Published in final edited form as:
J Learn Disabil. 2010 ; 43(4): 332–345. doi:10.1177/0022219410369067.

Kindergarten Predictors of Second vs. Eighth Grade Reading Comprehension Impairments

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Abstract

Multiple studies have shown that kindergarten measures of phonological awareness and alphabet knowledge are good predictors of reading achievement in the primary grades. However, less attention has been given to the early predictors of later reading achievement. This study used a modified best-subsets variable-selection technique to examine kindergarten predictors of early versus later reading comprehension impairments. Participants included 433 children involved in a longitudinal study of language and reading development. The kindergarten test battery assessed various language skills in addition to phonological awareness, alphabet knowledge, naming speed, and nonverbal cognitive ability. Reading comprehension was assessed in second and eighth grades. Results indicated that different combinations of variables were required to optimally predict second versus eighth grade reading impairments. While some variables effectively predicted reading impairments in both grades, their relative contributions shifted over time. These results are discussed in light of the changing nature of reading comprehension over time. Further research will help to improve the early identification of later reading disabilities.

Numerous studies have investigated early predictors of reading achievement in the primary grades. Such studies have involved a variety of factors, including environmental and demographic factors and measures of oral language, visual perception, fine motor skills, attention, and nonverbal intelligence (Badian, 1998; Catts, Fey, Zhang, & Tomblin, 2001; Elbro, Borstrom, & Peterson, 1998; Lonigan, Burgess, & Anthony, 2000; Scarborough, 1989, 2001; Schatschneider, Fletcher, Francis, Carlson, & Foorman, 2004; Share & Leikin, 2004). Across studies, there is converging evidence that alphabet knowledge and phonological awareness are among the strongest kindergarten predictors of young children's early reading skills (Catts et al., 2001; Elbro et al., 1998; Lonigan et al., 2000; Scarborough, 1989, 1998a, 2001; Schatschneider et al., 2004). These skills are also foundational for the development of word reading ability. Children must be able to recognize individual letters of the alphabet in order to later recognize the letter patterns that represent words. Likewise, they must have phonological awareness, or the knowledge of the sound structure of the language, in order to learn to map speech sounds onto alphabet letters.

These findings have had a great impact on educational policy and practice. For example, the Reading First initiative, enacted with the No Child Left Behind Act of 2001, provides federal funds for schools that utilize "research-based" methods to teach reading in the primary grades. The research-based methods that are endorsed are primarily code-based methods which incorporate instruction in phonological awareness and letter-sound correspondences. In addition, many schools utilize kindergarten screening batteries that rely on measures of phonological awareness and alphabet knowledge to identify children at risk for reading difficulties, such as the PALS: Phonological Awareness Literacy Screening (Invernizzi, Juel, Swank, & Meier, 1997), or the Texas Primary Reading Inventory screen

(Texas Education Agency, 2000). Additional programs, such as the Dynamic Indicators of Basic Early Literacy Skills (DIBELS; Good & Kaminski, 2002) have also been developed to measure progress in phonological awareness, alphabet knowledge, and word reading skills, as well as to provide effective treatment to children who exhibit delays in these areas.

Because of their relationship to word decoding skills, alphabet knowledge and phonological awareness are good predictors of early reading outcomes. However, we do not necessarily expect them to be the best predictors of reading achievement in the later grades, when measures of reading are more heavily influenced by comprehension skills. The simple view of reading states that reading comprehension is the product of word reading and language comprehension (Gough, Hoover, & Peterson, 1996; Gough & Tunmer, 1986; Hoover & Gough, 1990). Studies show that the combination of these two factors accounts for most of the variance in reading comprehension across grades, but the relative importance of each factor in predicting reading comprehension changes over time (Catts, Hogan, & Adlof, 2005; Francis, Fletcher, Catts, & Tomblin, 2005; Gough et al., 1996). Whereas word reading is most highly correlated with reading comprehension in the early grades, language comprehension shows a higher correlation in later grades. In fact, a recent study employing structural equation modeling to examine the simple view of reading found that in eighth grade the constructs of language comprehension and reading comprehension were indistinguishable. That is, all of the reliable variance in eighth grade reading comprehension was shared with eighth grade language comprehension (Adlof, Catts, & Little, 2006). More recently, twin studies examining the heritability of word reading and reading comprehension deficits have also concluded that the two types of difficulty arise from separate genetic sources (Keenan, Betjemann, Wadsworth, DeFries, & Olson, 2006). Thus, it is possible that different behavioral screening measures may be needed to identify children at risk for each source of reading difficulty.

Just as the relative importance of word reading and language comprehension in predicting reading comprehension changes across grades, so too do the profiles of children identified as poor readers. Most poor readers in the early grades have significant difficulties with word recognition. Some of these children remain poor readers across the grades, whereas others become good comprehenders later on (Catts, Hogan et al., 2005; Leach, Scarborough, & Rescorla, 2003). However, in later elementary grades, a subgroup of new poor readers begins to emerge who display poor reading comprehension in spite of good word reading skills (Badian, 1999; Catts, Adlof, & Ellis Weismer, 2006). These children, referred to as “poor comprehenders” generally display good phonological skills, but show difficulty on measures of broader language skills, including syntax, semantic, and narrative tasks (Catts et al., 2006; Nation, Clarke, Marshall, & Durand, 2004). This subgroup of poor readers could be problematic for early identification protocols containing tasks most strongly related to word reading development. Such protocols might under-identify children likely to become poor comprehenders.

Compared to the number of studies examining the predictors of early reading outcomes, few studies have examined early predictors of reading comprehension in adolescence (but see Badian, 2001; Scarborough, 1998b). One of the largest and most recent studies involved 200 Danish children who were followed longitudinally from three to 16 years of age (Frost, Madsbjerg, Niedersoe, Olofsson, & Moller Sorensen, 2005). At age three, the children completed brief oral language screens, including coarse assessments of phonology, vocabulary, sentence formation, and sentence comprehension that were administered by speech therapists. Phonological awareness screens were conducted at age six, and reading achievement was assessed in second, third, fourth, sixth, and ninth grades. Different tasks were used to assess reading achievement in different grades. In second grade, children were asked to read single words, whereas in third through ninth grades, children read sentences and short passages and answered comprehension questions. Results showed that phonological awareness at age six was the strongest predictor of reading scores in second grade, when reading achievement was measured by a word reading test. However, general language ability at age three was the better predictor of reading scores in every other grade, when reading comprehension was assessed. Thus, the results of this study by Frost and colleagues suggest that different kinds of language and cognitive skills are important for predicting reading in early versus later grades.

The purpose of the current study was to compare and contrast the best predictors of early and later reading impairments in a large longitudinal sample of American students followed from kindergarten through eighth grade. Our operating hypothesis was that kindergarten measures of phonological processing and alphabet knowledge would be good predictors of early reading outcomes, whereas kindergarten measures of broader language skills (e.g., vocabulary, grammar, and narrative skills) would be better predictors of later reading outcomes.

Method

Participants

This study involved 433 participants who were followed from kindergarten through eighth grade. These participants were initially recruited as part of an epidemiologic study of language impairment in kindergarten (Tomblin, Records, Buckwalter, Zhang, Smith, & O'Brien, 1997). The original epidemiologic study included a stratified cluster sample of 7,218 children. Following the completion of the epidemiologic study, a subsample of children was recruited to participate in a longitudinal investigation conducted by the Child Language Research Center (Tomblin, 1995). Because the primary purpose of the Center was the study of language impairments, all children who displayed language impairments in kindergarten were asked to participate. In addition, a random sample of children without impairments was also recruited. The initial longitudinal sample included 604 children: 328 children with language impairments in kindergarten and 276 children without language impairments in kindergarten. These children, segregated by diagnostic category, did not differ significantly in terms of demographic characteristics or language and cognitive abilities from those children from the epidemiologic sample who did not participate in the longitudinal study. Complete data on all measures was available for 433 participants through the eighth grade.

Because the sample includes more children with language impairments than would be expected in the normal population, a weighting procedure was used in all analyses, which allowed us generalize the results to the normal population. This weighting procedure used information from the epidemiologic study to estimate the likelihood that a subject with a given language, nonverbal cognitive, and gender profile would appear in the normal population, and then weighted his or her scores accordingly. Thus, children with language and cognitive impairments received proportionally less weight than children who showed typical language and cognitive development. Theoretically and statistically, the results of this study should not differ from those that would be obtained if the same analyses were conducted using a random sample from the normal population. The weighting procedure has been described in more detail in other published works involving this sample (e.g., Catts et al., 2006; Catts, Fey, Zhang, & Tomblin, 1999).

Measures

In kindergarten, children completed a battery of tests assessing language skills such as grammar, vocabulary, and narrative skills, as well as other known predictors of early reading including phonological awareness, rapid naming, and nonverbal IQ. These measures are listed and described in Table 1. Mother's level of education was also obtained, with the raw score representing the number of years of formal education. For the analyses in this study, raw scores (rapid naming, syllable/phoneme deletion, mother's level of education) or standard scores (all other tests except letter identification) were transformed to *z*-scores using the weighted sample means and standard deviations.

In second and eighth grades, reading comprehension was assessed using three tests. Two tests were administered in both grades: The Passage Comprehension subtest of the *Woodcock Reading Mastery Test-Revised* (*WRMT-R*; Woodcock, 1987) assessed children's ability to read and complete cloze sentences, and the Comprehension portion of the *Gray Oral Reading Test-3* (Wiederholt & Bryant, 1994) assessed children's ability to answer multiple choice questions about a passage. A third test in each grade assessed children's ability to answer open-ended questions about a passage. Because the *Diagnostic Achievement Battery-2* (Newcomer, 1990), administered in second grade, was not appropriate for use with eighth graders, this test was replaced with the *Qualitative Reading Inventory-2* in the eighth grade battery (Leslie & Caldwell, 1995). In each grade, *z*-scores were created for each test using the weighted sample mean and standard deviation; these *z*-scores were then combined to form the composite reading comprehension *z*-scores.

Word recognition was also assessed in second and eighth grades, using the Word Identification and Word Attack subtests of the *WRMT-R.* Although these scores were not included in the analyses for this study, descriptive statistics are provided as a basis for comparison of reading skills. Word recognition composite scores are also reported as *z*-scores based on the weighted sample mean and standard deviation.

Procedures

Fourteen examiners participated in the administration of the test battery in kindergarten, and another three participated in the administration of the test batteries in second and eighth grades. Seven of the examiners were certified speech-language pathologists, and the remaining had undergraduate degrees in speech and hearing (n = 3) or education (n = 7). Certified speech-language pathologists administered all of the language measures in the study. In addition, all examiners received approximately one week of training by the investigators on the administration of the testing protocols. Testing was conducted in specially designed vans parked at the participants' schools or homes.

Results

Descriptive Statistics

Descriptive statistics for each measure are displayed separately for second and eighth grade good and poor readers in Table 2. Children were classified as having a reading impairment in a given grade if their reading comprehension composite scores were at least one standard deviation below the mean. Based on this criterion, there were 128 children classified as having a reading impairment in second grade: 54 females (38.2% weighted) and 74 males (61.8% weighted). In eighth grade, 135 children met the criterion for reading impairment including 73 females (54.6% weighted) and 62 males (45.5% weighted). Of the 135 eighth graders who were classified as reading impaired, 57 (41.8% weighted) had reading comprehension composite scores that were above this criterion in second grade. Likewise, of the 128 second graders who were considered reading impaired, 50 (48.5% weighted) were good readers in eighth grade.

Correlation Analysis

We first examined the relationships between kindergarten language and pre-literacy skills and later reading outcomes in the full sample of participants using Pearson's product-moment correlations, as listed in Table 3. Most of the kindergarten measures showed medium to moderately high correlations with second and eighth grade reading comprehension. It is interesting to note that the overall correlations between kindergarten and eighth grade measures were only slightly lower than the correlations between kindergarten and second grade measures. The kindergarten measures that showed the strongest correlations with second grade reading comprehension were letter identification and sentence imitation (both $r = .61$, $p < .001$), but several other measures also showed strong ($r \geq .5$) correlations, including phoneme deletion, grammatical completion, oral vocabulary, nonverbal IQ, grammatical understanding, and rapid naming. The kindergarten measures that showed the strongest correlations with eighth grade reading comprehension were sentence imitation and grammatical completion (both $r = .56$, $p < .001$), followed by grammatical understanding, oral vocabulary, and rapid naming. As we hypothesized, kindergarten letter identification was much less correlated with eighth grade reading comprehension ($r = .36$, $p < .001$) than with second ($r = .61$, $p < .001$). However, kindergarten phoneme deletion retained a moderately high correlation with eighth grade reading comprehension ($r = .49$, $p < .001$).

Best-Subsets Logistic Regression Analysis

The results of the correlation analysis indicate several kindergarten measures would be good predictors of second and eighth grade reading comprehension status. However, no single measure appeared to provide optimal prediction by itself, accounting for at most 37.2% of the outcome variance in second grade. Furthermore, because the correlations were derived based on individual differences across the full distribution of reading comprehension scores, they alone do not provide the specific information we are looking for in terms of a dichotomous discrimination between "good" and "poor" readers in each grade.

We addressed this issue by using logistic regression to identify predictors of reading impairment status. Logistic regression is similar to traditional linear regression, except that binary scores can serve as the dependent variable. Linear regression is used to determine how much variance in a dependent variable can be explained by a given set of predictors. In contrast, with logistic regression, predictors account for the probability of a particular outcome of the dichotomous dependent variable. Because we were primarily interested in predictors of reading impairment status ("impaired" vs. "not impaired"), we dichotomized the reading comprehension composite scores, using the cut-off criterion of one standard deviation below the mean.

We employed a modified best-subsets variable-selection approach (Hosmer, Jovanovic, & Lemeshow, 1989; Hosmer & Lemeshow, 2000; King, 2003) to identify the optimal predictors of reading impairment in second and eighth grade. With this approach, all possible logistic regression models are generated, allowing the researcher to evaluate individual models based on model fit and parsimony as well as theoretical and practical issues. Such an approach is preferred over other fully automated model building approaches, such as stepwise procedures, where a computer algorithm selects a "best" fitting model but the researcher is unable to evaluate how alternative models would work in prediction.

For every set of p predictor variables, there are $2^p - 1$ models that can be generated. In our case, with 12 predictor variables, 4,095 models were generated for each grade. We used two summary statistics to determine the most appropriate model for each grade. First, Mallow's C_p, a measure of predictive squared error, was used to evaluate both model fit and parsimony. A good fitting model should have a C_p value equal to or less than $p + 1$. Second, we used the area under the receiver operating characteristic (ROC) curve to evaluate the clinical utility of the models. A ROC curve is a plot of the true positive rate (sensitivity) against the false positive rate (1−specificity) for every possible cut-point of a given model, and it serves as a measure of prediction accuracy. The area under the curve (AUC) ranges from .5 for models that provide no better than chance prediction to 1.0 for models that perfectly predict the outcome status. The AUC is sometimes referred to as the "concordance rate" because it reflects the percentage of accurate classifications among all possible pairs of subjects from each diagnostic group in the sample. For example, if the AUC for a model in our study was .9, then for 90% of all possible pairs of children in the sample, one classified with a reading impairment and one without, the model correctly assigned a higher probability of reading impairment to the child who was truly reading impaired. Typically, AUC values between .7 and .8 are considered "acceptable," values between .8 and .9 are considered "excellent," and values above .9 are considered "outstanding" (Hosmer & Lemeshow, 2000).

Second Grade—Selection of the best second grade models proceeded as follows. After all of the possible models were generated, we limited our examination to models that had an acceptable C_p value. Of all 4,095 possible models, 4,089 (99.9%) had acceptable C_p values.

We then generated a list of "best" models containing between one and 12 predictors based on the AUC. Beginning with the single-predictor models, the "best" model contained only letter identification, and its AUC was .821. Thus, in 82.1% of all possible pairs of children from each outcome group, this model correctly assigned a higher probability of reading impairment to the children who actually displayed the reading impairment in second grade. We continued to identify other best models containing more predictors so long as the addition of predictors increased the AUC by at least .01 (or 1% concordance rate) over the best models with one less predictor. This cut-off was chosen because increasing the number of predictors (i.e., clinical tests) would not be warranted if it did not increase accuracy in prediction to a clinically meaningful level. The best four-predictor model produced an AUC value of .897 and its predictors were sentence imitation, letter identification, mother's education level, and rapid naming. The best five-predictor model contained those same predictors and added phoneme deletion, producing an AUC value of .903. Because the AUC value increased by less than .01, and no six- to 12-predictor models increased the AUC by more than .01 over the best four-predictor model, we discontinued the examination of larger models, with one exception. We looked to find the highest AUC value resulting from all available models. Several models produced the highest AUC (.906), but the model with the fewest predictors contained sentence imitation, letter identification, mother's education level, rapid naming, phoneme deletion, narrative comprehension, nonverbal IQ, and picture vocabulary.

Next, we examined whether any other models containing the same number of predictors could be considered nearly as good as the "best" models. These "near-best" models were identified if their AUC values differed from the best models with the same number of predictors by no more than .01 (or 1% concordance rate). Again, this value was chosen because models differing less than .01 from the best model would have nearly as good clinical utility. The best and near-best second grade models containing one- to 12-predictors are listed in Table 4.

Finally, we examined the relative strength of the predictors in the best and near-best models by comparing their standardized regression coefficients within a given model. Because more than the available degrees of freedom had been used to fit all possible models, observed probability values, and hence statistical significance tests would have been invalid.

Therefore, we used a bootstrap procedure to obtain the robust standard error of each regression coefficient and its 95% confidence intervals from 2,000 resamples. The bootstrap (Efron, 1982) is a statistical method for approximating the sampling distribution of an estimate by sampling with replacement from the original sample. Table 5 lists the standardized and unstandardized regression coefficients (β and B, respectively) odds ratios, and confidence intervals associated with the best and near-best models for second grade. As can be seen in Table 5, although the letter identification measure was best at discriminating between good and poor readers (determined by the AUC value), sentence imitation was consistently assigned the highest β value in every model.

Eighth Grade—Eighth grade models were examined using the same approach as used in second grade. In contrast to second grade, only 114 of the 4,095 possible models showed acceptable C_p values. Therefore, although kindergarten measures were nearly as highly correlated with eighth grade reading comprehension as with second grade, we needed more predictors to optimally differentiate between “good” and “poor” readers in eighth grade. The model fit was poor for any models that contained one, two, three, or four predictors. As shown in Table 6, the best five-predictor model, which produced an AUC value of .862, contained phoneme deletion, grammatical completion, nonverbal intelligence, mother’s education level, and sentence imitation. Two other five-predictor models resulted in AUC values that differed by less than .01 from the best model. These models substituted rapid naming for either mother’s education level or grammatical completion. Adding additional predictors to the best five-predictor model did not increase the AUC by .01 or more over the best five-predictor model. The highest AUC value (.868) was achieved with an eight-predictor model containing phoneme deletion, grammatical completion, nonverbal intelligence, sentence imitation, mother’s education level, narrative expression, narrative comprehension, and oral vocabulary. Table 7 presents the bootstrap results for the best and near best eighth grade models.

Discussion

Although many screening batteries exist to identify children at risk for reading problems in the early elementary grades, few studies have examined early predictors of later reading comprehension. Because both the factors that account for variance in reading comprehension as well as the profiles of children identified as having reading impairments change over time, we hypothesized that different kindergarten measures would predict reading comprehension problems in eighth grade than in second grade. Specifically, we expected that alphabet knowledge and phonological awareness would be important predictors of reading status in second grade, whereas measures of broader language skills (e.g., vocabulary, grammar, and narrative skills) would be needed to best predict reading impairments in eighth grade.

The results of both the correlation and logistic regression analyses indicated that, of all available kindergarten measures in this study, the most accurate prediction of second grade reading status required the inclusion of letter identification and sentence imitation measures. These measures had the highest correlation with second grade reading comprehension; they were present in all 22 “best” and “near best” second grade models; and they were consistently assigned the largest β values in each of these models. In fact, a model consisting of these measures alone produced an AUC value of .871. However, if one wished to increase the area under the curve, the best additional predictor would be mother’s education level, which increased the AUC to .887. Several other measures provided nearly as good accuracy as the third predictor in a three-predictor model, including rapid naming, phoneme deletion, nonverbal IQ, oral vocabulary, grammatical understanding, and narrative comprehension. Four-predictor models, including letter identification, sentence imitation, and mother’s level of education or rapid naming as the first three variables, achieved AUC values of .888 to .897, nearing an "outstanding" level of discrimination (Hosmer & Lemeshow, 2000). Finally, after four predictors were in the model, there was little clinical utility in adding additional measures.

Turning to the results for eighth grade, the results of the correlation analyses suggested that several variables would be good predictors of eighth grade outcomes. However, in contrast to second grade, where good model fit was achieved for single-predictor logistic regression models, acceptable model fit for eighth grade prediction required at least five predictors. These included phoneme deletion, sentence imitation, nonverbal IQ with mother's education level, grammatical completion, and/or rapid naming. Phoneme deletion was consistently assigned the largest β value in each of the "best" and "near best" eighth grade models, followed by grammatical completion and nonverbal intelligence (except for one model that did not include grammatical completion). Because the AUC value did not increase substantially when additional predictors were included in the model, there was little clinical utility in adding other measures.

Thus, our initial hypothesis was partially confirmed. Alphabet knowledge, as measured by the letter identification task, was one of the strongest predictors of second grade reading status, and it did not enter as a predictor of eighth grade reading status. Likewise, the best prediction of eighth grade status required the inclusion of predictors such as grammatical completion and nonverbal intelligence that were less important for second grade prediction. However, we were surprised that the phoneme deletion task was one of the most important predictors of eighth grade status. In fact, phoneme deletion appeared to be more important for predicting eighth grade than second grade reading outcomes, even though its correlation with second grade reading comprehension was stronger than its correlation with eighth grade reading comprehension. Phoneme deletion appeared in only a few of the selected best and near best second grade models but all of the corresponding eighth grade models. Furthermore, phoneme deletion was consistently assigned the largest β value in every eighth grade model.

There are several possible explanations for these findings. First, it may be that because there were so many "good" kindergarten predictors of second grade reading status, phoneme deletion was just barely "beaten out" as a predictor by other measures. Support for this explanation is provided by the fact that phoneme deletion by itself showed an "acceptable" level of discrimination of second grade reading status. When phoneme deletion was entered as a single predictor in a second grade model, its AUC was .768, ranking it third behind single predictor models including letter identification (.821) or sentence imitation (.798). Likewise, when phoneme deletion was included in models containing three or more predictors, it was always assigned the third highest β value, behind sentence imitation and letter identification. The scores on the phoneme deletion measure also showed slight floor effects compared to scores on the letter identification and sentence imitation measures. Thus it is possible that the task demands of the phoneme deletion measure were somewhat high for predicting second grade reading outcomes but more appropriate for predicting later reading outcomes (c.f., Catts, Petscher, Schatschneider, Bridges, & Mendoza, 2008, for a discussion of the influence of floor effects on the predictive validity of universal screening measures). Lastly, it is possible that the phoneme deletion task taps other language and cognitive skills, in addition to phonological awareness, that are more important for predicting eighth grade comprehension than second. Further research is needed to examine this possibility.

Our finding that sentence imitation was one of the top predictors of second grade reading skill converges with findings from previous studies (e.g., Alloway & Gathercole, 2005;

Badian, 1982; Scarborough, 1998b). Sentence imitation tasks are frequently found in studies of language disabilities, and they are believed to tap a variety of language domains, such as syntax and semantics, as well as verbal working memory span (Conti Ramsden, Botting, & Faragher, 2001; Kamhi & Catts, 1986; Redmond, 2005). Because sentence imitation tasks draw on a diverse array of language skills, they may in some ways be considered an “all-purpose” measure for predicting both language and reading performance, offering fairly accurate prediction with a single measure. However, few commercially available literacy screening instruments include sentence imitation measures. Why would test developers not include such a useful predictor? It is possible that the very fact that makes sentence imitation a good predictor—that it draws on a wide range of language and cognitive skills—is part of the reason. Although difficulty repeating sentences accurately may be an indicator of language or memory weaknesses, such a measure does not offer specific information about those weaknesses or indicate what type of intervention would be most appropriate. Sentence imitation is not a skill that would likely be targeted in intervention. On the other hand, phonological awareness and alphabet knowledge are foundational skills for learning to decode text. When a child shows difficulty with those tasks, intervention is designed to improve those same skills.

Although poor performance on sentence imitation tasks does not directly point to clear intervention targets, the results of the eighth grade analyses indicate an added benefit to including sentence imitation tasks in early reading screening batteries. In addition to being one of the top predictors of reading status in second grade, sentence imitation was also included in the best and near-best models predicting reading status in eighth grade. Thus, by including sentence imitation in an early reading screening battery, one may be better able to make predictions about both early and later reading achievement. The earlier parents or teachers learn that a child has weak language skills, the more opportunities they have to provide language enrichment that may reduce or prevent later comprehension difficulties.

Mother’s education level was another predictor included in both second and eighth grade models. On average, mothers of good readers had two more years of education than mothers of poor readers for both second and eighth grades. There is a great deal of evidence for a genetic basis for reading and language impairments (Harlaar, Spinath, Dale, & Plomin, 2005; Olson, 2007; Raskind, 2001), but it is not clear whether the finding in this study is related to biological or environmental factors, as all of the mothers of children in this study were biological mothers, sharing both genes and environment. However, the findings indicate that including information about mother’s education level can improve the accuracy of identification of both early and later reading impairments without increasing cost or testing time.

Two measures that were important for the prediction of eighth grade reading impairments were rarely, if ever, included among the best predictors of second grade impairments, namely grammatical completion and nonverbal intelligence. We believe that this finding is due to qualitatively different reading impairments in second versus eighth grade, with those in second grade being more related to word reading abilities, and those in eighth grade being more related to overall language abilities and higher-level thinking. Although the language deficits observed in eighth grade poor readers are heterogeneous, the grammatical completion subtest was the most accurate non-phonological kindergarten language predictor. Notably, tests including measures of grammatical skills are often more sensitive indicators of language impairments than measures of vocabulary (Spaulding, Plante, & Farinella, 2006). Botting, Simkin, and Conti-Ramsden (2006) provided additional evidence for the importance of grammatical skills in predicting future reading achievement in their longitudinal study of children with language impairments. In this group of children, measures of receptive and expressive syntax, but not vocabulary, taken at age 7 accounted for unique variance in reading comprehension at age 11, after controlling for age, nonverbal intelligence, and reading accuracy. Likewise, nonverbal intelligence may have a more important role in predicting later reading impairments than earlier reading impairments due to the higher level critical thinking and problem solving skills required for answering comprehension questions in later grades. Such skills would be less important for comprehending reading materials in the primary grades, which often focus on narrative texts.

Another interesting finding within our sample relates to the proportion of males and females who were poor readers in second versus eighth grades. Although we did not include gender in the logistic regression analyses, we were intrigued by the shift in the proportion of males and females in the poor reader groups in second and eighth grades. There is a general acceptance that dyslexia affects more males than females, although the magnitude of the difference is generally small (e.g., 1.5 to 1) and depends on the diagnostic criteria employed (Rutter et al., 2004; Shaywitz, Shaywitz, Fletcher, & Escobar, 1990; but see Share & Silva, 2003). In our study, we found that the poor reader sample (including heterogeneous reading impairments) was comprised of more males in second grade (61.8% males vs. 38.2% females), but more females in eighth grade (45.4% males versus 54.6% females). Similar findings have been reported by Wright, Fields, and Newman (1996), who reported a higher percentage of girls showing a late-emerging, as opposed to persistent, dyslexia profile. In addition, Yuill and Oakhill (1991) and Nation and Snowling (1998) have shown that girls are significantly more likely than boys to be classified as poor comprehenders.[1] We note that poor comprehenders, by nature, are typically identified in the later elementary school years. Thus, the converging evidence seems to suggest that there may be different developmental trajectories for reading impairments in males versus females.

This study is unique in examining such a large number of early language and cognitive measures and early and later reading outcomes, but it comes with several limitations that should be acknowledged. First, although data collection occurred longitudinally, our analyses were retrospective, and the measures administered in kindergarten were not selected solely for this purpose. It is possible that employing other kindergarten language measures would result in different degrees of diagnostic accuracy. Second, there is a possibility that some of the changes in reading status may have been related to the change in reading comprehension measures between second and eighth grade. Recall that three comprehension tests were administered in each grade and scores were combined to create a composite. Two of the three tests were used in both second and eighth grades, but one was different (i.e., the *DAB-2* in second grade was replaced with the *QRI-3* in eighth grade). Both of these tests were of similar format, in that participants were asked to answer open-ended questions about texts they had read. Although we cannot rule out the possibility that some differences in reading outcomes were due to test differences, the similar test format as well as the creation of a composite score at each grade should mitigate any major differences between the two tests.

Summary and Implications

Overall these results have important implications for both research and practice. First, current screening batteries, with a main focus on phonological awareness and alphabet

[1]Because others have found that the diagnostic criteria used to define reading impairments can influence the ratio of males to females identified (e.g., Rutter et al., 2004), we examined the percentage of males vs. females who would be considered reading impaired if a −1.5 standard deviation cut-off criterion was used to diagnose reading impairment. Using this criteria, 59.1% of our second grade poor readers were male (40.9% female), and 51.1% of our eighth grade poor readers were male (48.9% female). Thus, the pattern of results was similar in that girls were more likely to be identified as poor readers in eighth grade than in second grade, even though the proportion of males vs. females who were poor readers in eighth did not favor females as much under the stricter criterion.

knowledge, are likely to miss children who are at risk for reading comprehension deficits that emerge in the later grades. Our intention in this paper is not to downplay the role of phonological awareness and alphabet knowledge in predicting reading outcomes, but rather to highlight the importance of including other predictors, including measures of language and nonverbal cognitive skills, that aid in the early identification of poor readers who might otherwise "fly under the radar." These children include both poor comprehenders, who are by nature identified in the later elementary school years, and other late-emerging poor readers with heterogeneous deficits that might also be missed by early reading screens. Second, more research is needed to determine whether other early measures of language and cognitive ability can provide better sensitivity and specificity in predicting later reading problems. It is likely that prediction from kindergarten to as late as eighth grade will never reach the level of accuracy as can be achieved for earlier grades. This is to be expected given that educational practices and interventions should have an effect on reading outcomes. However, with additional research into more sensitive predictors, we can improve our level of prediction accuracy and so that prevention and intervention resources can be dedicated to the children who are most in need.

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Table 1

Kindergarten Measures

Oral Language Skills	
Test of Language Development-2: Primary **(TOLD-2:P; Newcomer & Hammill, 1988)**	
Picture Vocabulary	The child points to pictures named by the examiner.
Oral Vocabulary	The child names pictures presented by the examiner.
Grammatical Understanding	The child points to the picture that illustrates the sentence spoken by the examiner. Tests understanding of grammatical concepts such as past tense, plurals, and negation.
Sentence Imitation	The child repeats sentences spoken by the examiner. Sentences increase in grammatical complexity.
Grammatical Completion	The child supplies correct word to complete sentence spoken by examiner. Tests use of plurals, past tense, comparatives and superlatives, etc.
Narrative Skills (Culatta, Page, & Ellis, 1983)	
Narrative Expression	The child retells a narrative read by the examiner. The raw score is the total number of story propositions recalled.
Narrative Comprehension	The child answers 10 comprehension questions about a narrative read by the examiner.
Phonological Awareness	
Syllable/Phoneme Deletion	The child repeats a word spoken by the examiner, then deletes specified sound/syllable, and says remaining word. Example, "Say *cowboy*. Now say cowboy without the *cow*."
Letter Knowledge	
Woodcock Reading Mastery Test-Revised **(WRMT-R**; Woodcock, 1987)	
Letter Identification	The child names printed letters of the alphabet.
Naming Speed	
Rapid Naming of Colored Animals	The child says the color and name of a series of colored animals (e.g., "blue horse, red cow, black pig") as quickly as possible.
Nonverbal IQ	
Wechsler Preschool and Primary Scale of Intelligence-Revised **(WPPSI-R; Weschler, 1989)**	
Nonverbal IQ was measured as a composite z- score based on two measures:	
Block Design	The child reproduces geometric designs using colored blocks.
Picture Completion	The child identifies the missing component of a picture. For example, the child is shown a picture of a face without an ear and responds, "ear."

Table 2

Descriptive Statistics for Second and Eighth Grade Good and Poor Readers

	2nd Grade Poor Readers (*n* = 128)		2nd Grade Good Readers (*n* =305)		8th Grade Poor Readers (*n* = 135)		8th Grade Good Readers (*n* =303)	
Kindergarten Predictor	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Letter Identification	−1.07	.67	.18	.89	−.55	.73	.07	1.00
Syllable/Phoneme Deletion	−.97	.37	.18	1.04	−.92	.42	.17	1.05
Rapid Naming of Animals	.92	.82	−.22	.96	.81	.78	−.20	1.01
Nonverbal IQ	−.71	.77	.16	1.02	−.84	.74	.19	1.01
Picture Vocabulary	−.76	.73	.15	1.05	−.61	.77	.12	1.08
Oral Vocabulary	−.69	.50	.12	1.04	−.65	.51	.11	1.05
Sentence Imitation	−1.00	.45	.24	1.11	−.86	.54	.21	1.14
Grammatical Understanding	−.90	.68	.13	1.03	−.87	.69	.12	1.05
Grammatical Completion	−.85	.69	.17	1.06	−1.01	.68	.20	1.02
Narrative Comprehension	−.46	.71	.11	1.11	−.30	.63	.07	1.16
Narrative Expression	−.87	.87	.06	.98	−.76	.87	.04	1.01
Mother's Education Level	−.60	.54	.14	1.10	−.51	.51	.12	1.12
Reading Outcome								
2nd Reading Comprehension	−1.54	.38	.32	.82	−1.01	.66	.20	.98
2nd Word Recognition	−1.32	.59	.27	.87	−.86	.72	.17	1.00
8th Reading Comprehension	−1.06	.60	.16	.98	−1.52	.34	.25	.85
8th Word Recognition	−1.19	.73	.25	.83	−1.02	.75	.21	.89

Table 3

Correlations between kindergarten predictors and second and eighth grade reading comprehension scores ($N = 433$)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Letter Identification	1.00													
2. Phoneme Deletion	.46	1.00												
3. Rapid Naming	−.44	−.43	1.00											
4. Nonverbal IQ	.36	.41	−.36	1.00										
5. Picture Vocabulary	.34	.38	−.36	.37	1.00									
6. Oral Vocabulary	.36	.46	−.37	.35	.46	1.00								
7. Sentence Imitation	.39	.61	−.44	.36	.55	.57	1.00							
8. Grammatical Understanding	.47	.51	−.38	.44	.41	.46	.51	1.00						
9. Grammatical Completion	.37	.54	−.42	.35	.50	.54	.65	.50	1.00					
10. Narrative Expression	.20	.25	−.26	.24	.33	.39	.36	.18	.38	1.00				
11. Narrative Comprehension	.32	.36	−.37	.24	.33	.40	.41	.27	.50	.36	1.00			
12. Mother's Education Level	.28	.35	−.29	.30	.30	.36	.35	.35	.31	.24	.21	1.00		
13. 2nd Grade Reading Comprehension	.61	.59	−.52	.53	.47	.56	.61	.53	.57	.35	.42	.41	1.00	
14. 8th Grade Reading Comprehension	.36	.49	−.51	.48	.45	.53	.56	.54	.56	.28	.41	.39	.70	1.00

All $p < .001$

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Table 4

Predictors, C_p values, and AUC values for second grade best and near best models

Model #	Predictor(s)	C_p	AUC
1	LI	−4.643	.821
2	SI, LI	−4.708	.871
3	SI, LI, ME	−3.396	.887
4	SI, LI, RN	−2.934	.882
5	SI, LI, PD	−3.839	.881
6	SI, LI, NI	−2.803	.880
7	SI, LI, OV	−2.945	.878
8	SI, LI, GU	−2.767	.877
9	SI, LI, NC	−2.770	.877
10	SI, LI, ME, RN	−1.607	.897
11	SI, LI, PD, ME	−2.423	.895
12	SI, LI, ME, NC	−1.503	.893
13	SI, LI, ME, OV	−1.555	.892
14	SI, LI, ME, PV	−1.568	.891
15	SI, LI, PD, RN	−2.084	.891
16	SI, LI, ME, NI	−1.456	.890
17	SI, LI, ME, GU	−1.418	.889
18	SI, LI, ME, NE	−1.423	.889
19	SI, LI, ME, GC	−1.409	.888
20	SI, LI, ME, PD, RN	−.654	.903
21	SI, LI, PD, ME, RN, NC, NI, PV	5.207	.906

Note. SI = Sentence imitation; LI = Letter identification; ME = Mother's education level; RN = Rapid naming; PD = Phoneme deletion; NI = Nonverbal IQ; OV = Oral vocabulary; GU = Grammatical understanding; NC = Narrative comprehension; PV = Picture vocabulary; NE = Narrative expression; GC = Grammatical completion. Predictors are listed in order of the absolute value of β, as determined by the bootstrapping procedure (see Table 5).

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Table 5

Bootstrapped regression coefficients, odds ratios and confidence intervals for second grade best and near best models.

Model #	Predictor	*β*	*B*	95% CI *B*		Odds Ratio	95% CI Odds Ratio	
1	LI	.85	1.58	1.23	1.93	4.85	3.43	6.86
2	SI	.94	1.58	1.13	2.04	4.86	3.09	7.66
	LI	.75	1.39	.99	1.78	4.01	2.70	5.95
3	SI	.98	1.62	1.12	2.12	5.04	3.06	8.32
	LI	.70	1.28	.83	1.73	3.59	2.29	5.63
	ME	.46	.81	.14	1.48	2.24	1.15	4.38
4	SI	.88	1.47	.99	1.94	4.33	2.69	6.97
	LI	.65	1.20	.81	1.60	3.32	2.24	4.94
	RN	−.30	−.51	−.85	−.18	.60	.43	.83
5	SI	.77	1.30	.79	1.82	3.68	2.20	6.17
	LI	.69	1.26	.85	1.66	3.51	2.34	5.25
	PD	.47	.85	.41	1.29	2.34	1.51	3.63
6	SI	.86	1.44	.97	1.91	4.22	2.64	6.76
	LI	.71	1.31	.90	1.72	3.71	2.47	5.58
	NI	.32	.55	.19	.90	1.72	1.21	2.47
7	SI	.81	1.37	.88	1.85	3.92	2.42	6.35
	LI	.74	1.35	.95	1.76	3.87	2.58	5.81
	OV	.27	.48	.06	.90	1.61	1.06	2.46
8	SI	.84	1.41	.94	1.89	4.10	2.55	6.61
	LI	.70	1.29	.88	1.70	3.64	2.42	5.47
	GU	.22	.39	.08	.70	1.48	1.08	2.02
9	SI	.86	1.45	.98	1.92	4.26	2.67	6.80
	LI	.71	1.31	.91	1.71	3.70	2.49	5.50
	NC	.19	.32	.03	.62	1.38	1.03	1.85
10	SI	.94	1.53	1.00	2.07	4.63	2.70	7.91
	LI	.60	1.10	.64	1.55	3.00	1.90	4.73
	ME	.48	.83	.10	1.56	2.30	1.11	4.76
	RN	−.28	−.47	−.87	−.08	.62	.42	.92
11	SI	.78	1.28	.73	1.82	3.58	2.07	6.20

Model #	Predictor	*β*	*B*	95% CI *B*		Odds Ratio	95% CI Odds Ratio	
	LI	.65	1.18	.72	1.65	3.27	2.06	5.19
	PD	.59	1.05	.54	1.57	2.86	1.71	4.80
	ME	.40	.70	.04	1.35	2.01	1.04	3.86
12	SI	.91	1.49	.97	2.00	4.41	2.64	7.39
	LI	.67	1.21	.76	1.65	3.35	2.15	5.22
	ME	.47	.82	.13	1.50	2.26	1.14	4.50
	NC	.21	.37	.01	.72	1.44	1.01	2.06
13	SI	.89	1.46	.95	1.97	4.30	2.58	7.16
	LI	.70	1.27	.82	1.73	3.57	2.26	5.64
	ME	.44	.76	.10	1.42	2.14	1.11	4.15
	OV	.20	.36	.13	.84	1.43	1.14	2.33
14	SI	.92	1.51	.98	2.04	4.53	2.67	7.68
	LI	.69	1.25	.80	1.71	3.50	2.22	5.54
	ME	.45	.77	.10	1.45	2.17	1.10	4.26
	PV	.16	.27	.15	.68	1.30	1.17	1.98
15	SI	.73	1.21	.69	1.74	3.36	1.99	5.69
	LI	.61	1.11	.70	1.52	3.03	2.00	4.57
	PD	.46	.82	.37	1.28	2.28	1.45	3.59
	RN	−.28	−.48	−.81	−.15	.62	.45	.86
16	SI	.94	1.54	1.02	2.06	4.65	2.76	7.83
	LI	.67	1.22	.76	1.68	3.38	2.13	5.37
	ME	.43	.75	.08	1.41	2.11	1.08	4.12
	NI	.20	.34	.04	.71	1.40	1.04	2.04
17	SI	.92	1.51	1.00	2.01	4.50	2.72	7.45
	LI	.67	1.21	.75	1.68	3.35	2.11	5.34
	ME	.42	.74	.08	1.41	2.10	1.08	4.10
	GU	.15	.26	.08	.59	1.29	1.09	1.81
18	SI	.95	1.56	1.04	2.07	4.74	2.83	7.94
	LI	.70	1.28	.83	1.73	3.59	2.29	5.65
	ME	.46	.81	.14	1.47	2.24	1.15	4.36
	NE	.09	.16	.22	.54	1.18	1.24	1.72

Model #	Predictor	β	*B*	95% CI *B*		Odds Ratio	95% CI Odds Ratio	
19	SI	.90	1.48	.95	2.00	4.38	2.60	7.40
	LI	.69	1.25	.80	1.70	3.49	2.23	5.48
	ME	.45	.78	.10	1.47	2.19	1.10	4.34
	GC	.12	.20	.20	.60	1.23	1.22	1.83
20	SI	.76	1.23	.65	1.82	3.43	1.91	6.16
	LI	.58	1.04	.57	1.51	2.84	1.77	4.55
	PD	.56	1.00	.46	1.55	2.72	1.58	4.70
	ME*	.42	.71	−.01	1.43	2.04	.99	4.19
	RN	−.24	−.41	−.81	−.01	.66	.44	.99
21	SI	.67	1.07	.42	1.72	2.91	1.52	5.58
	LI	.57	1.01	.53	1.49	2.75	1.70	4.44
	PD	.53	.92	.36	1.48	2.51	1.43	4.41
	ME*	.42	.70	−.02	1.42	2.02	.98	4.14
	RN*	−.19	−.31	−.73	.10	.73	.48	1.11
	NC*	.14	.24	−.14	.62	1.27	.87	1.86
	NI*	.06	.10	−.31	.51	1.11	.73	1.67
	PV*	.09	.14	−.32	.60	1.15	.73	1.83

*The regression coefficient (β) is considered to be nonsignificant within the model when its 95% confidence interval includes zero.

Note. SI = Sentence imitation; LI = Letter identification; ME = Mother's education level; RN = Rapid naming; PD = Phoneme deletion; NI = Nonverbal IQ; OV = Oral vocabulary; GU = Grammatical understanding; NC = Narrative comprehension; PV = Picture vocabulary; NE = Narrative expression; GC = Grammatical completion.

Table 6

Predictors, C_p values, and AUC values for eighth grade best and near best models

Model #	Predictors	C_p	AUC
1	PD, GC, NI, SI, ME,	4.033	.862
2	PD, GC, NI, RN, SI	5.925	.857
3	PD, SI, NI, RN, ME,	4.801	.855
4	PD, GC, NI, SI, ME, NE	5.356	.865
5	PD, GC, NI, SI, ME, NE, NC, OV	8.735	.868

Note. PD = Phoneme deletion; GC = Grammatical completion; NI = Nonverbal IQ; SI = Sentence imitation; ME = Mother's education level; RN = Rapid naming; OV = Oral vocabulary; NE = Narrative expression; NC = Narrative comprehension. Predictors are listed in order of the absolute value of β, as determined by the bootstrapping procedure (see Table 7).

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Table 7

Bootstrapped regression coefficients, odds ratios and confidence intervals for eighth grade best and near best models.

Model #	Predictor	β	*B*	95% CI *B*		Odds Ratio	95% CI Odds Ratio	
1	PD	.47	.84	.40	1.28	2.31	1.49	3.59
	GC	.42	.73	.27	1.18	2.07	1.31	3.27
	NI	.38	.65	.27	1.03	1.91	1.31	2.79
	SI	.23	.34	.31	.99	1.40	1.36	2.68
	ME	.21	.36	.06	.77	1.43	1.06	2.16
2	PD	.43	.77	.33	1.21	2.15	1.39	3.34
	GC	.38	.66	.21	1.10	1.93	1.23	3.01
	NI	.36	.60	.25	.96	1.83	1.28	2.61
	RN	−.26	−.44	−.88	−.01	.64	.42	.99
	SI*	.24	.36	−.26	.97	1.43	.77	2.65
3	PD	.48	.85	.36	1.35	2.35	1.43	3.85
	SI*	.38	.59	−.05	1.23	1.80	.95	3.40
	NI	.36	.62	.20	1.04	1.86	1.23	2.82
	RN	−.27	−.48	−.93	−.03	.62	.40	.98
	ME*	.21	.34	−.11	.79	1.40	.89	2.21
4	PD	.47	.82	.38	1.27	2.28	1.46	3.55
	GC	.45	.76	.29	1.23	2.14	1.34	3.43
	NI	.38	.66	.27	1.05	1.93	1.32	2.84
	SI*	.27	.41	−.23	1.05	1.51	.80	2.86
	ME*	.21	.36	−.06	.77	1.43	.94	2.16
	NE*	−.13	−.23	−.53	.07	.80	.59	1.08
5	PD	.45	.79	.32	1.26	2.21	1.38	3.54
	GC	.41	.70	.18	1.22	2.01	1.20	3.37
	NI	.38	.65	.25	1.04	1.91	1.29	2.82
	SI*	.24	.35	−.32	1.02	1.42	.73	2.78
	ME*	.20	.33	−.08	.75	1.40	.92	2.12
	NE*	−.16	−.26	−.64	.11	.77	.53	1.12

Model #	Predictor	β	*B*	95% CI *B*		Odds Ratio	95% CI Odds Ratio	
	NC*	.08	.12	−.31	.55	1.13	.73	1.72
	OV*	.07	.13	−.45	.70	1.14	.64	2.01

*The regression coefficient (β) is considered to be nonsignificant within the model when its 95% confidence interval includes zero.

Note. PD = Phoneme deletion; GC = Grammatical completion; NI = Nonverbal IQ; SI = Sentence imitation; ME = Mother's education level; RN = Rapid naming; OV = Oral vocabulary; NE = Narrative expression; NC = Narrative comprehension