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Specific Reading Disability
A View of the Spectrum

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Chapter • 5

Early Identification of Children At Risk for Reading Disabilities
Phonological Awareness and Some Other Promising Predictors

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"The greater becomes the volume of our sphere of knowledge, the greater also becomes its surface of contact with the unknown."

Jules Sageret

Research over the past two decades on the crucial role of phonological awareness in learning to read has greatly expanded "the volume of our sphere of knowledge." There is clear evidence that some degree of insight into the phonological structure of spoken words greatly enables a child to begin to discover the "alphabetic principle" (that printed letters ordinarily stand for phonemic segments of words), and that most children who have difficulty learning to read lack this insight (e.g., Adams and Bruck 1995; Brady and Shankweiler 1991; Liberman et al. 1974). Once the alphabetic principle has begun to be grasped, greater depths of phonological awareness are attained in conjunction with increasing mastery in the decoding of print, reflecting an apparent reciprocal relationship between the two developing abilities (e.g., Ehri and Wilce 1980, 1986; Perfetti et al. 1987). Not surprisingly, therefore, persistent weaknesses in both decoding and phonological awareness are defining characteristics of reading disability in both childhood and adulthood. (See Fowler and Scarborough 1993 for a review.) We also know that training novice readers and low achievers to attend to and manipulate phonemic segments, and to understand their relationship to letters, can facilitate reading acquisition (e.g., Blachman 1991; Torgesen in press). One current approach in circumventing dyslexia is to identify kindergartners who are weak in phonological awareness and provide them with such training.

As we have gained volumes of knowledge about phonological awareness, however, I think that our research efforts have also revealed how much more there is to understand about the etiology of dyslexia and the prediction of reading achievement; that is, the "surface of contact with the unknown" has also been enlarged. Without disagreeing with the insights gained about the role of phonological awareness, I think there is something more to be learned by looking at other findings from the recent literature on the prediction of reading (dis)abilities. That body of work indicates that, aside from phonological awareness, several other equally strong indicators of a young child's risk for developing reading problems exist. This information is potentially useful for improving methods for the early identification and treatment of at-risk children, for raising new questions to be pursued in future research, and for arriving, ultimately, at a comprehensive theoretical explanation of reading disabilities.

PREDICTING FUTURE READING ACHIEVEMENT FROM KINDERGARTNERS' CHARACTERISTICS AND SKILLS

Once a child has received some formal instruction in school and has begun to learn to read, the best predictor of *future* reading attainment is how well the child can already read. As shown in table I, the temporal stability of reading achievement scores is considerable. Children who succeed early on rarely stumble later; and a majority of children who initially have difficulty tend to remain behind their classmates, even though many receive remedial help in reading. Before children are able to read, predicting future achievement is a more challenging problem. At about the time they enter kindergarten, wide differences among children, many of whom have minimal or nonexistent reading skills, exist. Prediction research indicates that some of these differences among kindergartners are more informative than others about future academic success. I will begin by considering several kinds of

demographic and home background variables, and then focus on differences in children's abilities and knowledge in various domains.

Demographic and Home Background Differences

Sex. Historically, many more boys than girls have been identified by schools and clinics as having reading disabilities. This imbalance appears to arise mainly from ascertainment biases on the part of those who make referrals because on objective tests of reading ability, nearly as many girls as boys earn low scores (e.g., Naiden 1976; Shaywitz et al. 1990). Accordingly, a kindergartner's sex has generally been found to be a very weak predictor of future reading achievement in most longitudinal studies (e.g., Badian 1994; Horn and O'Donnell 1984; Mann and Ditunno 1990; Scanlon and Vellutino 1996; Share et al. 1984). In short, the risk for developing a reading disability is only slightly higher for boys than girls.

Age for grade. Because eligibility for school entry is usually based on a chronological age cutoff, there is typically a 12-month age range

Table I. Temporal stability of reading ability differences and of reading disability classifications in studies that have assessed reading with the same test on at least two occasions for the same sample of children. (RD = reading disabled, by research criteria; NRD = not reading disabled.)

Sample	From Grade	To Grade	Time Interval	r	% RD Who Remain RD	% NRD Who Remain NRD
Badian (1988)	3rd	8th	5 years	—		74%
98%						
Butler (1988)	3rd	6th	3 years	.77		
	3rd	8th	5 years	.78		
Butler et al. (1985)	1st	2nd	1 year	.69		
	1st	3rd	2 years	.69		
	1st	6th	5 years	.64		
	2nd	3rd	1 year	.88		
	2nd	6th	4 years	.78		
	3rd	6th	3 years	.86		
Juel (1988)	1st	4th	3 years	—	88%	87%
McGee et al. (1988)	1st	7th	6 years	—		56%
Satz et al. (1981)	2nd	5th	3 years	—	87%	76%
Scarborough (1995)	2nd	8th	6 years	.72	58%	97%
Shaywitz et al. (1992)*	1st	3rd	2 years	.67	47%	97%
	3rd	5th	2 years	.63	47%	92%
Wright et al. (1991)	2nd	7th	5 years	—	67%	91%

*Discrepancy of reading from aptitude, rather than absolute reading level, was examined in this study.

within a given entering class. Concerned that maturational differences could place their children at a disadvantage, parents whose children are the youngest in the class sometimes choose to defer the start of schooling (a practice often termed "red shirting") in the hope that their children will have more successful academic (and social and athletic) careers if they are among the oldest in the class. It appears, however, that with regard to reading attainment, maturational differences tend to be fully sorted out by the end of second grade, by which time age-for-grade is essentially unrelated to achievement scores (e.g., Morrison, Griffith, and Alberts 1997). It is not surprising, therefore, that weak correlations between age-for-grade and achievement have generally been obtained in longitudinal prediction studies (e.g., Badian 1994; Busch 1980; Horn and O'Donnell 1984; Scanlon and Vellutino 1996; Weller, Schnittjer, and Tuter 1992). Younger chronological age relative to classmates does not appear to be an important risk factor.

Socioeconomic and sociocultural differences. Household income and parents' education and occupations are conventional indices of the socioeconomic status (SES) of a family. Low SES is commonly associated with a broad array of environmental circumstances that may be detrimental to the development of young children, from poor prenatal and pediatric health care to the quality of neighborhood schools. Each of these associated conditions, on its own, could potentially place a child at risk for reading difficulties. Teasing them apart is virtually impossible, and this should be borne in mind when considering the evidence of SES as a predictor of reading disabilities.

The relationship between SES and reading achievement is more complex than is generally realized. In particular, the degree of risk associated with the SES of an *individual* child's family is considerably lower than the degree of risk associated with the SES level of a *group* of students attending a particular school. White (1982) reviewed 93 studies in which two pieces of information—the average SES of each school, and the average achievement level of the students attending that school—were obtained for a large sample of schools. He calculated that the average size of the correlation between SES and achievement was .68, which is very substantial. In contrast, in 174 studies that measured achievement scores and SES individually for all children in a large sample, an average correlation of only .23 was obtained. Similarly low estimates have been reported in numerous other studies of SES as an individual risk factor (e.g., Alwin and Thornton 1984; Estrada et al. 1987; Horn and O'Donnell 1984; Richman, Stevenson, and Graham 1982; Rowe 1991; Share et al. 1984; Walberg and Tsai 1985). In other words, *within a* particular school or district, socioeconomic differences among children are only weakly predictive of differing levels of reading achievement.

Home literacy environment. The finding that there are much weaker correlations between SES and achievement when child-to-child variation is analyzed than when school-to-school differences are examined may suggest that the quality of schooling is largely responsible for the low achievement typically shown by students from low SES families and communities; if so, preventing the reading problems of these children would best be addressed by improving their schools. On the other hand, it has been hypothesized that there are real socioeconomic or sociocultural differences that contribute to achievement differences, but that these dimensions of differences are not adequately captured by demographic measures such as income and parental education. Instead, characteristics of the home environment that are directly related to the acquisition of literacy skills and attitudes may be better predictors of an individual child's risk for reading difficulties. Hess and Holloway (1984) emphasized several such family practices: parental reading habits; reading to children by adults; stimulating verbal interactions between adults and children; high parental expectations of achievement by their children; and availability of reading and writing materials.

When these and other aspects of the home literacy environment have been investigated in relation to reading achievement in studies of elementary school children, the estimated strength of the relationship has been quite inconsistent, and weaker in the early grades than in older samples (e.g., Iverson and Walberg 1982; Rowe 1991; Walberg and Tsai 1985; White 1982). Of greater relevance to the focus of this chapter—the early prediction of reading disability—are longitudinal studies that have measured various aspects of preschool or kindergarten children's home experiences (usually as reported by parents) and examined differences in relation to subsequent reading achievement scores in the primary school grades. In such studies, the amount of reading that parents do in the home has been a very weak predictor (e.g., DeBaryshe et al. 1991; Scarborough, Dobrich, and Hager 1991; Thomas 1984), but future reading achievement has been found to correlate reliably with the availability of reading materials in the home (median $r = .27$) and with library experiences (.17) (DeBaryshe 1993; Mason 1980; Mason and Dunning 1986; Share et al. 1984; Wells 1985). The amount and quality of parent-child book reading during the preschool years is the aspect of the home environment that has been studied most often; and two recent meta-analyses of the several dozen studies on this issue both concluded that the average magnitude of this correlation is about .28 or less (Bus, van IJzendoorn, and Pellegrini 1995; Scarborough and Dobrich 1994). Scarborough and Dobrich (1994) also observed that stronger correlations did not appear to be obtained when home literacy practices were looked at in combination, rather than singly, as predictors of reading. Therefore, while indicating that positive relationships exist between several aspects of the preschool home literacy environment and subsequent reading achievement, the findings are not strong enough to be of much practical use for identifying children who are at risk for reading disabilities.[1]

Familial incidence of dyslexia. Reading problems tend to run in families, and great strides have recently been made in teasing apart the genetic and environmental bases for this. (See Smith, this volume.) Several studies have attempted to estimate the degree of risk imposed on a child whose family includes one or two parents (and/or older siblings) with reading disabilities. The percentages of children from such families who turned out to have reading disabilities are listed in table II. Although there is considerable variation in the degree of estimated risk from study to study, this, in part, reflects differences in the criteria used to define reading disability in adults and children. All together, the results indicate that the incidence of reading disability in a child's immediate family clearly puts a child at increased risk for dyslexia. It is also clear, of course, that while many children from such families are likely to have difficulty learning to read, many will not. In order to predict individual outcomes, it is important to know what early characteristics of individual children are the most reliable and informative indicators of risk.

Individual Differences in Knowledge and Skill

As noted earlier, one approach to the prevention of reading problems that is gaining widespread attention is to identify kindergartners who are at greatest risk for unsuccessful reading acquisition and direct intervention efforts toward those children. Clearly, the success of such an approach will depend, in part, on the accuracy with which the risk status of young children can be determined. If the basis for identifying at-risk youngsters is overly inclusive (i.e., if the number of "false positive" prediction errors is high), the costs will be magnified by the

[1] In light of the generally weak correlations between home factors and later achievement found in most studies, it is difficult to interpret the more encouraging results of the one study in which the home environment was evaluated at much younger ages (12 and 24 months). Bradley and Caldwell (1984; Bradley, Caldwell, and Rock 1988) found that in their sample of 37 children, the HOME index was highly correlated with reading in first grade ($r = .56–.65$) but not significantly in fourth grade ($r = .24$).

Table II. Estimates of Parent-to-Child Risk for Dyslexia

Study	Diagnostic Criteria: Parents	Diagnostic Criteria: Children	% of Children Affected
Badian (1988)	self-report	testing	23%
Finucci et al. (1985)	Gow School alumni	parent report	36%
Fowler and Cross (1986)	self-report	testing	33%
Gilger et al. (1991)			
Sample 1	self-report	testing	25–41%
Sample 2	self-report	testing	47–65%
Sample 3	self-report	testing	31–49%
Scarborough (1989)	self-report	school identif'n	42%
	self-report	testing	53%
	testing	school identif'n	43%
	testing	testing	62%

necessity of treating many more children than actually need any intervention. Furthermore, there may be unforseen consequences of labeling a large number of children "at risk" who would have acquired reading successfully without intervention. On the other hand, using an overly restrictive identification algorithm that yields large numbers of "false negative" errors will result in a failure to provide services to many children who need them. Minimizing both kinds of prediction errors, therefore, is an important concern in setting up procedures for identifying children who are at greatest risk for reading difficulties.

A great deal of information about the prediction of primary grade reading scores from earlier assessments has been amassed from longitudinal research during the past two decades.[2] The remainder of this chapter will be largely devoted to presenting a quantitative review of that body of work. In these studies, a sample of children has usually been assessed first during the kindergarten year (i.e., at about age 4.5 to 6 years, although some studies have begun testing during the year prior to kindergarten); and others (particularly from countries in which no reading instruction occurs before first grade) in the early months of the first grade. Most of this research has focused on "unselected" samples, although few of these have been truly population-representative. A few studies have included high-risk samples (e.g., clinic samples of children with early language impairment; children from low SES backgrounds; offspring of dyslexic parents), alone or in conjunction with

[2] Although many early prediction studies were carried out prior to the mid-1970s, the demands of today's primary curricula and the composition of the contemporary student body have changed enough since then that the relevance of the older studies may be reduced; this review is thus based primarily on more recent findings.

"control" groups; it is not yet clear whether particular factors are associated with the same degree of risk for all subgroups of children, although there is no evidence to the contrary. Many kinds of skills, attainments, and background differences have been investigated as prospective predictors of reading, and their correlations with future reading scores have usually been provided by the investigators (although, in a few studies, only classificatory or multivariate results have been reported). Therefore, for each predictor measure, I was able to estimate the average magnitude of its association with reading outcomes by aggregating findings across studies.

The criteria for inclusion in the analyses and the procedures for averaging correlation coefficients were as follows. All studies on the prediction of reading since 1976 that I could locate were included, providing that: (1) the sample size was 30 or larger; (2) at least one risk factor was assessed initially when the children were within ±1 year of beginning formal schooling in reading; and (3) at least one assessment of reading skill was made after one, two, or occasionally, three years of instruction. These criteria were met for 53 samples from 61 studies. If a word recognition outcome measure was obtained, its correlation with predictors was used; otherwise, a composite reading score or, rarely, a reading comprehension measure was accepted instead as the criterion variable. When more than one correlation value per risk factor was available in a given sample of children (because multiple reading assessments were conducted and/or because multiple measures of the predictor were used), the average correlation for the sample was used for aggregation. When correlations were averaged across studies, each research sample contributed only one, independent, observation.

The strengths of many kinds of predictor variables, alone and in combination, will be reviewed below. A summary comparison of the effects for different predictors is provided in table III. In addition, more detailed information about the aggregated data is provided in tables A-1 through A-7 of the Appendix.

Print-specific knowledge and skills. As already noted, reading ability itself is generally the best basis for predicting future reading scores of school children. Might this relationship extend downward to prediction from even earlier ages? Even before children can "read" (in the conventional sense), most have acquired some information about the purposes, mechanics, and component skills of the reading task. Especially now, opportunities for acquiring this information abound (e.g., daycare and preschool enrollment, exposure to educational television and software, engaging in joint book reading with parents), al-

though not all children receive equal amounts of exposure to such sources. By the time children begin school, they vary considerably in how much they already know about books and reading.

Two main kinds of measures of developing literacy knowledge and skills have been used in prediction studies. The more traditional type includes "reading readiness" tests and the kindergarten and prekindergarten levels of standardized achievement batteries. These usually assess a variety of component skills thought to play a role in reading acquisition, such as: visual discrimination of letters or letter-like forms; discrimination of speech sounds; phonological sensitivity to the structure of spoken words (e.g., Which words begin with the same sound: *king, gate, corn*?); recognition or production of the names of letters; knowledge of the correspondences between letters and sounds (e.g., Which two spoken words would begin with the same first letter: *dog, doll, boat*?); and actual reading aloud of printed words. The other, more functional types of measures, such as Clay's (1979) test of print concepts, evaluates a child's knowledge about the purposes and mechanics of reading; for example, the child's understanding of why people read, how a book is manipulated, and the differences between print and pictures.

Table A-1 in the Appendix lists the correlations with future reading achievement obtained in predictive studies using these types of tests. For the more traditional "readiness" measures, the average correlation across the 22 recent samples in my analysis was .56, which is similar to the estimate of .50 that Hammill and McNutt (1981) arrived at for 19 samples from studies between 1950 and 1977. On the other hand, in the seven prediction studies to date that used the newer, more functional measures, results were somewhat mixed, with an average effect size of .46–.49. Higher correlations were obtained in the two samples in which both types of tests were given, suggesting that using this combined approach may be useful for attaining greater accuracy in identifying children at risk for reading disabilities, although this needs additional confirmation in future research.

Among the "readiness" skills that are traditionally evaluated, the one that appears to be the strongest predictor on its own is *letter identification*. The rightmost column of table A-1 shows the results for longitudinal studies since 1976 that have included this measure. Across these 24 research samples, the median correlation between letter naming scores and subsequent reading achievement is .53, with a mean of .52 (*SD* = .14). (Earlier prediction studies produced similar results; Jansky and de Hirsch 1972.) In other words, just measuring how many letters a kindergartner is able to name appears to be nearly as successful at predicting future reading as is giving a more comprehensive readiness battery.

Although not so strong as the temporal stability of reading scores from first grade onward (median $r = .69$; see table I.), the prediction of future reading by kindergarten measures of letter identification and other early reading skills is quite substantial, accounting for nearly a third of the variance in reading at grades one through three. Nevertheless, the predictive accuracy derived from using such readiness measures alone is lower than desirable for practical purposes. In Scanlon and Vellutino's (1996) very large, district-wide sample, letter knowledge at the start of kindergarten was correlated .59 with reading test scores, and .61 with teacher ratings of reading skill, at the end of first grade. However, when letter identification was used to classify kindergartners as "at risk" or not, many errors occurred in predicting which children would end up in the bottom 20% in first grade reading. Distribution of prediction errors was contingent upon how strict the risk classification criteria were. For example, when a rather strict criterion was adopted, i.e., when letter identification scores were used to identify only the bottom 10% of kindergartners as "at risk," then 83.2% of the first grade outcomes of the approximately 1000 children would have been correctly predicted on the basis of letter knowledge. Of the 100 kindergartners who would have been identified as most at risk (and who would have been presumably targeted to receive intervention), fully 37% would have turned out not to have reading difficulties. Furthermore, of the 900 children deemed not to be at risk on the basis of letter knowledge, fully 131 (14.5%) would have developed reading problems by the end of first grade. In other words, only about one third of the children who became the poorest readers would have been selected initially for early intervention. When a more lenient criterion was used to classify kindergartners (25% rather than 10% were considered "at risk"), then the "negative predictive power" (NPP—the proportion of not-at-risk designees who did not become poor readers) would rise from 85.5 to 90%; but the overall accuracy of prediction would decrease slightly to 79.5% making the "positive prediction power" (PPP—the percentage of children in the at-risk group who indeed became poor readers) drop substantially, with less than half of the "at risk" group actually expected to develop reading difficulties.

To increase the accuracy with which the risk status of kindergartners can be identified, it is probably necessary to assess other individual risk factors that may provide additional information about how readily a child is likely to learn to read. The relative predictive strengths will be reviewed for phonological awareness and 18 other kinds of abilities, many of which have been hypothesized to contribute to, and perhaps be necessary for, successful reading acquisition.

Phonological awareness. Phonological awareness, or phonological sensitivity, is the ability to attend explicitly to the phonological structure of spoken words, rather than just to their meanings and syntactic roles. This is a particularly interesting skill to look at as a predictor of reading because, as mentioned earlier, training young children to attend to subsyllabic components, particularly phonemic segments, of words has been shown to facilitate their discovery of the regular correspondences between printed letters and phonemes they represent in alphabetic writing systems like English, suggesting that phonemic awareness plays a causal role in reading acquisition.

The predictive correlation of phonological awareness to subsequent reading has been examined in 27 research samples from 24 studies, whose results are listed in the first column of correlation coefficients in table A-2.[3] While a few studies have reported extremely high correlations, the more typical findings have clustered in the .37 to .46 range, so the mean effect (.46) exceeds the median (.42). On the average, phonological awareness accounts for less variance in future reading scores (18–21%) than does letter identification or traditional readiness scores (27–31%).

When classificatory analyses are conducted, phonological awareness in kindergarten appears to have the unfortunate tendency to be more of a successful predictor of future *superior* reading than of future reading *problems*. That is, among children who have recently begun, or will soon begin, kindergarten, few of those with strong phonological awareness skills will stumble in learning to read, but many of those with weak phonological sensitivity will go on to become adequate readers. Moreover, as was described earlier for letter identification, if classification criteria are adjusted to increase the positive prediction power and reduce "false positive" errors, overall prediction accuracy tends to drop, so that more children who will become poor readers fail to meet the risk criterion. The following three examples illustrate this tendency. First, an analysis of the data from Bradley and Bryant's (1983) landmark study was described in their subsequent book (Bradley and Bryant 1985, pp. 101–105). Depending on the reading test used (Neale or Schonell), the overall accuracy in predicting reading status from prior phonological awareness (each adjusted for age and IQ) was 80% to 82%. Of the 25 children who were initially weakest in phonological awareness, only 24% to 28% turned out to be poor readers; and of the remaining 291 children, 14% to 15% developed reading problems.

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[3]Because phonological awareness tasks that tap only a syllabic level of segmentation (e.g., syllable counting/tapping measures) have generally been less well correlated with later reading, results for such measures were not included in this analysis (table A-2).

Similarly, in a follow-up study of 41 language-impaired kindergartners, Catts (1991) found that a phoneme deletion task correctly classified 76% of the children with regard to their reading status at the end of first grade. (Another phonological awareness measure, requiring blending, was a bit less successful, predicting only 71% of outcomes in the sample.) Of the 25 children designated as "at risk" on the basis of their poor phonological awareness, 17 (68%) became poor readers but 8 (32%) did not; of the 16 "not at risk" children, 13% turned out to have reading problems despite their strong prior phonological awareness skills. The picture was much the same in the small study that yielded the highest correlation (.75) between phonological awareness skills (Mann 1984). The 12 kindergartners who became "poor" readers and the 22 who became "average" readers did about equally poorly on the phonological awareness test (M = 0% and 5% correct, respectively), while the 10 youngsters who became good readers did considerably better (33% correct). In other words, it is this large difference in phonological awareness between the highest-achieving group and the other groups (rather than the tiny difference between the two lower-achieving groups) that primarily underlies the correlational results.

Despite the theoretical importance of phonological awareness for learning to read, measures of this skill among 4.5- to 6-year-olds do not appear to predict subsequent reading achievement particularly well. This is mainly because at about the time of the onset of schooling, so many children who will go on to become normally achieving readers have not yet attained much, if any, appreciation of the phonological structure of oral language, making them nearly indistinguishable, in this regard, from children who will indeed encounter reading difficulties down the road.

Speech perception and production. Because phonological awareness is crucial for reading acquisition, yet, on its own, is only a moderately successful predictor of the future reading problems of kindergartners, the question can be raised as to whether deficiencies in phonological awareness might grow out of more basic deficits in phonological skills that develop from birth through the preschool years (Fowler 1991). For instance, perhaps children who have a better mastery of phonology—as exhibited by their ability to articulate speech sounds clearly and to hear spoken words accurately—can more readily gain a metalinguistic appreciation of the phonological structure of words. Moreover, Tallal (e.g., Tallal and Stark 1982) has further hypothesized that more fundamental weaknesses in auditory temporal processing may underlie speech perception deficits, ultimately resulting in reading disabilities.

Perceptual deficits have been observed in some, but not all, children with reading disabilities (For reviews see McBride-Chang 1995; Studdert-Kennedy and Mody 1995; and Watson and Miller 1993).

Several longitudinal prediction studies have examined kindergartners' receptive and productive phonological abilities in relation to future reading achievement, summarized in the last two columns of table A-2. From the available data, neither speech perception (median r = .23) nor speech production (.25), measured at about the time children enter school, appears to be a particularly useful predictor of subsequent reading differences.

General ability (IQ). Historically, the purpose of IQ tests was to assess scholastic aptitude, particularly to identify children who were likely to have difficulties in academic achievement. While the interpretation and use of IQ tests have changed considerably over time, the fundamental relationship between general intellectual abilities, especially verbal abilities, and achievement would be expected to hold; indeed, the predictive validity of such tests rests largely on such correlations. During the elementary school years, concurrently measured IQ and reading scores are reliably correlated. In Hammill and McNutt's (1981) meta-analysis, for instance, median correlations averaged over about a dozen studies were .44 for Full-Scale IQ, .42 for Verbal IQ, and .31 for Performance (nonverbal) IQ scores from the WISC, and .46 with scores on the Stanford-Binet. Stanovich, Cunningham, and Cramer's (1984) analyses of a larger sampling of studies suggested, furthermore, that concurrent IQ-reading correlations tend to be somewhat weaker during the primary grades (.30–.50) than at older ages (.45–.65).

Several longitudinal prediction studies have measured IQ at about age 4.5 to 6 years, primarily with the WISC-R, the WPPSI, or the McCarthy Scales of Preschool Abilities. As shown in table A-3, reading achievement was moderately well predicted by both Full-Scale IQ (mean r = .41) and Verbal IQ (.37), but less well by Performance IQ (.26) in these studies.

Vocabulary and naming abilities. Many researchers have used *receptive vocabulary* measures, such as the Peabody Picture Vocabulary Test, as a surrogate for general verbal ability in prediction studies. On each trial of such tests, the child must indicate which of several pictures best corresponds to the word (usually a noun, adjective, or gerund) spoken by the examiner. A long series of items of increasing difficulty is available, and testing terminates when the child's vocabulary level is exceeded. Correlations between kindergarten receptive vocabulary scores and subsequent reading scores in 19 prediction studies are listed in the first column of coefficients in table A-4. The distribution is negatively skewed, so the mean effect size (.33) differs somewhat from the median (.38), which resembles that for Verbal IQ.

Fewer prediction studies have examined expressive vocabulary, often called *confrontation naming*. On such measures as the Boston Naming Test, the child is shown a series of drawings of objects, and is asked to name each one. Compared to receptive tests, these measures place greater demands on accurate retrieval of stored phonological representations of lexical items, and on the formulation and production of spoken responses. Stimuli for confrontation naming tasks are presented with increasing difficulty, so that later items are readily recognizable objects whose names are not used very frequently. Some examples illustrating the range of difficulty on the Boston Naming Test are: whistle, seahorse, harmonica, escalator, funnel, and palette. Concurrent correlations of confrontation naming skill with reading, but not with attentional or mathematical problems, have been observed in numerous school-aged samples (e.g, Denckla and Rudel 1976a; Felton et al. 1987; Wolf 1991; Wolf and Goodglass 1986). To my knowledge, however, only five kindergarten prediction studies have included confrontational naming measures in the predictor battery. The magnitude (mean $r = .45$) and consistency of the results of those studies (listed in the second column of table A-4) suggest that naming vocabulary may be a reliable predictor of future reading success that has too often been overlooked by researchers.

Not just the accuracy of name production but also its speed can be measured. In *rapid serial naming* tasks, large arrays of highly familiar stimuli are presented, and the child is asked to name all of the items as quickly as possible. For instance, on the most widely used task of this sort, Denckla and Rudel's (1976b) Rapid Automatized Naming test, each 5 x 10 array contains ten recurrences, in random order, of a set of five items (pictured objects, color patches, digits, and letters). Each array can typically be named in about one minute or less, even by young children. Rapid serial naming speed has been shown to correlate with concurrent and future reading ability, but not with IQ, in several dozen studies of school children (e.g., Ackerman, Dykman, and Gardner 1990; Bowers and Swanson 1991; Cornwall 1992; Denckla and Rudel 1976b; Felton et al. 1987; Spring and Davis 1988; Wolf and Obregon 1991). Somewhat weaker associations with reading are obtained when "discrete" naming (response time to name an individual stimulus) rather than "serial" naming is measured, suggesting that the naming speed problems of poor readers involve more than just difficulty in retrieving and producing item names. However, a full understanding of the relationship between speed naming and reading remains to be determined. Recent evidence suggests, furthermore, that rapid serial naming speed

may be an especially good predictor of subsequent progress once a child has developed a reading problem in the primary grades (Korhonen 1991; Lovett 1995; Meyer et al. in press; Scarborough 1995).

As a kindergarten predictor, rapid serial naming is of particular interest in light of the recent "double deficit" hypothesis, advanced by Bowers and Wolf (1993) and Wolf (in press), that reading disability can stem from either of two core deficits—phonological awareness or naming speed—and that the most severe reading problems result from the occurrence of both weaknesses. Rapid serial naming measures have been included as predictors in 14 longitudinal studies of kindergarten samples. As shown in the last two columns of table A-4, the average correlations between kindergartners' naming speeds and their later reading scores were quite similar when the arrays to be named included alphanumeric symbols (digits or letters) or nonsymbolic stimuli (colors or objects). Overall, the median correlation of rapid serial naming speed with reading was .40 and the mean was .38 in the 14 studies to date.

Other aspects of language comprehension and production. Spoken language and reading have much in common. As long as the printed words can be efficiently recognized, comprehension of the connected text will depend heavily on the reader's oral language abilities, particularly on his or her understanding of syntactic and semantic relationships among the morphemes, words, and phrases. Indeed, many early research reports called attention to the differences between good and poor readers in their comprehension and production of structural relations within spoken sentences.

As shown in table A-5, numerous longitudinal prediction studies have included measures of semantic, morphological, and syntactic skills of kindergartners. (Rarely, however, have different researchers used the same measures of these abilities, unfortunately.) The highest average correlation (.46–.47) has been found when a broad composite index of language abilities has been used, but only four studies have taken this approach so the findings should be considered promising but not definitive. Receptive (sentence comprehension) measures that emphasized the understanding of complex syntactic and morphological forms have been more successful predictors (average $r \leq .38$) than other (or unspecified) kinds of receptive measures (.24–.25), and about equally strong predictors of reading as expressive (production) measures (.32–.37), which include mean length of utterance, sentence completion, morphological cloze tasks, and others. It should be recalled that the goal in these studies has been to predict reading achievement during the first few school grades, when the emphasis is primarily upon the acquisition of word recognition and decoding skills rather than on the comprehension of challenging material. In view of that, it is perhaps somewhat surprising that these kindergarten language measures, especially the broad composite indices, yield such respectable correlations with early reading. Nevertheless, from the practical standpoint of identifying individual children at highest risk for reading difficulties, it would seem that several predictor variables reviewed earlier appear to be more useful.

Verbal Memory. The ability to retain verbal information in working memory is essential for reading and learning, so it might be expected that verbal memory measures would be effective predictors of future reading achievement. As shown in the last two columns of table A-5, many prediction studies have included such measures within their predictor batteries. From the results of those studies, it is quite clear that on the average, kindergartners' abilities to repeat sentences (e.g., on the WPPSI Sentence Imitation subtest) or to recall a brief orally presented story are more strongly related to their future reading achievement (r = .45–.49) than are their scores on digit span, word span, and pseudo-word repetition measures (r = .31–.33). One might speculate that the former type of measure, which is among the best of the predictors reviewed so far, gains power by tapping both memory and sentence processing abilities.

Visual and motor skills. Learning to read requires that the child be able to perceive and discriminate letters of the alphabet, and learning to write further requires that these letter forms be reproduced by the child. Traditional readiness batteries typically included not just letter discrimination and writing measures (which will not be reviewed here) but also some measures of more basic visual and/or motor abilities. In both research and practice, these skills have been examined less often during the last two decades than before that time, as theoretical accounts of reading difficulties have shifted from an emphasis on sensorimotor deficits to an emphasis on language (especially phonological) weaknesses. As can be seen in table A-6, in the relatively few recent prediction studies that have examined these sorts of predictor variables, reading achievement has not been well predicted by measures of visual form discrimination (mean r = .22), visual-motor integration (.16), visual memory (.31), and motor skills (.25).

Summary: Comparison of Individual Risk Factors. Evidence has been reviewed regarding the strengths of the correlations of many specific abilities of kindergartners with their reading skills one to three years later. A summary of the aggregated data on these zero-order effects is

provided in table III, with predictor variables listed in decreasing order of strengths of correlations with future reading achievement.

Not surprisingly, measures of skills that are directly related to reading and writing—including knowledge about letter identities, about letter-sound relationships, and about the mechanics and functions of book reading—have yielded the highest simple correlations with subsequent reading scores. Each of these predictors, on its own, has typically accounted for about 21% to 31% of the variance in later reading achievement. Among the other measures that have been studied, four stand out as the strongest predictors of reading, each accounting for about 18% to 24% of the variance in later achievement scores: confrontation naming (expressive vocabulary); general language ability; sentence/story recall; and phonological awareness. Somewhat weaker effects (10–17% of reading variance) have been obtained for an-

Table III. Correlations of Individual Risk Factors with Future Reading Achievement: Summary

Predictor	# of Samples	median r	mean r	SD
Print-Specific Knowledge/Skills:				
Early Reading ("Readiness")	21	.56	.57	.12
Letter Identification alone	24	.53	.52	.14
Concepts of Print	7	.49	.46	.20
Non-Print-Specific Abilities:				
Confrontation Naming	5	.49	.45	.07
Sentence/Story Recall	11	.49	.45	.12
General Language Index	4	.47	.46	.15
Phonological Awareness	27	.42	.46	.13
Full-Scale IQ	11	.38	.41	.14
Verbal IQ	12	.38	.37	.11
Receptive Vocabulary	20	.38	.33	.17
Rapid Serial Naming	14	.40	.38	.09
Receptive Language (Syntax)	9	.40	≤.37	n.a.
Expressive Language Production	11	.37	.32	.16
Verbal Memory (Words, Digits)	18	.33	.33	.17
Visual Memory (Forms)	8	.28	.31	.12
Motor Skills	5	.26	.25	.09
Performance IQ	8	.25	.26	.11
Receptive Language (Semantic)	11	25	.24	.17
Speech Production	4	.25	n.a.	n.a.
Speech Perception	11	.23	.22	.09
Visual Discrimination	5	.20	.22	.15
Visual-Motor Integration	6	.13	.16	.12

other six predictors, all measures of general ability and various narrower facets of language skill. Weaker average correlations have been obtained for the nine other kindergarten abilities that have been examined, including speech production and perception, visual and verbal short-term memory measures, and other nonverbal abilities.

As noted earlier, however, even the best of these measures is not sufficiently discriminative on its own to insure the accurate early identification of children at greatest risk for reading difficulties. Too many errors of prediction ("false positives" and/or "false negatives," depending on the cut-off criterion chosen) will occur when one attempts to classify at-risk children on the basis of measures that account for only about a third or less of the variance in future reading. One approach to improving the accuracy of prediction is to try to combine predictor variables so that their cumulative strength exceeds the degree of prediction afforded by any one of them on its own. Research along these lines is reviewed next.

Combining Individual Risk Factors to Improve Prediction

Many researchers have examined the combined effects of several or many predictors of reading, with the results of such multivariate analyses summarized in table A-7. The first ten studies listed in the table provide data from school- or population-representative samples; the last four, provided mainly for comparison purposes, are based on samples from two special populations: samples of children who had received preschool diagnoses of language impairment (discussed in more detail later), and samples in which children with a family history of reading problems were deliberately over-represented. It should be noted, further, that the most successful prediction study listed in the table (Hurford et al. 1994) differs from the others in that the initial assessments were conducted during the fall of first grade, rather than in early kindergarten. Because my main concern is with predicting outcomes from kindergarten data, the other nine studies will be the focus of the following discussion.

In six of those nine studies, the predictor battery included letter identification and/or other measures of early literacy knowledge and skills (letter-sound knowledge, word recognition, concepts of print, teacher ratings, writing). Five included at least one measure of phonological awareness; four included an IQ score; and three included a verbal memory measure. Other predictors (rapid serial naming, other oral language skills, numerical knowledge, visual/visual-motor abilities, demographic variables) were included in two or fewer of the analyses. In some studies, the researchers assessed many other skills

that turned out not to make a significant contribution to the prediction of reading, and are, therefore, not listed in the table (e.g., perceptual skills, demographic variables, home literacy environment measures, and others). But some of the apparently strongest bivariate predictors, according to the preceding section of this chapter (i.e., sentence/story recall, confrontation naming, and broad language indices) were rarely assessed in these studies; so their potential contributions to prediction when combined with other variables remain unknown.

In seven of the nine studies, researchers conducted multiple regression analyses, yielding R and R^2 values as summary statistics of the strengths of the relationship between kindergarten measures and later reading achievement. R^2 ranged from .41 to .71, with an average of 57% of the variance in reading scores accounted for by the analysis (mean $r = .75$). In comparison, the mean effect size for readiness tests alone was considerably lower (mean $r = .57$, table A-1), indicating that adding other kinds of measures to the predictor set can effectively strengthen the prediction.

Classificatory analyses were conducted in six of the nine studies. As shown in the last five columns of table A-7, the percentage of children whose reading outcome status (reading disabled or nondisabled) was correctly predicted by kindergarten risk status (based on the predictor battery) ranged from 80% to 92%, with a mean of 89%. These prediction analyses tend to achieve high specificity (i.e., on the average, 91% of nondisabled readers had been classified as "not at risk" in kindergarten), but somewhat lower sensitivity (i.e., on the average, only 78% of dyslexic children had been classified initially as "at risk"). Negative predictive power ranged from 91% to 99%, with a mean of 96%; in other words, on the average, the proportion of "not at risk" children who, nevertheless, developed reading problems was only 4%. Positive predictive power, however, ranged from 31% to 75%, with a mean of only 55%; that is, the proportion of at-risk children who turned out not to have reading difficulties, was substantial (45%) and was not markedly lower than when predictions were based on letter identification or phonemic awareness alone, as described earlier.

A Special Case: Preschoolers with Specific Early Language Impairments.

Both the bivariate and multivariate results of prediction studies are consistent with the view, held by most researchers for the past two decades, that weakness in some sort of verbal/language skill underlies reading disabilities. If so, preschoolers with clinically diagnosed "specific early language impairments" (SELI) might be especially likely to develop reading disabilities. There are more than a dozen follow-up studies of the later academic achievements of SELI samples. Although the sampling criteria, the initial skill levels of the children, and the measures of outcome status have not always been well specified, and have rarely been comparable from study to study, several general trends are evident. First, about 40% to 75% of preschoolers with SELI develop reading difficulties later, often in conjunction with broader academic achievement problems (Aram and Hall 1989; Bashir and Scavuzzo 1992). Second, regardless of the child's general cognitive abilities or therapeutic history, the risk for reading problems is greatest when the child's impairment is severe in any aspect of language, broad in scope, and/or persistent over the preschool years. Nevertheless, some children with only mild to moderate language delays, and who appear to overcome their spoken language difficulties by the end of the preschool period, remain at greater risk than other youngsters for the development of a reading disability (e.g., Bishop and Adams 1990; Scarborough and Dobrich 1990; Stark et al. 1984).

Two recent longitudinal prediction studies are particularly informative about the prediction of reading for children with SELI based on their observed differences at about the time of school entry (Bishop and Adams 1990; Catts 1991, 1993). As summarized in table A-7, in both studies 50% of the variance in reading achievement within the SELI sample could be accounted for by a small set of predictors measured at about age five. The accuracy of prediction within these SELI samples was lower than in the other studies listed in the table, perhaps due to range restrictions since non-SELI children were not included in the samples. It is clear that children with SELI are at greatly elevated risk for having difficulties in learning to read, and are a population that should be specifically targeted to receive early intervention. Speech-language professionals, to whom these children are typically referred, are probably the most appropriate individuals to provide this intervention. What needs to be considered, however, is the most effective type of treatment that should be given to these children at ages three to five years. Because the causal relationships between SELI and RD are obscure (e.g., Kamhi and Catts 1989), and because apparent (often spontaneous) recovery to normal levels of language proficiency is commonly observed in this group (Scarborough and Dobrich 1990), it may not be sufficient simply to emphasize the improvement of articulatory, syntactic, and pragmatic language skills, as is typically done. Although there is no available research or clinical evidence on this point, the correlational data for unselected populations suggest that the focus of early intervention might fruitfully be expanded to include training in phonological awareness, naming vocabulary, verbal memory, and print-specific skills.

Prediction of Reading From Differences Measured at Younger Ages

Compared to their classmates, some children's literacy-related skills are so weak when they enter school that one could say that the problem we are seeking to prevent *has already begun* by kindergarten. That is, those children are already behind in "reading achievement." It is, therefore, not surprising that some of the best predictors of future reading are skills that are closely tied to (or, arguably, actually products of) the process of learning to decode print; namely, letter identification, letter-sound knowledge, and phonological awareness. Moreover, sentence/story recall, vocabulary, and general language skills may also be enhanced, less directly, through reading and learning to read. If so, it might be desirable to try to prevent or reduce these differences among entering kindergartners by identifying children who are at risk of being at the bottom of the distribution when they begin kindergarten, and to intervene prior to school entry.

Although dozens of investigations on reading predictions from measures taken at about the time of school entry (4.5 to 6 years old) have been conducted, only a handful of longitudinal prediction studies have assessed children at younger ages (birth to age 4). Consistent with the theoretical consensus that some kinds of language deficits underlie most difficulties in learning to read, the main focus of all these investigations has been the development of linguistic and metalinguistic abilities in very young children, who are then followed through their early school years.

To my knowledge, only one study has directly examined reading prediction from developmental differences among infants. Shapiro et al. (1990) obtained reading scores at age 7.5 years for 227 children for whom pediatric records from birth to two years were available for numerous language and motor milestones, i.e., first word, 50-word vocabulary, 2-word utterances, sits unsupported, crawls, and walks. A composite measure of infant achievement was found to predict reading status (RD or not) with .73 sensitivity and .74 specificity. Individually, the "expressive" language milestones made a particularly strong contribution to prediction. Bayley infant IQ scores were about as good at predicting outcomes as the expressive language measure, but including IQ in the composite did not improve accuracy. Although not sufficiently accurate for practical use, this degree of predictive success is, nevertheless, remarkable in comparison to the results of the kindergarten studies described in table A-7.

Three studies have examined language and IQ as predictors in 2.5- to 4.5-year-old children. First, Walker et al. (1994) cumulatively monitored two aspects of emerging language (mean utterance length and number of vocabulary words produced) in monthly visits for a sample of 40 children aged 7 to 36 months, chosen as nationally representative demographically. Stanford-Binet IQ scores were also obtained at age three. They were able to follow 32 of the children during their early school years. The two early language measures, which were highly intercorrelated (r = .85), each correlated moderately well with reading scores in grades one through three (r = .32 to .63, mean = .46), as did the preschool IQ scores (r = .33 to .47, mean = .42).

Second, Bryant and his colleagues (Bryant, Maclean, and Bradley 1990; Bryant et al. 1990; Maclean, Bryant, and Bradley 1987) obtained scores for 64 children aged 40 to 41 months on a test of receptive vocabulary (EPVS), on the Expressive and Receptive portions of the Reynell language scale, on a measure of nursery rhyme recitation skill, and on a phonological awareness test (rhyme matching). Other phonological awareness measures were given at 44, 48, and 55 months, and a WPPSI IQ score was obtained at 51 months. Performance on reading tests, which were given at 75 and 79 months of age, was predicted by receptive vocabulary (r = .43), expressive language ability (.57), receptive language ability (.43), nursery rhyme recitation (.59), and IQ (.67). Correlations of the rhyme matching measure with later reading were not reported, and this measure was only weakly related (mean r = .28) to the tests of phonological awareness at 40 to 55 months, the last of which were strongly predictive of reading (mean r = .66), as was reported in table A-2.

Third, I (Scarborough 1991a, 1991b) obtained several language and IQ scores for a sample of 62 children between the ages of three and four years, about half of whom had parents and/or older siblings with reading problems, and examined their reading outcomes at the end of second grade. McCarthy IQ scores from ages 36 and 48 months correlated .33 and .36, respectively, with later reading. Scores on the receptive portion of the Northwestern Syntax Screening Test, also given at 36 and 48 months, were associated with reading to about the same degree (r = .32 and .34, respectively). Expressive vocabulary skill (Boston Naming Test) at age 42 months predicted reading more strongly (r = .52) than did receptive vocabulary (PPVT) scores at the same age (r = .42). In addition, for a subset of 52 children (20 from affected families who became disabled readers, 20 demographically similar nondisabled readers from unaffected families, and 12 who became good readers despite a family history of RD), measures of expressive phonological (pronunciation accuracy), syntactic (length/complexity of sentences), and lexical (word diversity) abilities were derived from naturalistic observations of children's language during play sessions at age 2.5 years (Scarborough 1990). The children who became poor readers were much weaker than

the other groups on the syntactic and phonological measures at that early age.

What is most striking about the results of the preceding studies is that the magnitude of the bivariate correlations between reading and early preschool measures—taken three to five years prior to outcome assessments—is not markedly lower than that of the correlations of reading with kindergarten predictor scores for the same sorts of skills. Nevertheless, even if it might be possible to predict reading outcomes as successfully from age three as from age five, as these studies suggest, the practical utility of doing so is small. That is, in general it is probably not feasible to conduct population-wide screening of preschoolers for the purpose of identifying those who are at greatest risk for reading difficulties. Preschoolers with SELI and preschoolers with a family history of reading disability, however, are groups within the population for whom early detection and intervention are more realistic possibilities. If the future reading status of these children can be predicted from early measures of language and literacy skills, then it would be affordable potentially to assess that small subset of the population a year or two before kindergarten, and provide intervention to those with the weakest skills.

IMPLICATIONS FOR THEORY, RESEARCH, AND PRACTICE

Most contemporary accounts of the etiology of reading disabilities focus on phonological awareness as the predominant basis for the dyslexic child's difficulty in learning to read. As stated at the outset, on grounds of both logical importance (for grasping the alphabetic principle) and empirical evidence (from training studies), phonological awareness is the only predictor for which a strong claim for causality can be made. As has been reviewed, however, several other verbal abilities appear to be as strong or stronger than phonological awareness as predictors of the future reading achievement of kindergartners. Because correlation can never be presumed to imply causality, the etiological roles of these other predictor variables are open to question. The correlations can be interpreted differently based on different views about the underpinnings of dyslexia.

Within the prevailing "phonological" view, it is usually hypothesized that a deficit of some sort in more basic phonological processing is the root cause of dyslexia that impedes the attainment of phonological awareness, the proximal cause of reading failure. This more basic phonological deficit is hypothesized to have other ramifications too, some of which may also contribute to difficulties in learning to read, but many of which are largely irrelevant to the development of dyslexia despite their correlation with reading achievement. For example, verbal working memory weaknesses may arise if spoken material is poorly phonologically encoded for storage, and vocabulary acquisition may be impeded if the stored phonological representations of words are inaccurate or ill specified due to deficient encoding of speech. This provides a reasonable way of accounting for the results of prediction studies. That is, sentence/story recall may predict well because the phonological deficit weakens verbal working memory capacity; confrontation naming may predict well because lexical representations of names are degraded; and broad language indices may predict well because phonological difficulties interfere with the development of other aspects of language skill.

While plausible and admirably parsimonious, this account of the data is not yet airtight. For example, because they stem from a common core deficit, all of these successful predictors of reading should also correlate, at least moderately, with each other. This cannot be evaluated from the available data because few studies have included more than one of these measures and/or have reported the intercorrelations among predictor variables. Second, it is puzzling that other verbal working memory measures (digit span and word span) are not such strong predictors as sentence/story recall, even though the former would seem to require an even greater reliance on accurately encoded and retained phonological representations of the stimuli (due to the absence of contextual support). Similarly, it remains to be demonstrated convincingly that expressive vocabulary limitations have a phonological basis. In addition, the weak correlations of speech perception and speech production abilities with reading are also potentially inconsistent with the model, since these abilities would be expected to be compromised if a basic phonological deficit were present.

There are at least two other ways to account for the multiplicity of strong predictors. First, Wolf and Bowers (Bowers and Wolf 1993; Wolf in press) have put forth a "double deficit" hypothesis according to which either or both of two deficits (phonological awareness and naming speed) can underlie reading disability. While this particular combination does not receive strong support from the data reviewed above, some other sort of two-pronged causal model might work. Second, rather than hypothesizing there to be multiple causes of reading disabilities, one might postulate that there is a single core deficit, but one that is somewhat broader in scope than envisioned within the phonological core viewpoint (e.g., perhaps a language production deficit of some sort). Rather than postulating that sentence/story recall, confrontation naming, and broad language deficits all result from poor phonological

encoding, one might see them as various manifestations of the core deficit that are evident somewhat earlier in life than is weak phonological awareness (Scarborough 1990, 1991a), and are thus good markers of risk but *not* necessarily proximal causes of difficulty in learning to read. In this sense, the etiology of dyslexia might be better envisioned as similar to that of the disease syphilis (in which a single underlying cause leads to a succession of potentially unrelated symptoms at different times) than to that of glaucoma (a simple causal chain).

Although it is interesting to entertain alternative hypotheses, the fact remains that the preponderance of the available data is reasonably consistent with the phonological core model. Nevertheless, I would like to encourage researchers to explore more deeply the etiological roles of the several promising non-phonological predictor variables identified in this review, with an eye toward testing between two or more theoretical viewpoints. In particular, tracing the developmental relationships among these skills, through the early preschool years as well as from kindergarten on, may be an especially fruitful approach.

With regard to the practical challenge of identifying kindergartners who are most at risk for developing reading problems, it is clear that a multivariate approach will produce greater accuracy than will reliance on any single test or measure. Even when multiple predictors are used to identify children at risk (table A-7), both sensitivity (78% on average) and positive predictive power (55%) have generally been lower than desirable for practical applications. That is, 22% of children who developed reading disabilities were not initially classified as at risk, and 45% of kindergartners meeting the risk criterion did not become disabled readers. This pattern of classification errors was quite similar across studies and suggests that some fair number of children who will develop reading disabilities do not obtain low enough scores in kindergarten to merit an "at risk" designation on the basis of the kinds of measures that have been used (most typically literacy-specific knowledge, phonological awareness, and IQ). Whether the inclusion of sentence/story recall, naming vocabulary, and broader language measures in kindergarten testing would help to pick up these cases is unknown, but it merits investigation on the basis of the strong bivariate results that have been obtained for those measures. Another possibility is that reading difficulties can stem from more than one underlying weakness, as suggested by the "double deficit" hypothesis. If so, disjunctive classification criteria (e.g., that which considers a child to be at risk if a low score is obtained on measure A or measure B or measure C, regardless of the overall level of performance by the child), rather than conjunctive criteria (as employed in current approaches), may be a means of obtaining higher prediction accuracy. It bears mentioning, however, that the average multiple correlation in the studies in table A-7 ($r = .75$) was about as strong as the year-to-year correlations obtained among reading achievement scores (table I) during the elementary school grades. It may be unreasonable, therefore, to expect to see more than modest increases in the strength of multivariate correlations, even if an optimal predictor battery is used and optimal risk classification rules are adopted.

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APPENDIX

Table A-1. Prediction of Future Reading Achievement from Measures of Literacy Knowledge and Skills at About the Time of School Entry.

		Type of Measure			
Study	*N*	Concepts of Print	Letter-Sound and Reading Skills	Combined	Letter Identification Alone
Badian (1982)	143				.57
Badian (1994)	118				.52
Badian (1995)	81				.44
Blatchford et al. (1987)	343	.27			.61
Bowey (1995)	116				.60
Busch (1980)	1052		.56		.47
Butler et al. (1985)	320				.57
Chew and Lang (1990)	110				.49
Elbro et al. (1996)	91	.30			.69
Flynn and Flynn (1978)	81		.34		
Glazzard (1977)	87		.85		
Grogan (1995)	51		.45		
Gullo et al. (1984)	77		.57		
Horn and O'Donnell (1984)	218				.59
Juel et al. (1986)	80		.73		
Lundberg et al. (1980)	133		.64		
Mann (1984)	44				.52
Mann and Ditunno (1990)					
sample 1	31		.56		
sample 2	39		.51		
sample 3	32		.36		
Mason (1992)	109		.54		
McCormick et al. (1994)	38		.60		.52
Muehl and Di Nello (1976)	56				.41
Randel et al. (1977)	625		.51		
Rubin et al. (1978)	520		.62		
Scanlon and Vellutino (1996)	1000	.27	.64		.59
Scarborough (1989)	66		.36		
Share et al. (1984)	500				.63
Snow et al. (1995)	63	.54		.66	
Stanovich et al. (1984)	31		.52		
Stuart (1995)	30	.49	.75	.80	.76
Tunmer et al. (1988)	100	.50			.53
Vellutino & Scanlon (1987)					
sample 1	150		.44		.33
sample 2	61		.62		.66
sample 3	92		.53		.44
Wagner et al. (1994)	244			.51	
Weller et al. (1992)	415		.64		
Wells et al. (1984)	32	.82			
Wimmer et al. (1991)					
sample 1	50				.20
sample 2	42				.15
sample 3	36				.69
# of samples		7	22	2	24
median *r*		.49	.56	.73	.53
mean *r*		.46	.56	.73	.52
(*SD*)		(.20)	(.13)	n.a.	(.14)

Table A-2. Prediction of Reading Achievement from Phonological Awareness, Speech Discrimination, and Speech Production Abilities

Study	*N*	Phonological Awareness	Speech Discrimination	Speech Production
Badian (1995)	81	.42		
Bishop and Adams (1990)	76			.31
Bowey (1995)	116	.40		
Bradley and Bryant (1983)				
sample 1	118	.55		
sample 2	285	.46		
Bryant et al. (1990)	65	.66		
Busch (1980)	1052		.23	
Catts (1993)	56	.50		≤.26
Colarusso et al. (1980)	40		.19	
Elbro et al. (1996)	91	.33		.25
Felton (1992)	221	.33		
Grogan (1995)	51		.24	
Helfgott (1976)	31	.72		
Horn and O'Donnell (1984)	218		.28	
Hurford et al. (1993, 1994)	171	.40	.34	
Juel et al. (1986)	80	.60		
Levy and Stewart (1991)	56	.37		
Lundberg et al. (1980)	133	.43		
Mann (1984)	44	.75		
Mann and Ditunno (1990)				
sample 1	31		.02	
sample 2	39		.11	
sample 3	32		.16	
Muehl and Di Nello (1976)	56		.33	
Perfetti et al. (1987)	82	.42		
Scarborough (1989)	66	.38	.23	.19
Scanlon and Vellutino (1996)	1000	.42		
Share et al. (1984)	500	.64	.24	
Snow et al. (1995)	63	.58		
Stanovich et al. (1984)	31	.38		
Stuart (1995)	30	.34		
Tunmer et al. (1988)	100	.32		
Vellutino and Scanlon (1987)	126	.29		
Wagner et al. (1994)	244	.42		
Wimmer et al. (1991)				
sample 1	50	.45		
sample 2	42	.30		
sample 3	36	.60		
# of samples		27	11	4
median *r*		.42	.23	≤ .25
mean *r*		.46	.22	n.a.
(*SD*)		(.16)	(.09)	n.a.

Table A-3. Prediction of Reading Achievement from IQ Scores.

Study	*N*	Full-Scale	Verbal	Performance
Badian (1994)	118		.42	
Blatchford et al. (1987)	343		.36	
Bowey (1995)	116			.39
Bryant et al. (1990)	65	.68		
Busch (1980)	1052	.58		
Colarusso et al. (1980)	40		.25	
Elbro et al. (1996)	91			.22
Feshbach et al. (1977)				
sample 1		.39		
sample 2		.45		
Flynn and Flynn (1978)	81		.13	
Gullo et al. (1984)	77	.37		
Horn and O'Donnell (1984)	218		.51	
Lundberg et al. (1980)	133			.21
Mann & Ditunno (1990)				
sample 1	31	.52		
sample 2	39	.32		
sample 3	32	.31		
Mason (1992)	109		.50	
Massoth and Levenson (1982)	33	.33	.25	.38
Muehl and DiNello (1976)	56		.36	.35
Scanlon and Vellutino (1996)	1000		.38	.26
Scarborough (1989)	66	.31		
Stanovich et al. (1984)	31	.25		
Vellutino and Scanlon (1987)				
sample 1	150		.37	
sample 2	61		.41	
sample 3	92		.48	
Wimmer et al. (1991)				
sample 1	50			.24
sample 2	42			.04
# of samples		11	12	8
median *r*		.37	.38	.25
mean *r*		.41	.37	.26
(*SD*)		(.13)	(.11)	(.11)

Table A-4. Prediction of Reading Achievement from Lexical (Vocabulary) Skills

Study	N	Receptive Vocabulary	Expressive (Naming) Vocabulary	Rapid Serial Naming: Colors, Objects	Rapid Serial Naming: Digits, Letters
Badian (1982)	129		.36		
Badian (1994)	118		.49	.41	
Bishop and Adams (1990)	76	.44	.51		
Bowey (1995)	116	.46			
Bradley and Bryant (1983)					
sample 1	118	.52			
sample 2	285	.42			
Bryant et al. (1990)	65	.43			
Catts (1993)	56			.51	
Colarusso et al. (1980)	49	.21			
Elbro et al. (1996)	91	.25		.43	
Felton (1992)	221			.31	.36
Flynn and Flynn (1978)	81	.00			
Hurford et al. (1993, 1994)	171	.36			
Levy and Stewart (1991)	56			.29	.35
Mann (1984)	44				.42
Mann and Ditunno (1990)					
sample 1	31				.39
sample 2	39				.25
sample 3	32				.33
McCormick et al. (1994)	38	.43			
Scanlon and Vellutino (1996)	1000	.28		.32	
Scarborough (1989)	66	.31	.49	.21	
Share et al. (1984)	500	.40		.42	
Snow et al. (1995)	63	.44			
Tunmer et al. (1988)	100	.15			
Vellutino and Scanlon (1987)	150	.25			
Wagner et al. (1994)	244				.50
Wells et al. (1984)	32	.60			
Wimmer et al. (1991)					
sample 2	42	.12			
Wolf, Bally, and Morris (1986)	83			.39	.66
Wolf and Goodglass (1986)	89	.03	.38		
Zucker and Riordan (1990)	75	.51			
# of samples		20	5	9	8
median *r*		.38	.49	.39	.38
mean *r*		.33	.45	.37	.41
(*SD*)		(.17)	(.07)	(.10)	(.12)

Table A-5. Prediction of Later Reading by Measures of Language Skills and Verbal Memory.

Study	N	Overall Language Index	Receptive Syntax/ Morphology	Receptive Semantic/ Unspecified	Expressive Language Skills	Memory: Words, Digits	Memory: Stories, Sentences
Badian (1982)	143		.42	.25	.40		.52
Badian (1994)	118				.25		.27
Bishop and Adams (1990)*	76		.51	.41	.54		.52
Bowey (1995)	116		.35				
Bradley and Bryant (1983)						.56, .25**	
sample 1	118					.40	
sample 2	285					.24	
Bryant et al. (1990)	65						.51
Butler et al. (1985)	320	.45	.44				
Catts (1993)*	56			.30	.40		
Colarusso et al. (1980)	40				.05	.41	
Day and Day (1983)	56						.57
Elbro et al. (1996)	91					.34	
Felton (1992)	221					–.14	
Grogan (1995)	51					.47	
Juel et al. (1988)	80			.34			
Klein (1980)	678		.40				.46
Levy and Stewart (1991)	56			.08			
Lindquist (1982)	351	.27					
Lunzer et al. (1976)	184	.49				.32	.25
Mann (1984)	44		≤.29			.56	
Mann and Ditunno (1990)							
sample 1	31					.26	
sample 2	39					.53	
sample 3	32					.21	

Study	N	Overall Language Index	Receptive Syntax/ Morphology	Receptive Semantic/ Unspecified	Expressive Language Skills	Memory: Words, Digits	Memory: Stories, Sentences
Mason (1992)	109				.23	.56	
Muehl and Di Nello (1976)	56					.27	
Scanlon and Vellutino (1996)	1000		.30			.33	.34
Scarborough (1989)	66		.18	.05	.08		
Share et al. (1984)	500		.43			.31''	.41
Snow et al. (1995)	63			.42	.37		
Vellutino and Scanlon (1987)							
sample 1	150			.13	.39		
sample 2	61			.08	.50		.49
sample 3	92			.06	.27		.58
Wagner et al. (1994)	244					.33	
Wells et al. (1984)	32	.64		.54			
Wimmer et al. (1991)	42					.05''	
# of samples		4	9	11	11	18	11
median r		.47	.38	.25	.37	.33	.49
mean r		.46	≤.37	.24	.32	.33	.45
(SD)		(.15)	n.a.	(.17)	(.16)	(.17)	(.12)

'These samples included many children with diagnosed language impairments.

''Task was Pseudoword Imitation rather than recall of word/digit lists.

Table A-6. Prediction of Future Reading Achievement from Measures of Visual and Motor Skills.

Sample	N	Visual Perception	Visual-Motor Integration	Visual Memory	Motor Skills
Badian (1994)	118		.17	.33	
Badian (1995)	81		.10		
Busch (1980)	1052		.38		
Butler et al. (1985)	320	.44			.32
Colarusso et al. (1980)	40	.20	.15		
Flynn and Flynn (1978)	81		.02		
Grogan (1995)	51			.40	
Horn and O'Donnell (1984)	218			.48	.18
Linquist (1982)	105				.26
Lundberg et al. (1980)	133	.19			
Lunzer (1976)	184			.47	
Mann and Ditunno (1990)					
sample 1	31			.18	
sample 2	39			.22	
sample 3	32			.19	
Massoth and Levinson (1982)	33				.35
McCormick et al. (1994)	38		.11		
Scanlon and Vellutino (1996)	1000	.26		.23	
Scarborough (1989)	66	.01			
Share et al. (1984)	500				.14
# of samples		5	6	8	5
median r		.20	.13	.28	.26
mean r		.22	.16	.31	.25
(SD)		(.15)	(.12)	(.12)	(.09)

Table A-7. Predicting Future Reading Achievement from Multiple Kindergarten Measures

Study	Grade (From-To)	Combined Predictors	N	R^2	% At Risk	% RD	% Correct	PPP	NPP	Sensitivity	Specificity
Badian (1982)	K-3	Letter Names, WISC-Info., Sent. Mem., Counting, Drawing	129	.55	16	10	92	57	99	92	92
Badian (1994)	K-1	Early Ach., VIQ, SES, age	118	.60							
		Early Ach., VIQ, SES, age, Letter Names, Letter Discrim., RSN-Objects, Syll. Counting	118	.63	21	13	91	48	99	93	90
Butler et al. (1985)	K-3	Factor Scores: Language-1, Language-2, Vis. Skills, Motor Skills, Rhythm, sex	320	.50	10	10	91	56	95	56	95
Felton (1992)	K-3	IQ, RSN-letters, PA (oddity)	215	.41	26	10	80	31	97	81	80
Horn and O'Donnell (1984)	K-1	Letter Names, Vis. Discrim., Vis-Motor, Write Name, Verbal Mem., Attention, Teacher Rating and others	218	—	8	10	93	55	97	71	95
Hurford et al. (1994)	1-2	Grade 1 Reading, PA (Deletion), Phon. Discrim., PPVT	171	—	13	15	97	88	100	100	98
Lundberg et al. (1980)	K-1	PIQ, Vis. Perc., PA (segment), PA (reverse), sex	133	.54	27	27	87	75	91	75	91

Study	Grade (From-To)	Combined Predictors	N	R^2	% At Risk	% RD	% Correct	PPP	NPP	Sensitivity	Specificity
Scanlon and Vellutino (1996)	K-1	Letter Names Word Recogn.	1000	.41							
		Letter Names Word Recog'n Number Names Counting/Math PA (segment) and 23 others	1000	.49							
Share et al. (1984)	K-1	Letter Names PA (segment) Sent. Memoryy Copy Letters sex	479	.63							
Wells et al. (1984)	K-1	Conc. Print Oral Lang.	31	.71							
Samples of Children with Early Language Impairment											
Bishop and Adams (1990)	K-2	PIQ Lang. Production Lang. Compreh. Speech Prod.	81	.50							
Catts (1991)	K-1	PA (Deletion) RSN-Objects	41	.50			83	77	89		

Study	Grade (From-To)	Combined Predictors	N	R^2	% At Risk	% RD	% Correct	PPP	NPP	Sensitivity	Specificity
Samples Containing Many Children with Family History of RD											
Elbro et al. (1996)	K-2	Letter Names PA (Deletion, PA (Match 1st Sound) Distinctiveness of Phonol. Repres'ns of Words Speech Prod.	90	—	19	26	84	76	89	57	94
Scarborough (1989)	K-2	Family History Confr. Naming Letter Names PA (Rhyme, Match 1st Sound) Let-Sound	62	.43	39	37	82	75	97	78	95

RD = Reading Disability; PA = Phonological Awareness; RSN = Rapid Serial Naming.
% At Risk = percentage of sample below chosen cutoff on combined predictor measures.
% RD = percentage of sample below chosen cutoff on outcome reading measure.
% Correct = percentage of sample whose outcome status (RD or not) was correctly predicted.
PPP = Positive Predictive Power: percentage of children designated as at risk who became RD.
NPP = Negative Predictive Power: percentage designated as not at risk who did not become RD.
Sensitivity = percentage of the RD children who had been correctly identified as at risk.
Specificity = percentage of the non-RD children who had been correctly identified as not at risk.