Journal of Learning Disabilities*, *22*, 514–518.

Siegel, L. S. (1990a). IQ and learning disabilities: R.I.P. In H. L. Swanson & B. Keogh (Eds.), *Learning disabilities: Theoretical and research issues* (pp. 111–128). Hillsdale, NJ: Erlbaum.

Siegel, L. S. (1991a, July). *Phonological processing, working memory, and syntactic awareness as determinants of reading skill.* Paper presented at the International Conference on Memory, Lancaster, UK.

Siegel, L. S. (1992). An evaluation of the discrepancy definition of dyslexia. *Journal of Learning Disabilities, 25,* 618–629.

Siegel, L. S. (1993a). Alice in IQ land, or why IQ is still irrelevant to learning disabilities. In R. M. Joshi & C. K. Leong (Eds.), *Reading disabilities: Diagnosis and component processes* (pp. 71–84). Dordrecht, The Netherlands: Kluwer.

Siegel, L. S. (1993b). Phonological processing deficits as the basis of a reading disability. *Developmental Review, 13,* 246–257.

Siegel, L. S. (1994). The modularity of reading and spelling: Evidence from hyperlexia. In G. D. A. Brown & N. C. Ellis (Eds.), *Handbook of spelling: Theory, process and intervention* (pp. 227–248). Chichester, NY: Wiley.

Siegel, L. S. (1998). The discrepancy formula: Its use and abuse. In B. K. Shapiro, P. J. Accardo, & A. J. Capute (Eds.), *Specific reading disability: A view of the spectrum* (pp. 123–135). Timonium, MD: York Press.

Siegel, L. S., & Faux, D. (1989). Acquisition of certain grapheme–phoneme correspondences in normally achieving and disabled readers. *Reading and Writing: An Interdisciplinary Journal, 1,* 37–52.

Siegel, L. S., & Feldman, W. (1983). Nondyslexic children with combined writing and arithmetic difficulties. *Clinical Pediatrics, 22,* 241–244.

Siegel, L. S., & Heaven, R. K. (1986). Categorization of learning disabilities. In S. J. Ceci (Ed.), *Handbook of cognitive, social, and neuropsychological aspects of learning disabilities* (Vol. 2, pp. 95–121). Hillsdale, NJ: Erlbaum.

Siegel, L. S., & Linder, B. A. (1984). Short-term memory processes in children with reading and arithmetic learning disabilities. *Developmental Psychology, 20,* 200–207.

Siegel, L. S., & Ryan, E. B. (1984). Reading disability as a language disorder. *Remedial and Special Education, 5*(3), 28–33.

Siegel, L. S., & Ryan, E. B. (1988). Development of grammatical sensitivity, phonological, and short-term memory skills in normally achieving and learning disabled children. *Developmental Psychology, 24,* 28–37.

Siegel, L. S., & Ryan, E. B. (1989a). The development of working memory in normally achieving and subtypes of learning disabled children. *Child Development, 60,* 973–980.

Siegel, L. S., & Ryan, E. B. (1989b). Subtypes of developmental dyslexia: The influence of definitional variables. *Reading and Writing: An Interdisciplinary Journal, 1,* 257–287.

Snowling, M. J. (1980). The development of grapheme–phoneme correspondence in normal and dyslexic readers. *Journal of Experimental Child Psychology, 29,* 294–305.

Spellacy, F., & Peter, B. (1978). Dyscalculia and elements of the developmental Gerstmann syndrome in school children. *Cortex, 14,* 197–206.

Stanovich, K. E. (1988a). Explaining the differences between the dyslexic and garden variety poor reader: The phonological-core variable-difference model. *Journal of Learning Disabilities, 21,* 590–604, 612.

Stanovich, K. E. (1988b). The right and wrong places to look for the cognitive locus of reading disability. *Annals of Dyslexia, 38,* 154–177.

Stanovich, K. E. (1999). The sociopsychometrics of learning disabilities. *Journal of Learning Disabilities, 32,* 350–361.

Stanovich, K. E., & Siegel, L. S. (1994). Phenotypic performance profile of children with learning disabilities: A regression-based test of the phonological-core variable-difference model. *Journal of Educational Psychology, 86,* 24–53.

Stanovich, K. E., & Siegel, L. S. (1998). The role of IQ in the diagnosis of reading disorders: The quest for a subtype based on aptitude/achievement discrepancy. In J. Rispens, T. A. van Yperen, & W. Yule (Eds.), *Perspectives on the classification of specific developmental disorders* (pp. 105–136). Dordrecht, The Netherlands: Kluwer.

Vellutino, F. R. (1978). Toward an understanding of dyslexia: Neuropsychological factors in specific reading disability. In A. L. Benton & D. Pearl (Eds.), *Dyslexia: An appraisal of current knowledge* (pp. 61–112). New York: Oxford University Press.

Vellutino, F. R. (1979). *Dyslexia: Theory and research.* Cambridge, MA: MT Press.

Vellutino, F. R., Scanlon, D. M., & Lyon, G. R. (2000). Differentiating between difficult-to-remediate and readily remediated poor readers: More evidence against the IQ–achievement discrepancy definition of reading disability. *Journal of Learning Disabilities, 33,* 223–238.

Vellutino, F. R., Scanlon, D., Sipay, E., Small, S., Pratt, A., Chen, R., et al. (1996). Cognitive profiles of difficult-to-remediate and readily remediated poor readers: Early intervention as a vehicle for distinguishing between cognitive and experiential deficits as basic causes of specific reading disability. *Journal of Educational Psychology, 88,* 601–638.

Wechsler, D. (1949). *Manual for the Wechsler Intelligence Scale for Children.* San Antonio, TX: Psychological Corp.

Wechsler, D. (1974). *Manual for the Wechsler Intelligence Scale for Children–Revised.* San Antonio, TX: Psychological Corp.

Woodcock, R. W. (1987). *Woodcock reading mastery test–Revised.* Circle Pines, MN: American Guidance Service.