Explaining the Differences Between the Dyslexic and the Garden-Variety Poor Reader: The Phonological-Core Variable-Difference Model

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A coherent conception of dyslexia has been difficult to arrive at because research findings have continually created logical paradoxes for the psychometric definition of reading disability. This paper develops the phonological-core variable-difference model. This model of the cognitive characteristics of dyslexic children is one of the few that does not create psychometric paradoxes of the type that have plagued the learning disabilities field. The model provides a way to conceptualize the differences between dyslexic and garden-variety poor readers. The model highlights the importance of viewing the concept of dyslexia as the outcome of the application of an arbitrary criterion in a continuous distribution, thus avoiding the connotations of discreteness that have continually undermined our understanding of reading disability.

The field of learning disabilities (LD) is contentious and it has a checkered history. It is commonplace to bemoan the state of confusion and disagreement in the field. Here, however, I wish to focus on a positive trend that is discernible in current research. There has recently been an increasing recognition that the field in some sense "got ahead of itself," that educational practice simply "took off" before a thorough investigation of certain foundational assumptions had been carried out. Thus, much recent research has a "get back to basics" feel to it, as researchers double back to retrace crucial empirical and theoretical steps that were skipped during the mad rush to implement what we now know were nascent hypotheses rather than established empirical facts.

The signs that the field is making an attempt to establish itself on a firmer foundation are numerous. The National Institute of Child Health and Development (NICHD) is supporting long overdue large-scale epidemiological and subtype investigations. The statistical and psychometric complexities of defining disabilities on the basis of behavioral and cognitive discrepancies are becoming more widely understood and are beginning to affect practice (McKinney, 1987; Reynolds, 1985).

The development I would like to focus on here is the recent flurry of work that goes back to the most critical foundational assumption underlying the learning disability concept: the concept of qualitative differences in cognitive/behavioral characteristics. I will confine the remaining discussion to reading disability—the most prevalent type of learning disability and also my particular area of expertise.

From the beginning, what has fueled both theoretical interest in dyslexia (and/or reading disability, specific reading retardation, etc.; the terms are used interchangeably here) and has justified differential educational treatment has been the assumption that the reading difficulties of the dyslexic stem from problems different from those characterizing the "garden-variety" poor reader (to use Gough & Tunmer's, 1986, term); or, alternatively, the assumption that if reading difficulties stem from the same factors, the degree of severity is so extreme for the dyslexic that it constitutes, in effect, a qualitative difference.

I should mention as an aside that I view the interminable semantic debates in developmental psychology over what constitutes a qualitative as opposed to a quantitative difference as utterly futile and scientifically useless. Alternative terms would do equally well and probably would not trigger what are essentially linguistic debates. Nevertheless, I use the terms for convenience, ease of communication, and to make clear the connections with previous research.

What *is* important is the experimental contrasts that have operationalized the idea of qualitative difference and/or differential causation in the literature. This operationalization has been dominated by two different designs. One is the reading-level match design, where an older group of dyslexic children is matched on reading level with a younger group of nondyslexic children. The cognitive characteristics and reading subskills of the two groups are then compared. The logic here is fairly straightforward. If the reading subskills and cognitive characteristics of the two groups do not match, then it would seem that they are arriving at their similar reading levels via different routes, and this would support the idea of differential causation. In contrast, if the reading subskill profiles of the two groups are identical, this would seem to undermine the rationale for the differential educational treatment of dyslexic children and for their theoretical differentiation. If dyslexic children are reading just like any other child who happens to be at their reading level, and are using the same cognitive skills to do so, why should we consider their reading behavior to be so special?

The second major design—one pertinent not only to theoretical issues but also to the educational politics of LD—is to compare dyslexic children with children of the same age who are reading at the same level, but who are not labeled dyslexic. (Adapting the terminology of Gough & Tunmer, 1986, this design will be termed the "garden-variety control" design.) Again, the inferences drawn are relatively straightforward. If the reading subskills and cognitive characteristics of the two groups do not match, then it would seem that the two groups are arriving at their similar reading levels via different routes. In contrast, if the reading subskill profiles of the two groups are identical, this would certainly undermine the rationale for the differential educational treatment of dyslexic children and would make dyslexic children considerably less interesting theoretically. As Fredman and Stevenson (1988) state, if "there is no clear distinction between the groups in terms of how they read, then the practice of identifying a special group of poor readers for special attention may no longer be necessary" (p. 105).

Unfortunately, the results of research employing both of these designs have been inconsistent. Empirically, there are reading-level match studies that have revealed similar processing profiles (Beech & Harding, 1984; Treiman & Hirsh-Pasek, 1985) and those that have identified differences (Baddeley, Ellis, Miles, & Lewis, 1982; Bradley & Bryant, 1978; Kochnower, Richardson, & DiBenedetto, 1983; Olson, Kliegl, Davidson, & Foltz, 1985; Snowling, 1980; Snowling, Stackhouse, & Rack, 1986). Similarly, garden-variety comparisons have supported qualitative similarity (Fredman & Stevenson, 1988; Taylor, Satz, & Friel, 1979) and difference (Jorm, Share, Maclean, & Matthews, 1986; Rutter & Yule, 1975; Silva, McGee, & Williams, 1985).

The mixed results have troubled many in the field because they relate to some of the foundational assumptions of the concept of dyslexia as it is used in both research investigations and in educational practice. Indeed, these unresolved issues have provoked Andrew Ellis (1985) to ask, in an emperor-has-no-clothes fashion, "Is it worth studying dyslexia?" (p. 199); and to further press the point:

> Does applying all the exclusionary tests discussed earlier to a group of poor readers in order to obtain a sample of high-grade, refined dyslexics actually yield a sample whose reading problems are qualitatively different from those of non-dyslexic subjects? Surprisingly this question seems to have received hardly any attention at all....No one, it seems, has ever shown that the initial laborious screening is necessary in the sense that it produces a population of individuals whose reading characteristics are different from the great mass of poor readers. (pp. 199–200)

Ellis's use of the word "surprisingly" alludes to the point mentioned earlier—that the field of learning disabilities expanded and grew in virtual absence of the critical data needed to test its foundational assumptions. This situation has only recently begun to be remedied by researchers employing the two designs that I described above.

Unfortunately, as was mentioned, the results have been somewhat equivocal. It has not always been possible to differentiate the performance of dyslexic children from garden-variety poor readers or from younger reading-level controls. Thus, the field still invites skeptical questioning like that of Ellis, and challenges such as,

> It may be timely to formulate a concept of reading disability which is independent of any consideration of IQ. Unless it can be shown to have some predictive value for the nature of treatment or treatment outcome, considerations of IQ should be discarded in discussions of reading difficulties. (Share, McGee, & Silva, in press, p. 12)

or,

> If the dyslexic readers differ from poor readers along the same dimensions that differentiate poor readers from good, it cannot be concluded that the dyslexic readers' performance is due to decoding processes specific to this group. Hence the results fail to provide evidence for the kind of qualitative differences between groups entailed by the standard view....If a term is to be reserved for those children who perform at the lowest end of the continuum, we suggest that it be something other than "dyslexic" or "reading disabled," which carry other connotations. Perhaps simply "very poor readers" would do. (Seidenberg, Bruck, Fornarolo, & Backman, 1986, pp. 79–80)

THE DEVELOPMENTAL LAG MODEL

One notable theoretical attempt to salvage the dyslexia concept has been the characterization of reading disabled children as not qualitatively different, but as suffering from a developmental lag in reading-related cognitive processes. The developmental lag notion has a venerable history in the psychology of mental retardation (see Zigler, 1969). Its theoretical importance in the LD literature resides in the fact that, unlike the deficit models that emphasize qualitative difference, lag models predict that when older disabled and younger nondisabled children are matched on reading level, their performance should not differ on any cognitive tasks causally related to reading (see Fletcher, 1981). Thus, at least some of the results that are problematic for those wishing to distinguish dyslexic children (e.g., the similarities in some reading-level control studies) are accommodated by the developmental lag theory.

However, there are several problems involved in conceptualizing and testing the lag notion. For example, predictions derived from the lag hypothesis depend critically on how the matching on reading level is done. It is somewhat surprising to find that researchers have been quite inconsistent in specifying exactly what "reading level" refers to in this literature or, for that matter, in the research employing garden-variety controls. Specifically, some investigations have matched children with reading comprehension tests (e.g., Bruck, 1988; Seidenberg, Bruck, Fornarolo, & Backman, 1985), while others have matched the children on word recognition skills (e.g., Olson et al., 1985; Treiman & Hirsh-Pasek, 1985). And finally, some have matched children using a composite of both word recognition and reading comprehension (Bloom, Wagner, Reskin, & Bergman, 1980; Jorm et al., 1986). Unfortunately, all of these investigations have been referred to as reading-level (RL) match studies, thus substantially increasing the difficulty of integrating the research findings in this area. It has been insufficiently recognized that the results and interpretation of an RL-match design may vary depending upon whether the matching is done with a comprehension test or with a word recognition test. We have suggested (Stanovich, Nathan, & Zolman, 1988) that future investigators refer to their designs as either decoding-level matches or comprehension-level matches.

The necessity of differentiating decoding-level (DL) matches from comprehension-level (CL) matches illustrates that researchers have really been asking two different questions. A study matching on comprehension is investigating whether the relative contributions of the subskills determining comprehension ability are the same in skilled and less skilled readers. Studies that match subjects purely on the basis of decoding ability are asking the same question within the more restricted domain of the word recognition module; that is, they are asking whether the two groups perform equally on word recognition tests for the same or different reasons.

Consider, for example, the implications for the predictions derived from the developmental lag hypothesis if the matching in an RL study is done with a comprehension test and dyslexics—identified by strict discrepancy criteria—are the poor reader group. The two groups will presumably be close in intelligence. Of course, similar intelligence test scores at different ages mean different things in terms of the raw score or absolute level of performance on a given test or index of ability. Thus, when older dyslexics are matched with younger children progressing normally in reading, the former will have higher raw scores on the intelligence measure. It should then also be the case that the dyslexics will score higher on any cognitive task that is correlated with the raw score on the intelligence test, and of course there are a host of such tasks. This has implications for the expected outcome in a CL design.

The argument goes as follows. The best candidates for the critical loci of reading disability (see Stanovich, 1986b, 1988) are tasks tapping a "vertical" faculty (i.e., processes operating in a specific domain; see Fodor, 1983) that is closely associated with reading but relatively dissociated from intelligence. According to the lag model, dyslexics lag in the development of certain vertical faculties and, as a result, their reading progress also lags. But consider that on any "horizontal" faculty, cognitive processes (those operating across a variety of domains) like metacognitive awareness, problem solving, and higher level language skills, the dyslexic should outperform the younger children (due to a higher mental age). However, when the reading test is a comprehension test, rather than a word recognition measure, the comprehension requirements of the test will implicate many of these higher level processes. Thus, the psychometric constraints imposed by the matching in a CL investigation should result in a pattern that I have previously characterized as compensatory processing (Stanovich, Nathan, & Vala-Rossi, 1986).

The compensatory processing hypothesis begins by assuming the importance of phonological processing skills in early reading development (Bradley & Bryant, 1985; Liberman, 1982; Mann, 1986; Stanovich, 1986b, 1988; Williams, 1984). From this assumption, and the psychometric constraints mentioned above, it follows that a rigorously defined sample of reading disabled children should display performance inferior to that of the younger CL-matched children on phonological analysis and phonological recoding skills, but should simultaneously display superior vocabulary, real-world knowledge, and/or strategic abilities (i.e., superior performance on other variables that should be correlated with the raw score on the IQ test). The similar overall level of comprehension ability in the two groups presumably obtains because the dyslexic children use these other skills and knowledge sources to compensate for seriously deficient phonological processing skills.

THE DEVELOPMENTAL LAG HYPOTHESIS AND THE GARDEN-VARIETY POOR READER

The situation is different when the lag hypothesis is applied to CL comparisons involving less skilled readers defined simply on the basis of reading ability relative to age. Such children are not statistically precluded from matching the complete cognitive performance profile of younger children who read at the same level. It is thus possible that population differences are the source of some of the empirical discrepancies in RL designs. These studies, like many in the dyslexia/LD literature, often fail to obtain a close IQ match between the dyslexic and nondisabled groups (Stanovich, 1986a; Torgesen & Dice, 1980). According to the hypotheses outlined here, any mismatch on IQ in a CL study will tend to change the pattern of results.

With respect to the specifically disabled reader, I have argued that the interrelations of the processes that determine comprehension are different for the two groups in a CL match. However, it is important to note that even if compensatory processing does explain the similar levels of comprehension, this does not necessarily guarantee the applicability of an analogous explanation of similar levels of decoding in a DL match. That is, it is perfectly possible that the comprehension ability of disabled readers is determined by compensatory processing (relative to younger CL controls), but that the operation of their word recognition modules is similar (in terms of regularity effects, orthographic processing, context effects, etc.) when compared to that of younger DL controls. (Note that from the compensatory hypothesis it follows that the DL match controls for an older disabled group of readers will not completely overlap with the disabled group's CL controls.)

Thus, in the case of the CL match, the finding of similar profiles across a wide variety of reading-related tasks is most likely to be observed with garden-variety poor readers. Such a finding would have implications for our understanding of specific reading disability, because it follows that when one of these groups (garden-variety versus dyslexic poor readers) displays a profile match in a broad-based CL study the other is logically precluded from doing so. In short, if we could nail down one of the possible data patterns in one of the populations of interest, the decreasing degrees of freedom would go a long way toward constraining further theoretical speculation. This, then, is the theoretical background that motivates the question we have asked in the research to be reported: Do garden-variety poor readers show matching profiles in a multivariate CL match that probes a variety of reading-related cognitive skills? I will report on two separate CL comparisons that are defined by a longitudinal research design.

A GARDEN-VARIETY CL MATCH

Our investigation began as a multivariate study of the reading-related cognitive subskills of third- and fifth-grade children. The far left column of Table 1 displays the variables in this investigation. The main criterion variable was the score on the Reading Survey Test of the Metropolitan Achievement Tests (Prescott, Balow, Hogan, & Farr, 1978), which is a test of reading comprehension. The Peabody Picture Vocabulary Test (Dunn, 1965) was employed as a measure of receptive vocabulary. Two measures of phonological sensitivity were employed: a rhyme production task and the odd-sound-out task popularized by Bradley and Bryant (1978, 1985). Response time, as well as errors, was assessed on these two tasks in an attempt to determine whether, for children of this age, speed might have a diagnosticity that accuracy lacks due to ceiling effects. In addition, it was thought that the speed instructions might serve to create more errors in the tasks and thus preclude ceiling effects that would ordinarily occur with children of this age.

Discrete-trial letter- and picture-naming tasks were included because previous investigators (e.g., Denckla & Rudel, 1976; Wolf, 1984) have linked deficiencies in naming speed and accuracy to reading problems. Pseudoword naming, an indicator of phonological recoding ability and potent predictor of reading ability at all levels, is associated with three variables in Table 1. Since both accuracy and speed have tended to be diagnostic, both were assessed. In addition, overall pseudoword naming skill was assessed by combining z-score indices for both time and accuracy into a composite z-score variable. Word naming was assessed under two conditions: with and without a related prior context (here termed the neutral and related conditions). These two conditions were administered using the contextual priming methodology that Richard West and I have utilized extensively (see Stanovich & West, 1983; West & Stanovich, 1978, 1982, 1986). A derived contextual facilitation variable was constructed by simply subtracting the mean time for word naming with related contexts from the mean time for word naming with neutral contexts.

Table 1 displays the intercorrelations among all of the variables for the third-grade children above the diagonal and for the fifth-grade children below the diagonal. Although there are many interesting relationships here, I will draw attention only to the top row where the correlations with the Metropolitan scores are displayed. The strongest predictors of reading comprehension are scores on the Peabody and word naming times (particularly in related contexts). The phonological sensitivity tasks and pseudoword naming errors are also moderate predictors. The far left column of correlations reveals similar, but

TABLE 1
Intercorrelations of All Variables

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Metropolitan		.76*	−.50*	−.17	−.44*	−.02	−.07	−.18	−.16	−.45*	−.33*	−.72*	−.53*	.47*
2. PPVT[a]	.64*		−.48*	−.10	−.25	−.02	−.08	.00	.03	−.37*	−.15	−.51*	−.22	.59*
3. Rhyme Production Errors	−.43*	−.37*		.29*	.43*	.29*	.00	.12	−.25	.42*	.00	.50*	.35*	−.37*
4. Rhyme Production Time	−.29*	−.26	.24		.21	.06	−.20	−.14	.01	.28	.14	.20	.29*	.10
5. Oddity Errors	−.38*	−.36*	.42*	.33*		.36*	−.02	.25	−.04	.42*	.16	.50*	.45*	−.19
6. Oddity Time	−.29*	−.14	.30*	−.06	.13		.16	.15	.01	.22	.11	.26	.23	.11
7. Letter-Naming Time	−.30*	−.42*	.41*	.16	−.04	.16		.25	−.09	.02	−.06	.13	.00	−.25
8. Picture-Naming Time	−.38*	−.40*	.30*	.07	.18	.33*	.49*		−.15	−.16	−.20	.10	.00	−.20
9. Pseudoword-Naming Time	−.76*	−.54*	.67*	.30*	.30*	.31*	.43*	.48*		.23	.89*	.27	.33*	.06
10. Pseudoword-Naming Errors	−.52*	−.46*	.74*	.26	.42*	.18	.36*	.38*	.72*		.65*	.64*	.67*	−.08
11. Pseudoword z-Score	−.73*	−.55*	.73*	.31*	.36*	.29*	.43*	.48*	.97*	.86*		.51*	.57*	.01
12. Word Naming – Related Contexts	−.57*	−.36*	.34*	.15	.14	−.02	.27	.40*	.67*	.52*	.67*		.85*	−.45*
13. Word Naming – Neutral Contexts	−.71*	−.53*	.61*	.23	.31*	.28*	.46*	.48*	.91*	.67*	.89*	.80*		.08
14. Contextual Facilitation	−.36*	−.35*	.53*	.17	.30*	.48*	.37*	.22	.53*	.36*	.51*	−.11	.51*	

Correlations for the third-grade children are above the diagonal, and correlations for the fifth-grade children are below the diagonal.
[a]PPVT = Peabody Picture Vocabulary Test; *$p < .05$.

not identical, relationships for the fifth-grade children. Here, every variable displayed a statistically significant relationship with reading ability, the strongest correlations involving pseudoword and word naming, in addition to the Peabody.

Table 2 presents the data of greatest interest. Here, the children in each grade are partitioned into skilled and less skilled readers, and the mean on each variable is presented for each group. Importantly, the partitioning was done so that the skilled third-grade children and the less skilled fifth-grade children formed a comprehension-level match, both obtaining similar grade equivalent scores on the Metropolitan (5.2 and 5.1, respectively). The critical comparisons are thus represented in the second and third columns from the left. A statistical test of the means for each variable for the CL-matched groups is presented in the far right column.

The results of the CL comparisons are easily summarized. The performance patterns of these two groups were remarkably convergent. They differed significantly on only 1 of the 13 variables listed in Table 2. The performance of the two groups was virtually identical on the Peabody, rhyme-production errors, oddity errors, oddity response time, picture naming, pseudoword *z*-score, word naming speed in both related and neutral contexts, and contextual facilitation score. The fifth-grade children were 97 msec faster on the rhyme production task, but this difference was not significant. The fifth-grade students were also somewhat faster at pseudoword naming (again, not significantly so), but there are indications that this difference may be due to differential speed/accuracy tradeoff criteria. Although the fifth-grade readers were somewhat faster at pseudoword naming, they made more errors than the third-grade readers. Consistent with the idea of a conservative criterion among the skilled third graders was the finding that skill differences within this grade were large in the error rates (3.43 vs. 1.44) but small in the naming times (984 msec vs. 956 msec). Given a possible difference in speed/accuracy criteria in the two age groups, the best comparison of performance on pseudowords is the *z*-score variable, where both performance indices are combined. On this variable the two CL-matched groups were very similar.

Thus, only one variable—letter-naming time—differentiated the two groups. This variable has been shown to track age much more strongly than reading ability in previous investigations (Jackson & Biemiller, 1985; Stanovich, Feeman, & Cunningham, 1983) and so its statistical significance in a CL match is predictable and empirically convergent. With this one exception, the reading-related cognitive performance profiles of these two groups of readers were highly similar. This pattern of performance similarities is consistent with a developmental lag model of the reading skill deficits displayed by the less skilled fifth-grade children that extends over rather broad cognitive domains. Cognitively, they resemble younger children who are at the same stage of reading acquisition.

Two years later we conducted a similar investigation that had some new design features (Stanovich et al., 1988). First, we tested children in three grades—third, fifth, and seventh—and formed a three-group CL match spanning all three grades. Virtually all such designs in the current literature involve only two-group comparisons. Embedded within this new multivariate investigation was a longitudinal follow-up of the third- and fifth-grade children in the previous investigation, now fifth and seventh graders, respectively. These children, plus additional children not tested before, formed part of the larger sample in the second investigation. This second testing enabled us to examine a situation virtually unreported in the

TABLE 2
Means for Each Task as a Function of Grade and Skill

	Less Skilled Third Grade	Skilled Third Grade	Less Skilled Fifth Grade	Skilled Fifth Grade	Grade $F(1,60)$	Skill $F(1,60)$	Interaction $F(1,60)$	Skilled Third Grade vs Less Skilled Fifth Grade $t(34)$
PPVT[a]	64.8	78.0	78.6	92.4	38.68*	35.40*	0.02	−0.26
Rhyme Production Errors	2.93	1.06	1.33	0.43	9.62*	15.03*	1.83	−0.60
Rhyme Production Time	1117	1050	953	937	5.92*	0.51	0.20	1.39
Oddity Errors	6.71	4.61	4.89	3.71	4.49*	6.51*	0.52	−0.33
Oddity Time	693	584	563	482	3.67	2.50	0.05	0.27
Letter-Naming Time	581	576	518	497	25.96*	0.81	0.32	3.16*
Picture-Naming Time	829	756	771	702	3.70	5.97*	0.01	−0.39
Pseudoword-Naming Time	984	956	870	696	13.81*	4.03*	2.13	1.12
Pseudoword-Naming Errors	3.43	1.44	2.11	0.64	3.67	9.75*	0.22	−0.88
Pseudoword *z*-Score	0.64	0.12	−0.11	−1.14	13.42*	8.09*	0.87	0.55
Word Naming—Related Contexts	672	508	494	463	30.54*	23.15*	10.63*	0.59
Word Naming—Neutral Contexts	763	642	624	549	28.55*	20.08*	1.13	0.70
Contextual Facilitation	92	134	130	86	0.11	0.01	8.14*	0.26

[a]PPVT = Peabody Picture Vocabulary Test; *$p < .05$.

literature and one with some interesting theoretical implications: namely, a longitudinal comparison of groups of children who, 2 years earlier, had been CL matched.

The Metropolitan Reading Survey Test was again the criterion reading measure. The tasks that were carried over into the follow-up study were the Peabody, letter naming, rhyming, pseudoword naming, word recognition, and contextual facilitation. The oddity task and picture naming were eliminated. Replacing them were several new tasks and variables dictated by developments in reading research and theory. Motivated by Cohen's work (e.g., Cohen, 1982; Cohen & Netley, 1981; Cohen, Netley, & Clarke, 1984) showing differential linkages between various types of memory tasks and reading ability, we adapted two memory tasks—one relatively nonstrategic and the other intended to be strategy loaded—for use in a multivariate battery like this one. The nonstrategic task was an adaptation of the running serial memory task investigated by Cohen and Netley (1981). The speed and unpredictability of the end of the stimulus sequence serve to preclude the use of memory strategies in the task. The strategic memory task was an adaptation of Brown's (1972) "keeping track" task, judged to be relatively strategy loaded.

In this investigation the words named under neutral contextual conditions were subdivided in order to allow us to examine another variable. Half of the stimuli were regular words having common spelling-to-sound correspondences and half were exception words having uncommon spelling-to-sound correspondences (stimuli were chosen from those used in the investigation of Treiman & Hirsh-Pasek, 1985). Some recent studies (e.g., Backman, Bruck, Hebert, & Seidenberg, 1984; Manis, 1985; Morrison, 1984, 1987; Waters, Seidenberg, & Bruck, 1984) have indicated that more skilled readers may display smaller spelling-to-sound regularity effects, presumably because of greater reliance on visual/orthographic mechanisms to mediate lexical access. Several theorists have viewed regularity effects as a window on the mechanisms operating in the word recognition module. Thus, regularity effects are the type of indicator one wants when comparing children of different ages who have arrived at similar levels of reading ability.

A final new measure was an articulation speed task adapted from the work of Hulme, Thomson, Muir, and

TABLE 3
Means of Variables for Skilled and Less Skilled Readers in Each Grade

	Third Grade			Fifth Grade			Seventh Grade		
Variable	Skilled	Less Skilled	*t*(38)	Skilled	Less Skilled	*t*(40)	Skilled	Less Skilled	*t*(42)
Metropolitan raw score	45.4	23.8	10.31**	48.2	28.1	11.55**	52.0	32.1	10.46**
Metropolitan grade equivalent	4.35	2.37	5.64**	8.00	4.02	9.07**	9.73	4.60	8.42**
PPVT[a]	73.4	69.8	1.45	83.4	73.9	3.25**	91.7	76.5	4.67**
Strategic memory task	14.1	12.5	1.86	15.0	14.1	1.21	16.0	14.8	1.71
Nonstrategic memory task (items)	27.3	23.4	2.23*	28.6	26.8	1.18	30.0	28.9	.78
Nonstrategic memory task (order)	21.3	15.2	2.66*	20.4	18.4	1.11	23.0	20.3	1.37
Letter-naming time	533	575	1.81	505	500	.26	461	474	1.04
Regular word-naming time	666	892	3.00**	633	648	.45	557	678	2.68*
Regular word-naming errors	1.30	2.60	3.19**	.76	1.81	3.53**	1.05	1.64	2.06*
Exception word-naming time	706	1006	4.27**	648	679	.99	588	743	3.12**
Exception word-naming errors	2.20	4.15	3.97**	1.05	2.00	3.13**	1.32	2.00	1.88
Mean neutral word-naming time	686	949	3.73**	641	663	.80	573	711	3.12**
Mean neutral word-naming errors	1.75	3.38	4.10**	.90	1.90	3.94**	1.18	1.82	2.40*
Neutral word *z*-score	−.061	1.260	4.42**	−.514	−.056	3.77**	−.577	.030	3.62**
Regularity effect (times)	40	114	2.04*	15	31	.58	32	65	.96
Regularity effect (errors)	.90	1.55	1.51	.29	.19	.30	.27	.36	.24
Regularity *z*-score	.084	.671	2.49*	−.269	−.232	.21	−.197	−.011	.86
Related word-naming time	518	675	2.89**	482	485	.16	422	495	3.77**
Related word-naming errors	.35	1.50	2.81**	.05	.48	3.07**	.14	.14	.00
Contextual facilitation	168	274	2.19*	159	178	.80	151	216	1.95
Pseudoword-naming time	828	1304	4.24**	807	854	.69	652	952	4.11**
Pseudoword-naming errors	2.75	7.25	5.55**	1.86	2.71	1.34	1.14	3.95	3.83**
Pseudoword *z*-score	−.181	1.267	5.84**	−.358	−.147	1.31	−.707	.202	4.48**
Rhyming reaction time	1098	1127	.38	924	1058	1.74	1056	1081	.36
Rhyming errors	4.05	4.80	1.06	2.57	4.19	2.42*	2.68	4.14	2.42*
Rhyming *z*-score	.157	.348	.82	−.527	.107	2.44*	−.232	.142	1.60
Articulation time	9290	9447	.37	8334	8577	.73	7604	7298	1.34

*Difference between skilled and less skilled readers significant at the .05 level (two-tailed test).
**Difference between skilled and less skilled readers significant at the .01 level (two-tailed test).
[a]PPVT = Peabody Picture Vocabulary Test.

Lawrence (1984). These investigators have linked articulation speed to memory span, and Manis (1985) has observed a difference of 50 msec in production latency (the time to initiate the pronunciation of a known word) between disabled and nondisabled readers. Theoretically, the recent emphasis on the critical importance of the operation of the phonological module in the development of individual differences in reading (Liberman & Shankweiler, 1985; Mann, 1986; Stanovich, 1986b) also motivates an interest in articulation speed. While no theorist believes that the critical differences are actually located at the articulatory level, it could be that articulation speed taps into the module in a way that would make it act as a marker variable for phonological problems at deeper levels (see also Catts, 1986).

Table 3 contains a listing of all the variables that were analyzed, along with the means for each of six groups defined by the factorial combination of grade and skill level based on a median split within each grade. Clearly, the comparisons of skill within each grade resulted in many significant differences. Perhaps a more comprehensible presentation of the results is contained in Tables 4 and 5, which display correlation matrices for a selected set of the variables. In order to reduce the size of these matrices, composite *z*-score variables were used for the rhyming task, pseudoword naming, regularity effect, and word naming in neutral context. Focusing again on the predictors of performance on the Metropolitan, we see that for the third-grade children (above the diagonal in Table 4), the strongest relationships were with pseudoword and word naming and to a lesser extent with the Peabody. For the fifth-grade children (below the diagonal, column one), the best predictors were word naming and the Peabody. For the seventh graders (Table 5), the Peabody was the best predictor, followed by pseudoword and word naming.

More important are the results displayed in Table 6, which are the

TABLE 4
Intercorrelations of Variables for Third- and Fifth-Grade Children

Variable	1	2	3	4	5	6	7	8	9	10	11
1. Metropolitan		.50	.29	.29	−.13	−.34	−.21	−.69	−.38	−.37	−.72
2. PPVT[a]	.51		.22	.05	−.44	−.25	−.01	−.24	−.15	−.01	−.28
3. Strategic Memory Task	.15	.19		.28	−.13	−.30	−.15	−.12	−.20	−.15	−.15
4. Nonstrategic Memory Task (correct order)	.25	.26	.05		−.05	−.23	−.25	−.03	−.08	.01	−.27
5. Articulation Time	−.03	.04	.05	−.23		.46	−.08	.00	−.08	.24	.20
6. Letter-Naming Time	.02	.06	.08	.02	.54		.44	.36	.28	.30	.49
7. Rhyming *z*-Score	−.32	−.03	−.17	−.16	.37	.17		.42	.21	.22	.41
8. Neutral Word *z*-Score	−.56	−.18	−.01	−.22	.19	.03	.39		.26	.56	.69
9. Regularity *z*-Score	−.03	−.15	−.03	.03	−.17	−.06	−.02	−.06		−.01	.35
10. Contextual Facilitation	−.19	−.08	.00	−.17	.07	.08	−.12	.42	−.09		.35
11. Pseudoword *z*-Score	−.22	−.13	.00	−.13	.04	.07	.14	.36	−.10	.46	

Correlations for the third-grade children are above the diagonal, and correlations for the fifth-grade children are below the diagonal. Correlations above .31 are significant at the .05 level (two-tailed).
[a]PPVT = Peabody Picture Vocabulary Test.

TABLE 5
Intercorrelations of Variables for Seventh-Grade Children

Variable	1	2	3	4	5	6	7	8	9	10	11
1. Metropolitan		.70	.31	.31	.05	−.36	−.34	−.59	−.20	−.37	−.62
2. PPVT[a]			.30	.18	−.05	−.18	−.19	−.43	−.06	−.22	−.55
3. Strategic Memory Task				.23	.04	−.10	−.12	−.29	−.17	−.23	−.42
4. Nonstrategic Memory Task (correct order)					.02	−.19	−.30	−.43	−.10	−.43	−.47
5. Articulation Time						.50	.06	−.09	−.04	.13	−.02
6. Letter-Naming Time							.05	.43	.05	.44	.36
7. Rhyming *z*-Score								.27	.08	.25	.25
8. Neutral Word *z*-Score									.31	.70	.77
9. Regularity *z*-Score										.08	.15
10. Contextual Facilitation											.76
11. Pseudoword *z*-Score											

Correlations above .29 are significant at the .05 level (two-tailed).
[a]PPVT = Peabody Picture Vocabulary Test.

TABLE 6
Means for Groups Matched on Reading Ability

Variable	Third Grade	Fifth Grade	Seventh Grade	$F(2,61)$
Metropolitan grade equivalent	4.35	4.32	4.37	.01
PPVT[a]	73.4	74.4	76.7	.97
Strategic memory task	14.1	14.3	14.6	.24
Nonstrategic memory task (items)	27.3	26.8	28.5	.57
Nonstrategic memory task (order)	21.3	18.2	19.6	1.35
Letter-naming time	533	503	477	4.37*
Regular word-naming time	666	652	695	.50
Regular word-naming errors	1.30	1.64	1.58	.60
Exception word-naming time	706	678	752	1.23
Exception word-naming errors	2.20	1.88	2.05	.42
Mean neutral word-naming time	686	665	723	.98
Mean neutral word-naming errors	1.75	1.76	1.82	.03
Neutral word *z*-score	−.061	−.109	.061	.58
Regularity effect (times)	42	25	57	.45
Regularity effect (errors)	.90	.24	.47	1.93
Regularity *z*-score	.084	−.239	−.005	1.51
Related word-naming time	518	487	498	1.15
Related word-naming errors	.35	.40	.16	1.36
Contextual facilitation	168	178	226	1.56
Pseudoword-naming time	828	841	937	.89
Pseudoword-naming errors	2.75	2.48	4.05	2.07
Pseudoword *z*-score	−.181	−.205	.196	2.06
Rhyming reaction time	1098	999	1094	1.12
Rhyming errors	4.05	3.88	4.47	.47
Rhyming *z*-score	.157	−.082	.243	.91
Articulation time	9290	8471	7298	17.76**

[a]PPVT = Peabody Picture Vocabulary Test.
$^{*}p < .05$; $^{**}p < .001$.

means for the three CL-matched groups. It should be noted that because the fifth- and seventh-grade children took the same test, the match for these two groups was particularly good since they could be equated on actual raw scores. The third-grade children, who completed the Elementary rather than the Intermediate form of the test, were matched on grade equivalents and thus their match is psychometrically less secure. The resulting three groups represented a seventh-grade group considerably below average for their age, a fifth-grade group that is below average, and a third-grade group of above-average ability.

Table 6 indicates that only two of the variables differed significantly across the three CL-matched groups. Letter naming was significantly faster for older children. This variable, however, was unrelated to reading ability (see Table 3). Thus, this study replicated the finding in our previous study and in the work of other investigators (e.g., Jackson & Biemiller, 1985) that letter-naming speed tracks chronological age more strongly than reading ability. The other variable to show a significant difference—articulation time—displayed a pattern similar to letter-naming time, although in even stronger form. As is clear from Tables 3 through 5, articulation time appears to be completely unrelated to reading ability. However, it is strongly related to chronological age. Overall, then, with the exception of two variables that are relatively unrelated to reading ability, the performance profiles of these three groups of children displayed remarkable similarity. They had similar vocabularies, strategic and nonstrategic memory abilities, and rhyming ability. Their word recognition processes were very similar, as indicated by their context effects, regularity effects, and pseudoword naming ability.

There are several reasons why this uniformity of performance among the three CL-matched groups is striking. First, it is noteworthy in light of the varied set of tasks employed. Most previous RL-match investigations have used a much more restricted battery of tasks. In addition, when such a large number of statistical tests are run on a set of variables, some spurious significant differences could well appear. Also, one might worry if nonsignificant statistical results were observed in the presence of large absolute differences between the means, which might indicate that large variability and/or small sample sizes were rendering real differences nondetectable. However, this was clearly not the case, as in most instances the mean performance levels of the three groups were quite close (the possible exception being pseudoword naming). Finally, the analyses on the median splits (see Table 3) indicate that the design and measurement techniques were powerful enough to detect differences.

THE LONGITUDINAL COMPARISON

As mentioned previously, subgroups of the fifth- and seventh-grade children tested in 1986 had been tested 2 years earlier (in 1984), as third and fifth graders, respectively. Individual differences in reading achievement were quite stable. Correlations between Metropolitan raw scores in 1984 and 1986 were .93 and .78 for the fifth- and seventh-grade children, respectively. Table 7 presents the correlations between the 1986 Metropolitan scores and the variables assessed 2 years earlier. In general, the variables that predicted 1986 achievement were the same variables that had predicted concurrent achievement in 1984.

More interesting is the longitudinal comparison involving the previously CL-matched groups. What does the performance of these two groups—which 2 years earlier had been as displayed in Table 2—look like 2 years later? Are they still a CL match? The performance of these two groups—matched on reading comprehension performance in 1984—is compared on the variables administered 2 years later in Table 8. Interestingly, the two groups are now no longer matched on reading comprehension ability. The raw scores on the Metropolitan Reading Survey are significantly different. In terms of grade equivalents, the skilled younger readers showed a gain of 2.8 years during the 2-year period compared with 1.5 for the older less skilled readers. The results from the other variables do not indicate a large number of differences. However, there were significant tendencies for the younger readers to be superior in word-naming accuracy in neutral contexts and in rhyme performance. The older children were significantly faster in the articulation task, a finding anticipated by the previous results indicating that this task is strongly linked to chronological age.

TABLE 7
Correlations Between Reading Ability and Tasks Administered Two Years Earlier

Variable	Fifth-Grade Children	Seventh-Grade Children
PPVT[a]	.74	.58
Rhyming errors	−.47	−.42
Rhyming time	−.15	−.26
Phonological oddity errors	−.53	−.49
Phonological oddity time	−.15	−.21
Letter-naming time	−.04	−.31
Picture-naming time	−.30	−.38
Pseudoword-naming time	−.12	−.61
Pseudoword-naming errors	−.23	−.59
Pseudoword *z*-score	−.24	−.65
Related word-naming time	−.53	−.34
Neutral word-naming time	−.38	−.51
Contextual facilitation	.44	−.37

Correlations above .40 and .38 are significant at the.05 level (two-tailed) for the fifth- and seventh-grade children, respectively.
[a]PPVT = Peabody Picture Vocabulary Test.

TABLE 8
Performance of Groups Matched on Reading Ability in 1984 on the Tasks Administered in 1986

Variable	Skilled Fifth-Grade Children	Less Skilled Seventh-Grade Children	*t*(26)
Metropolitan raw score	48.1	39.5	2.38*
Metropolitan grade equivalent	7.94	6.59	1.38
PPVT[a]	85.7	84.4	.36
Strategic memory task	15.1	15.6	.91
Nonstrategic memory task (items)	29.6	29.4	.13
Nonstrategic memory task (order)	21.9	20.3	.81
Letter-naming time	489	470	.99
Regular word-naming time	604	623	.41
Regular word-naming errors	.36	1.43	5.61**
Exception word-naming time	625	640	.34
Exception word-naming errors	.93	2.14	3.61**
Mean neutral word-naming time	614	632	.38**
Mean neutral word-naming errors	.64	1.79	5.43**
Neutral word *z*-score	−.687	−.184	3.74**
Regularity effect (times)	21	17	.20
Regularity effect (errors)	.57	.71	.41
Regularity *z*-score	−.133	−.096	.23
Related word-naming time	469	448	.73
Related word-naming errors	.07	.21	1.06
Contextual facilitation	145	184	.98
Pseudoword-naming time	789	746	.53
Pseudoword-naming errors	2.00	2.36	.33
Pseudoword *z*-score	−.362	−.367	.02
Rhyming reaction time	984	1140	1.93
Rhyming errors	2.36	3.50	1.76
Rhyming *z*-score	−.453	.121	2.18*
Articulation time	8131	7266	2.34*

[a]PPVT = Peabody Picture Vocabulary Test.
$^{*}p < .05$; $^{**}p < .01$.

Most versions of the developmental lag hypothesis posit that there are acquisition rate differences between readers of differing skill: that skilled and less skilled readers go through the same sequence of stages but at different rates. The hypothesis of rate differences clearly predicts that the younger skilled readers should show more growth in reading in a fixed amount of time than the older less skilled readers. Most of the previous and conflicting research on this issue (e.g., Baker, Decker, & DeFries, 1984; Bruck, 1988; Trites & Fiedorowicz, 1976) has compared groups of similar chronological age but differing initial reading levels. Thus, the hypothesis must be assessed by evaluating a group by time interaction that is vulnerable to many artifacts. Perhaps a longitudinal CL match design provides a less artifact-ridden method of assessing whether there are differential growth rates. Our results appear to reveal the predicted differential reading growth rates.

In summary, the results from the three-group CL match longitudinal design converged with our earlier results. Both sets of results confirmed the hypothesis (Stanovich et al., 1986) that the performance of unlabeled poor readers—those children who read poorly but do not necessarily fit the psychometric criteria for the label *dyslexia*—would show a broad-based developmental lag. It is hypothesized that this pattern will contrast with the results from studies where the reading-level match involves reading disabled children defined by strict psychometric criteria.

A RESEARCH SYNTHESIS

In the following discussion I will try to amalgamate a number of findings and theoretical ideas into a coherent global model for understanding reading problems of both the garden-variety and dyslexic type. Although the "grain" of the model will be rather coarse, I would argue that we are better off with even a gross summary if it can help us to escape from the interminable definitional and semantic disputes that plague the LD field—and I think that my model does do this. My summary model builds on the basic result regarding garden-variety readers that I feel my work has established. It supplements this empirical finding with some of the logical, statistical, and psychometric arguments that began my paper. Not the least important, however, is my reliance on the previous theoretical arguments and empirical results established by other investigators.

Here is what I think has been roughly established. First, Andrew Ellis (1985) is right that the proper analogy for dyslexia is not measles, but instead a condition like obesity. There is considerable evidence from a variety of different sources (Jorm, 1983; Olson et al., 1985; Scarborough, 1984; Seidenberg et al., 1985; Share, McGee, McKenzie, Williams, & Silva, 1987; Silva et al., 1985) that we are not dealing with a discrete entity but with a graded continuum. Several years ago, Rutter and Yule (1975) led researchers down a blind alley by reporting that there was a somewhat discontinuous "hump" near the bottom of the reading distribution, and this hump suggested a discrete pathology model to many investigators. However, there is now much converging evidence that indicates that the hump was a statistical artifact, perhaps involving ceiling effects on the tests (Rodgers, 1983; Share et al., 1987; Silva et al., 1985; Van der Wissel & Zegers, 1985). There is in fact no hump in the distribution.

However, the fact that the distribution is a graded continuum does not render the concept of dyslexia scientifically useless, as many critics would like to argue. This is why obesity is such a good example—no one doubts that it is a real health problem, despite the fact that it is operationally defined in a somewhat arbitrary way by choosing a criterion in a continuous distribution:

> For people of any given age and height there will be an uninterrupted continuum from painfully thin to inordinately fat. It is entirely arbitrary where we draw the line between "normal" and "obese," but that does not prevent obesity being a real and worrying condition, nor does it prevent research into the causes and cures of obesity being both valuable and necessary. (Ellis, 1985, p. 172)

It follows that, "To ask how prevalent dyslexia is in the general population will be as meaningful, and as meaningless, as asking how prevalent obesity is. The answer will depend entirely upon where the line is drawn" (p. 172).

Likewise, I think that it is also important to conceive of *all* of the relevant distributions of reading-related cognitive skills as being continuously arrayed in a multidimensional space and not distributed in clusters. In short, I accept the model of heterogeneity without cluster-

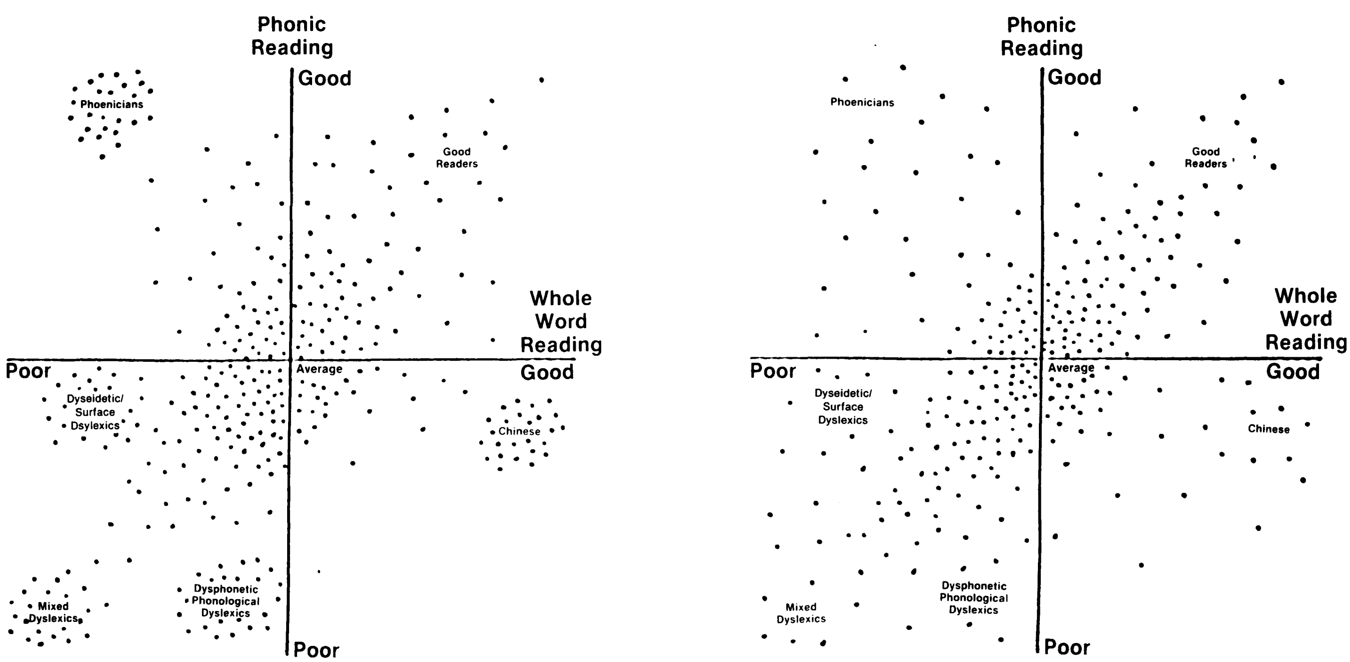

Figure 1. On the left side of the figure, hypothetical distribution on whole-word (direct-visual) reading skill and phonic (assembled, sublexical) reading skill of a sample of readers age 15 years or over with IQ = 100+, on a categorical model. On the right side of the figure, hypothetical distribution of the same sample of readers but on a dimensional model. Note: From "The Cognitive Neuropsychology of Developmental (and Acquired) Dyslexia: A Critical Survey," 1985, *Cognitive Psychology, 2*(2), pp. 192, 193. Copyright 1985 by Lawrence Erlbaum Associates. Reprinted by permission.

ing that has been discussed by Ellis (1985), Olson et al. (1985), Satz, Morris, and Fletcher (1985), and others. I further posit that the existence of heterogeneity without clustering is precisely the empirical fact that has obscured and stymied the search for discrete subtypes among dyslexic children. Ellis (1985) illustrates the idea with a figure that I think is instructive (see Figure 1). It doesn't tell us anything new, but it does shift our thinking into a quantitative mode, which often helps to clarify precisely the things that the verbal debate obscures because of the inherent connotations of discreteness carried by many natural language terms.

The categorical model implicit in many discussions of dyslexic subtypes is illustrated on the left. This is the model that motivated the earlier, more naive attempts at finding a dyslexia typology. The two dimensions (note that all of the same arguments would apply in a space of higher dimension) represent ability at accessing the lexicon on a visual/orthographic basis (termed "whole word reading" on Ellis's X-axis) and phonological recoding ability (termed "phonic reading" on Ellis's Y-axis). The categorical model assumes that there are "galaxies" of dyslexics—and of nondyslexic readers as well. If this model were true, the subtyping literature would not have remained so confused for so long. Nevertheless, it is worthwhile to consider the figure further. In it, we can identify the dysphonetic and dyseidetic dyslexic typology popularized by Bodor (1973) and somewhat recapitulated in the distinction between phonological and surface dyslexia in the literature on acquired dyslexia. These two groups are defined by severe deficits on one of the dimensions and normal ability on the other. Since both abilities are necessary for fluent reading, the result of both of these patterns is a disabled reader. In the lower left are the unfortunate individuals handicapped by deficits in both word recognition mechanisms. The other two clusters are two subtypes of fluent readers, the so-called Chinese and Phoenecians—extremely facile at one type of lexical access mechanism, but with normal skill on the other (see Baron & Strawson, 1976; Treiman & Baron, 1984).

The right side of Figure 1 portrays what Ellis calls the "dimensional model." The poor readers in the lower left quadrant are a heterogeneous lot, but they do not form clusters. Like Ellis and several other investigators (e.g., Olson et al., 1985), I believe that if we really want to have a useful concept of dyslexia, this is the model we must always keep in mind. Again, like in the obesity example, we may decide to arbitrarily cut the variability in the lower left and for various purposes treat the subgroups in a discrete fashion—but this again would be an arbitrarily imposed partitioning. Clearly, this state of affairs creates statistical problems for cluster analyses, but it is important to understand—via a logic similar to that in the obesity example—that such problems do not undermine the idea of forming abstract subtypes for certain theoretical or practical purposes:

> What the dimensional model predicts, however, is that there will be a complete and unbroken gradation of intermediate dyslexics linking such extreme cases. A dimensional model does not deny heterogeneity, only homogeneity of subtypes (cf. Olson, Kliegl, Davidson, & Foltz, 1985). It does not preclude the study of selected individuals to highlight dimensions of difference, nor does it prevent one from drawing conclusions about reading processes in general from the observed individual differences. It may, however, undermine an attempt to impose syndromes upon the dyslexic population. That is, the dimensional approach primarily creates problems for a syndrome-based version of preformism; other versions may be less affected by the denial of homogeneous subgroups. (Ellis, 1985, pp. 192-193)

Finally, it is important to notice that there is a great degree of heterogeneity within the normal sample as well (simply draw a line connecting the Phoenecians to the Chinese). This figure illustrates graphically why Bryant and Impey (1986) were able to find RL-matched younger children who showed the same extreme patterns as some of the well-known case studies of phonological and surface dyslexia. One can see, for example, how some Phonecians who are adequate readers will display performance patterns as extreme as surface dyslexics on some tasks.

I would, however, modify Ellis's figure in one extremely important way. His scatter plot displays dysphonetics as roughly equal in frequency to dyseidetics. There is now voluminous data—some in Bodor's (1973) classic paper itself—indicating that the dysphonetic pattern is far more common than the dyseidetic (Gough & Hillinger, 1980; Liberman, 1982; Liberman & Shankweiler, 1985; Pennington, 1986; Perfetti, 1985; Stanovich, 1986b, 1988; Vellutino, 1979). This fact meshes nicely with an interesting finding of Bryant and Impey (1986). There was only one performance pattern that they could not recapitulate with an RL-matched younger child: the extremely poor nonword reading of a phonological dyslexic (see Snowling et al., 1986). A greater bunching of phonological dyslexics at the bottom of the figure would make it more likely that certain outliers in this group would not find matches on phonological skills with nondyslexic readers in the lower right quadrant.

THE PHONOLOGICAL-CORE VARIABLE-DIFFERENCE MODEL

The concepts inherent in the dimensional model outlined above can be generalized to account for contrasts between the dyslexic and the garden-variety poor reader. The bivariate distribution of reading and IQ is continuous, as is the univariate distribution of reading ability. What this means is that there is a continuous gradation between these two types of poor reader, defined by where they are on the bivariate relation of IQ and reading. That is, conditionalized at a given level of reading ability (low, in the case of the poor reader), the distribution of IQ is continuous, with an "unbroken gradation of intermediate cases" between the "pure" dyslexic (with relatively high IQ for that level of reading) and the "pure" garden-variety (with a lower and more typical IQ). This means that to whatever extent the processing patterns of these two groups are dissimilar, that dissimilarity will be attenuated the closer we get to the "fuzzy" and arbitrary boundary between them. Or, to put it more concretely, studies employing dyslexics with somewhat depressed IQs and garden-variety poor readers with somewhat elevated IQs may be unable to detect whatever critical processing differences there are between the two groups.

And I do believe that such processing differences exist. They can be described within what I will term the phonological-core variable-difference model; actually, perhaps more of a framework than a model. The model rests on a clear understanding of the assumption of specificity in definitions of dyslexia (see Hall & Humphreys, 1982; Stanovich, 1986a, 1986b). This assumption underlies all discussions of the concept of dyslexia, even if it is not explicitly stated. It is the idea that a child with this type of learning disability has a brain/cognitive deficit that is reasonably specific to the reading task. That is, the concept of dyslexia requires that the deficits displayed by such children not extend too far into other domains of cognitive functioning. If they did, this would depress the constellation of abilities we call intelligence, reduce the reading/intelligence discrepancy, and the child would no longer be dyslexic! Indeed, he or she would have become a garden variety!

In short, the key deficit in dyslexia must be a vertical faculty rather than a horizontal faculty (see Fodor, 1983); that is, a domain-specific process (Cossu & Marshall, 1986) rather than a process that operates across a wide variety of domains. For this and other reasons, many investigators have located the proximal locus of dyslexia at the word recognition level (e.g., Gough & Tunmer, 1986; Morrison, 1984, 1987; Perfetti, 1985; Siegel, 1985; Vellutino, 1979) and have been searching for the locus of the flaw in the word recognition module. Research in the last 10 years has focused intensively on phonological processing abilities. It is now well established that dyslexic children display deficits in various aspects of phonological processing. They have difficulty making explicit reports about sound segments at the phoneme level, they display naming difficulties, they utilize phonological codes in short-term memory inefficiently, and they may have other-than-normal categorical perception of certain phonemes (see Liberman & Shankweiler, 1985; Mann, 1986; Pennington, 1986; Wagner & Torgesen, 1987; Williams, 1984). Importantly, there is increasing evidence that the linkage from phonological processing ability to reading skill is a causal one (Bradley & Bryant, 1985; Liberman & Shankweiler, 1985; Maclean, Bradley, & Bryant, 1987; Stanovich, 1986b, 1988; Wagner & Torgesen, 1987). Presumably, their lack of phonological sensitivity makes the learning of grapheme-to-phoneme correspondences very difficult.

The model of individual differences I will present thus posits this core of phonological deficits as the basis of the dyslexic performance pattern. This is an oversimplification, since it ignores—at least temporarily—the existence of those (admittedly many fewer) cases in the upper left corner of the poor reader quadrant in Figure 1: the dyseidetics, or surface dyslexics. I believe that there is growing evidence for the utility of distinguishing a group of dyslexics who have severe problems in accessing the lexicon on a visual/orthographic basis (see Stanovich, 1988). But a crucial caveat is in order. I believe that the problem encountered by these children is not similar to the "visual perception" problems popular in the early history of the study of dyslexia, but now thoroughly debunked (Aman & Singh, 1983; Kavale & Mattson, 1983; Vellutino, 1979). In addition to the empirical evidence refuting this old view, the arguments presented here add to the negative convergence. The older conceptualizations of visual deficits had the additional flaw that the purported problematic processes were too global and not modular enough. The actual problems in orthographic processing must be much more subtle and localized. I am not prepared to say anything more specific about this issue, except that I would speculate that the problem involves the automatic and nonintentional induction of orthographic patterns (and thus would not be discernible under most intentional learning situations, for example, most standard paired-associate learning paradigms). However, the smaller group of dyslexics with orthographic-core deficits would mirror the phonological-core group in all of the other processing characteristics of the model. What are those characteristics?

One important factor mentioned earlier was that of compensatory processing. CL-matched younger children should display superior word recognition skill and phonological abilities, whereas the older dyslexics should display superior vocabulary, memory, and real-world knowledge—the latter skills and knowledge presumably balancing the inferior word recognition skills to yield the equivalent reading comprehension performance (see Bruck, 1988). A similar tradeoff should characterize comparisons of dyslexics and garden-variety poor readers matched on comprehension: poorer word recognition but superior "horizontal faculties" on the part of the dyslexics. There is some evidence supportive of this trend (Bloom et al., 1980; Fredman & Stevenson, 1988; Seidenberg et al., 1985).

A DL match should yield complementary results. The older dyslexics, matched at the word recognition level, should display superior reading comprehension. Similarly, dyslexics matched with garden-variety chronological age (CA) controls on decoding skill should display superior reading comprehension and horizontal faculties (see Bloom et al., 1980; Ellis & Large, 1987; Jorm et al., 1986; Silva et al., 1985).

For the majority of dyslexics with a phonological-core deficit, a DL match with a younger group of nondyslexic controls should reveal another pattern of ability tradeoffs: deficits in phonological sensitivity and in the phonological mechanisms that mediate lexical access—but superior visual/orthographic mechanisms and orthographic knowledge (an opposite but analogous pattern should obtain for those with an orthographic-core deficit). Several investigations have shown this predicted pattern (Baddeley et al., 1982; Baron & Treiman, 1980; Bradley & Bryant, 1978; Kochnower et al., 1983; Olson et al., 1985; Snowling, 1980, 1981). A similar pattern should hold when dyslexics are compared to a CA garden-variety group. These, then, are the patterns of relationships that can be derived from the phonological-core deficit of the dyslexic reader and the psychometric constraints inherent in the operational definition of dyslexia. (Note that Olson et al., 1985, have used similar ideas of compensatory processing to explain the variability *within* a dyslexic sample.)

In the phonological-core variable-difference model, the term variable differences is used to contrast the performance of the garden-variety and the dyslexic reader. As outlined above, the cognitive status of garden-variety poor readers is well described by a developmental lag model. Cognitively, they are remarkably similar to younger children reading at the same level. A logical corollary of this pattern is that the garden-variety reader will have a wide variety of cognitive deficits when compared to CA controls who are reading at normal levels.

However, it is important to understand that the garden-variety poor reader does share the phonological problems of the dyslexic reader—though perhaps in less severe form—and the deficits appear also to be a causal factor in the poor reading of these children (Perfetti, 1985; Stanovich, 1986b). But for them the deficits—relative to CA controls—extend into a variety of domains (see Ellis & Large, 1987), and some of these (e.g., vocabulary, language comprehension) may also be causally linked to reading comprehension. Such a pattern does not characterize the dyslexic, who has a deficit localized in the phonological core. This core deficit is actually more severe (they show deficits in DL matches) than that of the garden-variety reader—whose performance matches younger DL controls—but it is not accompanied by other cognitive limitations.

One straightforward prediction that we then might derive is that the dyslexic's decoding problem will be more difficult to remediate. Interestingly, however, if the decoding problem can be remediated, then the contingent prognosis for dyslexic children should be better—they have no additional cognitive problems that may inhibit reading comprehension growth. This prediction fits nicely with Gough and Tunmer's (1986) "simple view" of reading comprehension (R) as a multiplicative combination of decoding skill (D) and listening comprehension ability (C); in short, $R = D \times C$. If dyslexics and garden-variety poor readers are matched on reading comprehension (for example, $.4 \times .9 = .6 \times .6$) and if (in some benign world) we were to totally remediate the decoding deficits of each, then the dyslexics would have superior reading comprehension ($1.0 \times .9 > 1.0 \times .6$).

The framework of the phonological-core variable-difference model fits nicely with Ellis's dimensional model described earlier. Consider the following characterization: As we move in the multidimensional space—through the "unbroken gradation of intermediate cases"—from the dyslexic to the garden-variety poor reader, we will move from a processing deficit localized in the phonological core to the global deficits of the developmentally lagging garden-variety poor reader. Thus, the actual cognitive differences that are displayed will be variable depending upon the type of poor reader who is the focus of the investigation. The differences on one end of the continuum will consist of deficits located only in the phonological core (the dyslexic) and will increase in number as we run through the intermediate cases that are less and less likely to pass strict psychometric criteria for dyslexia. Eventually we will reach the part of the multidimensional space containing relatively "pure" garden-variety poor readers who clearly will not qualify for the label dyslexic (by either regression or exclusionary criteria), will have a host of cognitive deficits, and will have the cognitively immature profile of a developmentally lagging individual. As we travel in this direction through the space the phonological core deficit will attenuate somewhat. That is, the phonological problem will attenuate in severity as the number of other deficits spreads. One would need an impressive multidimensional graphic to illustrate this more concretely, but I hope that the previous consideration of Ellis's figure has primed our imaginations.

I believe that this phonological-core variable-deficit (PCVD) conceptualization provides a useful global framework within which to consider the plethora of controversial issues in the area of reading disabilities—issues of definition, subtypes, prevalence, etiology, process analysis, educational policy, remediation, and prognosis. For example, the framework provides an explanation for why almost all processing investigations of reading disability have uncovered phonological deficits, but also why some investigations have found deficits in *other* areas as well. This outcome is predictable from the fact that the PCVD model posits that *all* poor readers have a phonological deficit, but that other processing deficits emerge as one drifts in the multidimensional space from "pure" dyslexics toward garden-variety poor readers. Thus, the model's straightforward prediction is that those studies that revealed a more isolated deficit will be those that had more psychometrically select dyslexic readers. In short, the reading/IQ discrepancy of the subject populations should be significantly greater in those studies displaying more specific deficits. Presumably, studies finding deficits extending beyond the phonological domain are in the "fuzzy" area of the multidimensional space and are picking up the increasing number of processing differences that extend beyond the phonological domain as one moves toward the garden-variety area of the space.

This example of how the PCVD model clarifies and explains problematic findings in the LD literature is not a trivial one. I have previously discussed (see Stanovich, 1986a) how the research findings indicating multiple and somewhat global deficits threaten to make nonsense of the very concept of a learning disability. Escaping this paradox is a not inconsiderable problem for the LD field.

Nevertheless, I should not imply that the further necessary elaboration and quantification of the model will be an easy task. Numerous complications threaten to obscure its basically simple structure. I have already mentioned the likely existence of a smaller group of dyslexic readers whose core deficit is in the orthographic processing and lexical knowledge domain. Second, the model will need a stronger developmental component than it now has. The developmental lag characterization of the garden-variety poor reader is a step in the right direction, but the appropriate developmental model for the dyslexic is largely unsketched. Some of the complications that elaboration of the developmental component entails have been discussed in my analysis (see Stanovich, 1986b, 1988) of Matthew effects in reading: The fact that the early acquisition of reading skill results in reading/academic experiences that facilitate the development of other cognitive structures that lay the foundation for successful reading achievement at more advanced levels. In short, there are many rich-get-richer and poor-get-poorer phenomena resulting from the interaction of the cognitive characteristics of children and their academic and home environments. I have previously outlined (see Stanovich, 1986b) how such Matthew effects can lead to a pattern where poor readers display increasingly global cognitive deficits as they get older and how early modular deficits can grow into generalized cognitive, behavioral, and motivational problems. The existence of Matthew effects raises the startling possibility that a young dyslexic might actually develop into a garden-variety poor reader! Thus, these Matthew effects complicate the prediction of the developmental growth curves for reading ability and reading-related cognitive skills, but they simply must be accounted for.

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