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A Longitudinal Analysis of the Trajectories and Predictors of Word Reading and Reading Comprehension Development among At-Risk Readers

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Abstract

This study explored the developmental trajectories and predictors of word reading and reading comprehension among young at-risk readers. In fall of 1st grade, 185 students identified as at-risk for reading difficulties were assessed on measures of domain-specific skills (phonological awareness, letter knowledge, and vocabulary), domain-general skills (working memory, nonverbal reasoning, and processing speed), and word reading and reading comprehension. Word reading and reading comprehension were assessed again in spring of grades 1– 4. Individual growth curve modeling showed that the children demonstrated decelerated growth on word reading and linear growth on reading comprehension, although their performance on both word reading and reading comprehension were consistently below average on national norms. After controlling for word reading and reading comprehension in 1st grade, letter knowledge predicted growth in word reading; vocabulary and non-verbal reasoning predicted growth in reading comprehension. That is, we found different developmental trajectories and different predictors for word reading and reading comprehension among our at-risk sample. Implications are discussed for theory and early reading instruction for at-risk children.

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Keywords

reading development; at-risk readers; word reading; reading comprehension; domain-specific and domain-general skills

It has been estimated that between 5–10% of school-aged children are at risk for serious reading problems (e.g., Wanzek & Vaughn, 2009). Weak beginning reading skills negatively affect children's enjoyment of reading, achievement in content areas like mathematics and science; and social adjustment (e.g., Swanson & Harris, 2013). Thus, it is important to understand how at-risk students' early reading skills (including reading comprehension) develop, and which domain-general (e.g., working memory, processing speed) and domain-specific (e.g., phonological awareness, letter knowledge) factors explain this development. Such investigation may provide insight into the nature of reading development, establish links between it and early cognitive/linguistic factors, and suggest important components of reading readiness programs.

Prior Research on Typically Developing Children

According to the Simple View of Reading, reading comprehension is the product of word recognition skills and oral language comprehension (Hoover & Gough, 1990). For typically developing (TD) children, the Simple View suggests word recognition is especially important before fourth grade, whereas language comprehension becomes increasingly critical at this point and beyond (e.g., Hoover & Gough, 1990; Aaron, Joshi, Gooden, & Bentum, 2008). This isn't to suggest a lack of overlap in the development of word reading and comprehension. There is indeed overlap, a fact logical on its face, theoretically explainable, and empirically supported (e.g., Aaron et al., 2008; Cutting & Scarborough, 2006; Keenan, Betjemann, & Olson, 2008). Unsurprisingly, research on TD readers has often focused on word reading and comprehension and suggests important developmental characteristics of each.

As one example, code-related skills like letter knowledge and phonological awareness in pre-kindergarten and kindergarten seem to be strong predictors of concurrent (e.g., Chaney, 1992) and later word reading skills (e.g., Kirby, Parrila, & Pfeiffer, 2003; Lesaux, Rupp, & Siegel, 2007; Lonigan, Burgess, & Anthony, 2000; Muter, Hulme, Snowling, & Stevenson, 2004; Roth, Speece, & Cooper, 2002; Storch & Whitehurst, 2002), as well as of later reading comprehension (e.g., Catts, Fey, Zhang, & Tomblin, 1999; Catts, Herrera, Nielsen, & Bridges, 2015; Cromley & Azevedo, 2007; Kirby, Parrila, & Pfeiffer, 2003; Lesaux, Rupp, & Siegel, 2007). Second, early word reading and oral language skills predict concurrent and later reading comprehension (e.g., Cain, Oakhill, & Bryant, 2004; Catts et al., 2015; Dickinson & Porche, 2011; Kieffer & Vukovic, 2012), with word reading demonstrating a stronger connection to reading comprehension than to oral language, especially in the early grades (e.g., Muter et al., 2004; Roth et al., 2002; Storch &Whitehurst, 2002). A third example is that domain-general skills such as working memory and non-verbal reasoning appear directly and indirectly related to concurrent and later reading comprehension (via inferencing and vocabulary), even when other reading skills are controlled (Cain et al., 2004; Lesaux et al., 2007; Kim, 2017; Korpipää et al., 2017; Peng et al., 2018; Swart et al., 2017).

Fourth, Lesaux et al. (2007) reported that the development of word reading decelerates in the intermediate grades. We are unaware of research on the developmental trajectory of reading comprehension across grades 1 to 4.

Much of this research on TD children reflects either a concurrent approach (i.e., data are collected at one time point; Cain et al., 2004; Chaney, 1992; Joshi, Tao, Aaron, & Quiroz, 2012) or longitudinal approach (data are collected at two or more time points) that focuses on how reading skills measured previously predict subsequent reading outcomes (Cunningham, & Stanovich, 1997; Catts et al., 2015, 2016; D. Fuchs et al., 2012; Kieffer & Vukovic, 2012; Lonigan et al., 2000; Kirby et al., 2003; Muter et al., 2004; Roth et al., 2002). Research suggests that a task like reading text to make main idea statements requires reading/comprehension skills that change as a function of when in a child's development such tasks are assessed (e.g., Paris, 2005). Predictors of task performance may vary, too, depending on when in a child's development performance is explored.

For example, code-related skills may be more important predictors of reading to make main idea statements at an earlier stage, whereas more advanced domain-general skills (e.g., non-verbal reasoning) may be more important at a later stage (Korpipää et al., 2017). This possibility suggests that in addition to focusing on reading performance and its predictors at one time point, it is necessary to investigate the developmental trajectories of reading and its predictors over multiple time points, which may provide better understanding of general reading development as well as specify important (constant and inconstant) predictors of that development.

Prior Research on At-risk Children

We know of only three studies in which investigators focused on development of word reading and reading comprehension among young at-risk readers (Catts, Nielsen, Bridges, & Liu, 2016; D. Fuchs et al., 2012; Mancilla-Martinez & Lesaux, 2010). In Catts et al.'s (2016) study, at-risk kindergarteners' vocabulary added significantly to the prediction of reading comprehension problems in third grade beyond what word reading skills in second grade predicted. D. Fuchs and colleagues (2012) explored early predictors of reading comprehension among weak first-grade readers. Phonological processing, rapid letter naming, oral language comprehension, and non-verbal reasoning, measured in fall of first grade, predicted reading comprehension in spring of fifth grade when controlling for first-grade word reading. Finally, Mancilla-Martinez and Lesaux (2010) determined that at-risk English learners' English word reading and vocabulary knowledge at preschool, and their preschool-to-fifth-grade reading and vocabulary growth, predicted fifth-grade reading comprehension.

Thus, Catts et al. (2016), D. Fuchs et al. (2012), and Mancilla-Martinez and Lesaux (2010) investigated whether at-risk readers' early reading skills predicted reading comprehension in later grades. Whereas their findings shed light on reading development and its early precursors, none of these research teams addressed the trajectories of reading comprehension. Nor did they explore the relative importance of domain-general (i.e., cognitive) skills and domain-specific (i.e., linguistic) skills in early word reading and reading comprehension development. D. Fuchs et al., (2012) included only non-verbal reasoning; Catts et al. (2016) and Mancilla-Martinez and Lesaux (2010) did not include domain-general skills.

Purpose of This Study

We explored the trajectories and predictors of early reading development among young at-risk readers. We first examined the trajectories of their word reading and reading comprehension across 4 years (grade 1 to grade 4, inclusive). As mentioned, prior studies of TD readers suggest early growth in word reading decelerates in the intermediate grades (e.g., Lesaux et al., 2007). By contrast, at-risk readers often experience persistent word reading difficulties (Swanson & Harris, 2013), sometimes despite remedial efforts (e.g., Snowling, 1998). This suggests that their word reading growth may follow a different course. Understanding their developmental trajectories may have implications for instruction. If, for example, at-risk children's early growth in word reading and comprehension decelerates, or remains well-below grade expectations, supplementary intervention, considerably more intensive than is customary, may be necessary.

A second and related question is whether there are similar or different sets of domain specific predictors of word reading and reading comprehension trajectories. Studies on TD children (e.g., Muter et al., 2004; Roth et al., 2002; Storch &Whitehurst, 2002) indicate that early word reading has a strong relation with early reading comprehension. However, at-risk readers' weak word reading (Swanson & Harris, 2013) suggests code-related skills may also be important for reading comprehension development. In other words, at-risk readers' weak word reading may be a bottleneck for reading comprehension. As a consequence, domain-specific predictors of word reading (i.e., code-related skills) may also affect development of reading comprehension. This assumption is consistent with conventional early reading instruction targeting at-risk readers. That is, reading programs often focus on code-related skills in hopes of improving children's overall reading performance, including their reading comprehension (see Ehri, Nunes, Stahl, & Willows, 2001, for a review). However, this belief needs further investigation with at risk readers by comparing the domain-specific skills associated with word reading and with reading comprehension development.

A third question is whether domain-general skills predict word reading and reading comprehension development. Exploring this question may shed light on the developmental role of domain-general skills and may have implications for early reading instruction that directly addresses, and perhaps compensates for, weaknesses in such skills (e.g., Peng & Fuchs, 2017). As mentioned, most studies have looked at domain-specific predictors of early reading. However, because domain-general skills (e.g., working memory) usually develop at an early age to support later learning (e.g., Welsh, Nix, Blair, Bierman, & Nelson, 2010), it is reasonable to expect such skills to influence early reading as well. Thus, in this study, we collected data on several potentially important domain-general skills (i.e., working memory, non-verbal reasoning, and processing speed), in addition to domain-specific skills (i.e., phonological awareness, letter knowledge, and vocabulary), to investigate their respective roles in at-risk children's reading development.

We hypothesized that because of weak domain-specific skills many at-risk readers rely on domain-general skills to read (e.g., Peng et al., 2017). That is, domain-specific skills may play a “compensatory” role and may be more important than domain-specific skills in predicting reading development. However, because many at-risk readers also demonstrate wide-ranging cognitive weaknesses (e.g., Cirino et al., 2015; Peng & Fuchs, 2016), an equally plausible hypothesis is that their domain-general skills may be insufficiently strong to support reading development and that domain-specific skills will eventually prove more important. In the current study, we included both domain-specific and domain-general predictors in analyses to simultaneously test these two competing hypotheses.

In sum, this study’s purpose was to explore the trajectories of word reading and reading comprehension in at-risk children (from fall of grade 1 to spring of grade 4) and how fall-of-firstgrade domain-general skills (working memory, non-verbal reasoning, and processing speed) and domain-specific skills (letter knowledge, vocabulary, and phonological awareness) predicted word reading and reading comprehension growth, controlling for fall-of-first-grade word reading and reading comprehension. Unlike the investigators of most previous studies who relied on onepoint-in-time reading performance, we looked at reading growth over time, which may provide better understanding of reading growth and reveal important predictors of reading development among at-risk readers.

Methods

Participants

Students.—Participants were 185 first-grade children who were identified as “at-risk readers” in fall of first grade. They came from 24 elementary schools in a mid-size southern city in the U.S. They were part of a larger number of first-grade students who were recruited and met selection criteria for an evaluation of a large-scale implementation of a reading intervention. The implementation was conducted in three successive years. The sample of children for this study had been randomly assigned in Years 1, 2, or 3 to the control group. Hence, they represented three cohorts each of whom was followed in second, third, and fourth grades (see below). Among the 24 study schools, participants ranged from 1–22 per school, with a mean of 8.

They (and treatment-assigned children) were initially identified as “at-risk” by their classroom teachers, and were then tested on a battery of reading measures. A factor score based on these measures was derived for each child, and the children were rank-ordered by this score. The top 50% were eliminated from further study participation. Those who performed below a Tscore of 37 (corresponding to a percentile rank of 10) on both the Vocabulary and Matrix Reasoning subtests of the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999) were also excluded from the study because of the possibility that they were intellectually disabled. Study measures, child demographics, and correlations among variables are presented in Table 1 and 2. We received appropriate Institutional Review Board approval from our university and from the school district and written consents from participating teachers and parents/guardians of participating students.

Research assistants (RAs).—Across the 3-year large-scale implementation study, 22–25 RAs were selected each year by means of a competitive process that yielded full-time graduate students in education policy, special education, and teaching and learning, and who had experience working with young children. The RAs worked 20-hour weeks and were trained to tutor at-risk readers in the treatment group and to test them and control children at pre- and posttreatment in first grade. As described below, a smaller group of RAs were recruited separately to test our first-grade sample in "follow-up" years: spring of second, third, and fourth grade.

Screening Measures

Letter knowledge.—The Rapid Letter Naming Test (D. Fuchs, Fuchs, Thompson, Al Otaiba, Yen, Yang, Braun, & O'Connor, 2001) measures the number of letters named correctly in 60 seconds. The Rapid Sound Naming Test (D. Fuchs et al., 2001) measures the number of letter sounds named correctly in 60 seconds. Scores are adjusted if students finish in less than 60 seconds. Test-retest reliability for the Rapid Sound Naming Test is .92 among first-grade students (D. Fuchs et al., 2001).

Word reading.—The Sight Word Efficiency subtest of the TOWRE (Torgesen, Wagner, & Rashotte, 1999) measures the number of sight words identified correctly in 45 seconds. The manual reports an alternate-form coefficient of .97 for a sample of 6-year-olds. Word Identification Fluency A (WIF A; L. Fuchs, Fuchs, & Compton, 2004) comprises 2, 50-word lists. Students have 60 sec to read each list. Their score is the mean number of words read correctly across them. Alternate-form reliability is .95 to .97 at first grade (L. Fuchs et al., 2004). In the Word Identification subtest of the WRMT (Woodcock, 1998), students read sight words, arranged from easiest to most difficult. The manual reports the split-half reliability coefficient for a first-grade sample as .98.

Non-word reading.—In the Phonemic Decoding Efficiency subtest of the TOWRE (Torgesen et al., 1999), students read pseudo-words (e.g., pim) presented from easiest to most difficult. Alternate-form reliability for 6-years-olds is .97. For the Word Attack subtest of the WMRT (Woodcock, 1998), students read pseudo-words arranged from easiest to most difficult. Split-half reliability for first-grade children is .94.

IQ.—IQ was assessed by the Vocabulary and Matrix Reasoning subtests of the WASI (Wechsler, 1999). In Vocabulary, children identify pictures and define words. Test-retest reliability, as reported in the manual for 6 to 11-year-olds, is .85. In Matrix Reasoning, one selects 1 of 5 options that best completes a visual pattern. Test-retest reliability for children between the ages of 6 and 11 is reported as .76.

Domain-Specific Measures

Phonological awareness.—To assess phonological awareness, we used a 20-item sound matching subtest from Comprehensive Test of Phonological Processing (Wagner, Torgesen, & Rashotte, 1999). The student is asked to select a word from three options that ends with the same sound as a word the tester reads. There is also a picture that represents each of the three words to which the tester points while reading the words. The student may either point to or say the word aloud. The test is discontinued after the student incorrectly answers four of seven items. The tester is required to administer a minimum of seven test items. The score is the total number of correct items. The reliability for children aged 5~7 is above .91

Letter knowledge.—Letter knowledge was assessed by our Screening measures.

Vocabulary.—We used the Vocabulary subtest of the WASI (Wechsler, 1999). Cronbach's alpha was .74 for the current sample

Domain-General Measures

Working memory.—Working memory was measured with the Listening Recall and Backward Digit Recall subtests from the Working Memory Test Battery for Children Listening Recall (Pickering & Gathercole, 2001). For Listening Recall, the child listens to a series of short sentences, judges the veracity of each by responding "yes" or "no," and then recalls the final word of each of the sentences in sequence. There are six trials at each set size (1 to 6 sentences per set). The score is the number of trials recalled correctly. Cronbach's alpha was .85 for the current sample. With Backward Digit Recall, the tester says a string of random numbers, and children say the series backwards. Item difficulty increases as more numbers are added to the series. The score is the number of trials recalled correctly. Cronbach's alpha was .87 for the current sample. We modified administration of both working memory tests to lower their floors. We did this by giving children feedback on the first three test items. We discontinued testing when a child incorrectly answered three items within a set.

Non-verbal Reasoning.—We used the Matrix Reasoning subtest of the WASI (Wechsler, 1999). Cronbach's alpha was .75 for the current sample.

Processing speed.—We used the Cross Out subtest from the Woodcock-Johnson III (WJIII; Woodcock, McGrew, & Mather, 2001), which requires children to locate and circle five pictures that match a target picture, all of which are displayed in the same row. Children have 3 min to complete 30 rows and they earn 1 point for each row answered correctly. Woodcock et al. (2001) report that test-retest reliability coefficient is .91.

Reading Outcome Measures

Word reading.—Sight-word reading was explored with the TOWRE-Sight Word Efficiency (Torgesen et al., 1999) as described under Screening Measures. Alternate-form reliability is above .85 for 6 ~ 9 year olds.

Reading comprehension.—The Reading Comprehension subtest of the Iowa Test of Basic Skills (ITBS, Hoover, Dunbar, & Frisbie, 2000) has three sections. First, students read sentences with a missing word and select the right word to complete it. Second, they select among options to describe pictures. Last, they read passages each of which is followed by four questions. The developmental standard score is used to reflect reading comprehension development (Hoover et al., 2000). Reliabilities for first grade through fourth grade range from .80 to .94.

Procedure

Fall and spring testing in first grade.—For each of the three cohorts constituting the study sample, 22 to 25 RAs individually administered all tests to the children in the quietest places available in their schools. The RAs were unfamiliar to the children and unaware of study purposes or hypotheses. In fall of first grade, there were four testing sessions, each of which lasted 60 min. Two project staff trained the RAs on multiple occasions. Each training session began with staff explaining the purpose and content of the tests and then modeling their proper administration. The RAs next role-played as examiner and examinee and obtained corrective feedback from staff.

Following training, the RAs were required to practice test administration with a partner for 10 hours prior to pretreatment testing. Two days after training, each RA "tested" project staff on all measures. Staff recorded their performances on detailed checklists. They were required to achieve at least 90% accuracy when administering and scoring every test. If they performed less well on one or more tests, they were required to complete additional training and try again to meet administration and scoring criteria. No testing of children was permitted before they did so.

RA training in spring of first grade was similar to that of fall, with the exception that spring training was abbreviated because of the RAs' familiarity with the tests. Tests were again individually administered to children in four 60-min sessions. All sessions in fall and spring were audiotaped. Twenty percent of those in fall and spring were randomly selected in equal proportions across testers. Administration fidelity and scoring accuracy were measured by RAs with detailed checklists. The fidelity and accuracy scores exceeded 90% at both time points. The scores were double checked by another RA and inter-rater agreement was 90% or better.

Testing in Years 2, 3, and 4.—Study participants, as mentioned, were controls in a large efficacy study of a first-grade reading program for at-risk children. The control children were tested at the same time as the treatment children—before and after treatment implementation in first grade. In addition, their word reading and reading comprehension performance was evaluated in spring of second, third, and fourth grades. For this follow-up testing, RAs were recruited and trained by project staff in the same manner as RAs were recruited and trained to assess the children's first-grade performance. And the same first-grade procedures were applied during follow-up to determine testing fidelity and scoring accuracy, which were both comparable to the earlier first-grade estimates.

Data Analysis

We used Little's MCAR test (Little & Rubin, 2014) on all variables is $\chi^2 = 502.66$, df = 455, $p = .06$, which indicated that the missing data were missing at random. Thus, we used maximum likelihood estimate for the growth models. We also created a composite score using principal component factor analysis for letter knowledge (rapid sound naming and rapid letter naming) and working memory (listening recall and backward digit recall) to better reflect those constructs (Bartholomew, Steele, Galbraith, & Moustaki, 2008).

Then, we ran separate unconditional baseline growth models (HLM-7; Raudenbush, Bryk, Cheong, Congdon, & Toit, 2011) for word reading and reading comprehension, which were measured across four time points (i.e., spring of first, second, third, and fourth grades). Because of the nested nature of our data (time nested within students, students nested in school), all analyses were run in an HLM framework with growth, student, and school as first, second, and third levels, respectively. Because we were interested in growth from first to fourth grade, intercept was centered in spring of first grade.

Based on the χ^2 test on the deviance, we first tested different baseline growth models to find the best fit model for word reading and reading comprehension. That is, we compared different baseline models for word reading and reading comprehension to decide if we should include the quadratic term and whether the slope and quadratic term had random variance at the student or school level. Next, we ran conditional models to examine whether fall-of-first-grade letter knowledge, phonological awareness, vocabulary, non-verbal reasoning, working memory, and processing speed predicted the intercept, slope, and/or the quadratic term of word reading/reading comprehension. Because we have two outcome variables (word reading and reading comprehension), we corrected the p value (.05/2 =.025) to reduce possible type I errors.

Results

Baseline Model

Table 1 displays descriptive statistics. Overall, the study sample demonstrated relatively poor performance in domain-general and domain-specific skills (as indicated by their percentile rankings). Based on the χ^2 test on the deviance, we tested different models of baseline growth to find the best fit for word reading and reading comprehension. For word reading, the best fit included the intercept, slope, and quadratic term. The intercept, slope, and quadratic indices were random at the student level. The intercept was also random at the school level. The following equations represent a quadratic growth model of four time points (t) nested within students (i) in schools (j).

Level 1: Word Reading $_{tij} = \pi_{0ij} + \pi_{1ij}$ *(time) $_{tij} + \pi_{2ij}$ *(time^2) $_{tij}$ + e_{tij};

Level 2: $\pi_{0ij} = \beta_{00j} + e_{0ij}$; $\pi_{1ij} = \beta_{10j} + e_{1ij}$; $\pi_{2ij} = \beta_{20j} + e_{2ij}$;

Level 3: $\beta_{00j} = \gamma_{000} + e_{00j}$; $\beta_{10j} = \gamma_{100}$ s; $\beta_{20j} = \gamma_{200}$.

For reading comprehension, the best fit for the baseline growth model included the intercept and slope. The intercept was random at the student and school level. The slope was random at the student level. The following equations represent a linear growth model of four time points (t) nested within students (i) in schools (j).

Level 1: Reading Comprehension $_{tij} = \pi_{0ij} + \pi_{1ij}$ *(time) $_{tij}$ + e_{tij};

Level 2: $\pi_{0ij} = \beta_{00j} + r_{0ij}$; $\pi_{1ij} = \beta_{10j} + r_{1ij}$;

Level 3: $\beta_{00j} = \gamma_{000} + u_{00j}$; $\beta_{10j} = \gamma_{100}$.

In sum, the at-risk readers showed individual differences in word-reading growth from spring of first grade to spring of fourth grade. Overall, however, their growth in this time interval gradually decelerated. In contrast, their growth in reading comprehension remained linear. Individual differences were also observed in reading comprehension.

Conditional Model

Next, we examined whether fall-of-first-grade domain-general skills (working memory, non-verbal reasoning, and processing speed) and domain-specific skills (phonological awareness, letter knowledge, and vocabulary) predicted reading growth (slope and/or the quadratic term). For word reading, letter knowledge was the only statistically significant predictor of the linear slope, $\beta = 6.21$, $p < .001$, and the quadratic term, $\beta = -1.73$, $p = .002$, when controlling for cohort and first-grade word reading and comprehension performance. That is, the children with better letter knowledge showed faster growth in spring of first grade on word reading. But they also showed greater deceleration of word reading growth (see Figure 1). For reading comprehension, after controlling for cohort effects and fall-of-first-grade word reading and reading comprehension, vocabulary, $\beta = .23$, $p = .01$, and non-verbal reasoning, $\beta = .47$, $p = .01$, were the only statistically significant predictors of slope (see Table 3). Working memory, processing speed, and phonological awareness did not uniquely contribute to growth in reading comprehension or word reading. Regarding the total R^2, the predictors for word reading explained 45.59% and 72.08% of the variances in slope and the quadratic term, respectively. Predictors for reading comprehension explained 45.44% of the variance in slope.

Discussion

We explored word reading and reading comprehension development among young at risk readers and whether domain-general and domain-specific skills predicted this development. Growth in word reading continued from spring of first grade through fourth grade, but slowed over time. Reading comprehension developed more consistently. Children with stronger letter knowledge in fall of first grade generally showed faster growth in word reading from first to fourth grade, but their growth also decelerated more quickly. Early vocabulary and non-verbal reasoning predicted growth in reading comprehension such that the children with stronger vocabulary and non-verbal reasoning in fall of first grade advanced reliably faster in comprehension skills across these early grades.

Developmental Trajectories

Previous studies have shown that TD children’s word reading growth accelerates at first but then slows in the intermediate grades (e.g., Lesaux et al., 2007). We hypothesized a different trend for young at-risk readers. Because many of them have serious word reading problems, we anticipated that their growth would neither accelerate nor decelerate, but remain relatively linear. Nevertheless, their word reading trajectory was similar to that of TD children shown in previous research (e.g., Lesaux et al., 2007). There are several possible reasons for this, the first of which is that word reading performance “plateaus” in the intermediate grades because of ceiling effects. Second, the focus of reading instruction shifts in the early grades from word reading to reading comprehension (e.g., Hoover & Gough, 1990; Etmanskie et al., 2016). Table 1 shows the percentiles of our sample’s word reading performance from first through fourth grade: 45.54, 58.33, 43.68, 42.59, and 37.83. These data do not indicate ceiling effects. Thus, we suspect that the nonlinear trajectory we observed was more likely a result of less frequent word reading instruction as children moved through the early grades.

There is a third possible explanation. Prior research suggests that the development of early word reading and reading comprehension is bidirectional (Hoover & Gough, 1990; Etmanskie et al., 2016). Hence, the relatively weak reading comprehension of our sample may have contributed to its slow word reading development. Specifically, weak reading comprehension might have interfered with a process by which children often learn words; through independent reading of increasingly advanced texts during the intermediate grades.

In contrast to our sample's word reading trajectory, its growth in comprehension was linear. Nevertheless, percentile scores across the four grades were considerably below average on national norms (i.e., 24^{th} percentile ~ 35^{th} percentile; see Table 1). This indicates that although our young readers were steadily developing comprehension skills, their performance was still low. Thus, even as the focus of reading instruction presumably shifts from word reading to reading comprehension (e.g., Hoover & Gough, 1990; Etmanskie et al., 2016), this shift did not appear to produce adequate comprehension performance in our children. This result may also reflect the children's poor word reading (across all measured time points), and that their initial word reading predicted reading comprehension performance. Taken together, the trajectories we obtained indicate insufficient development of word reading and reading comprehension among our sample of at-risk children. Classroom instruction may have contributed to this, but we did not explore it as a possibility. Future research should look at whether variations in word reading and reading comprehension instruction differentially influence at-risk students' reading trajectories.

Domain-Specific and Domain-General Predictors

We also examined whether our sample's reading and comprehension development shared similar early predictors. These predictors represented domain-general and domain-specific child characteristics. Because at-risk readers often have very poor word reading skills, which interfere with comprehension, we had reason to believe that the predictors of word reading and comprehension development would be similar. However, our findings suggested otherwise.

Letter knowledge was the sole predictor of growth in word reading, whereas vocabulary and non-verbal reasoning were predictors of comprehension development. The relative importance of letter knowledge versus phonological awareness in predicting word reading may have been because our letter knowledge measure tapped phonological processing (e.g., lettersound naming) as well as print knowledge (e.g., letter naming). Because we required the speeded naming of letter sounds and names, our letter knowledge tasks may have also measured rapid naming. Rapid naming, in turn, taps processes critical to the formation of orthographic representations of words (e.g., Wolf & Bowers, 1999), which is related to word reading development (e.g., Kirby et al., 2003). Not unrelated, findings from behavioral genetics suggest that the heritability of phonological awareness is shared with word reading only through letter knowledge (e.g., Erbeli, Hart, & Taylor, 2017). Our findings are consistent with this suggestion. Letter knowledge appears to be a rather complex construct and a more important index than phonological awareness in predicting growth in word reading among at-risk beginning readers.

That said, caveats must be expressed. Our word reading test (i.e., TOWRE sight word reading efficiency) included some sight words not generally considered decodable (e.g., is, we, of), which may have attenuated relations between phonological awareness and word reading. Future work should use word reading tests that more consistently measure decoding skills (e.g., TOWRE Phonemic Decoding Efficiency) to determine the accuracy and importance of our findings. Moreover, letter knowledge and word reading are timed tests, whereas our phonological awareness measures were not.

Vocabulary (meaning-related knowledge) was more important than letter knowledge and phonological awareness (code-related skills) in predicting comprehension development, which is consistent with most previous research on TD children (e.g., Roth et al., 2002; Storch & Whitehurst, 2002). This finding also raises the possibility that domain-specific skills like letter knowledge necessary for word reading may not be the bottleneck some believe for early comprehension development.

Additionally, we found that domain-general skills (non-verbal reasoning) predicted comprehension growth, but not word reading growth. This, too, may be an important difference between word reading and comprehension development in young at-risk readers. The relative importance of non-verbal reasoning is consonant with prior research (Lobier, Matthieu, & Valdois, 2013), perhaps because advanced cognitive processes such as non-verbal reasoning are necessary for complicated text analysis (e.g., inference making; Nation, Clarke, & Snowling, 2002). After controlling for word reading and vocabulary, Swat et al. (2017) found non-verbal reasoning was both concurrently related to reading comprehension, as well as influential in later reading comprehension performance through vocabulary. Thus, our findings and those of Swat et al. (2017) highlight a possible mechanism underlying the relation between non-verbal reasoning and reading comprehension.

Working memory was *not* a significant predictor of reading comprehension development, which was unexpected given that it is widely considered important to reading comprehension (e.g., Cain et al., 2004). This may have been because the children selected as study participants demonstrated weak working memory (mean accuracy on our two working memory tests was .10). In comparison to their stronger non-verbal reasoning skills (34^{th} percentile), their working memory may have been inadequate to support development of reading comprehension. In this vein, a meta-analysis conducted by Peng et al. (2018) obtained only a moderate correlation between working memory and reading comprehension ($r = .31$; 95 CI [.28, .34]), and working memory did not uniquely contribute to comprehension beyond word reading and vocabulary. Our findings are partly in line with these results. Relations between working memory and reading comprehension may not be as strong as previously theorized; working memory may not be a critical component when predicting growth in the comprehension of young at-risk readers if vocabulary and non-verbal reasoning are also considered.

Our exploration of predictors of reading development also helped us consider two hypotheses of interest. The so-called compensatory hypothesis posits that at-risk readers' weak domain-specific skills require them to rely on domain-general skills for reading development, thereby signaling the importance of domain-general skills. An alternative hypothesis is that weak beginning readers may not have the necessary cognitive capacity to support adequate reading development and that the acquisition of early reading skills is pivotally important. The children in our study displayed below-average performance across domain-general and domain-specific skills. Nevertheless, our results may support both hypotheses. That is, although at-risk children may indeed have insufficient domain-general and domain-specific skills, both skill sets are important in reading development beyond what may be explained by pretreatment reading skills (i.e., auto-regressors). We believe the ongoing exploration of relations between domain-general and domain-specific skills and reading development may prove useful to both theory and practice.

Limitations

We note the following study limitations. First, although we tried to reduce floor effects of several tests, some students still performed poorly on non-verbal reasoning and working memory measures. Future studies should attempt to use more sensitive tests of advanced cognitive skills for young at-risk readers. Second, vocabulary was our only index of oral language. We encourage investigators to use multiple measures that index listening comprehension and syntax to better reflect an oral language component. Third, this study has statistical limitations. We did not use joint growth models because we observed a poor model fit. This may have been because we used only half of the sample distribution. An analysis using a complete sample would be helpful to improve modal fit and contextualize results. Alternative residual structures may be possible such as heterogeneous variances and lag covariance. Because of limited sample size, and that students changed teachers and classrooms from first through fourth grade, classroom variance could not be modeled.

Implications for Theory and Practice

Notwithstanding these limitations, we believe our findings add nuance to the Simple View of Reading, which suggests that word reading and reading comprehension are closely related to each other and that word reading is pivotal to comprehension among TD children (e.g., Hoover & Gough, 1990). Our findings suggest that for young at-risk readers, word reading and reading comprehension may have relatively independent developmental trajectories and different domain-specific and domain-general predictors. These different development trajectories may be partly related to the shifting instructional focus (e.g., decreasing instruction in word reading) in the elementary grades. This, in turn, suggests that weak beginning readers would benefit from intensive word-level instruction throughout the primary grades rather than just in first grade as is often the case.

In a different vein, we note that a majority of interventions for at-risk readers have focused exclusively on word reading skills (e.g., Chard, Vaughn, & Tyler, 2002; Ehri et al., 2001). Our findings suggest that word reading and reading comprehension have different development trajectories and different sets of early predictors among at-risk readers. We encourage early interventionist to consider reading comprehension components such as vocabulary and general cognitive processes (e.g., non-verbal reasoning) to facilitate reading comprehension for these children. That said, our findings are correlational. Experimental investigations focusing on intensive word reading and reading comprehension instruction are necessary to help clarify the mechanism(s) underlying word reading and reading comprehension among at-risk readers.

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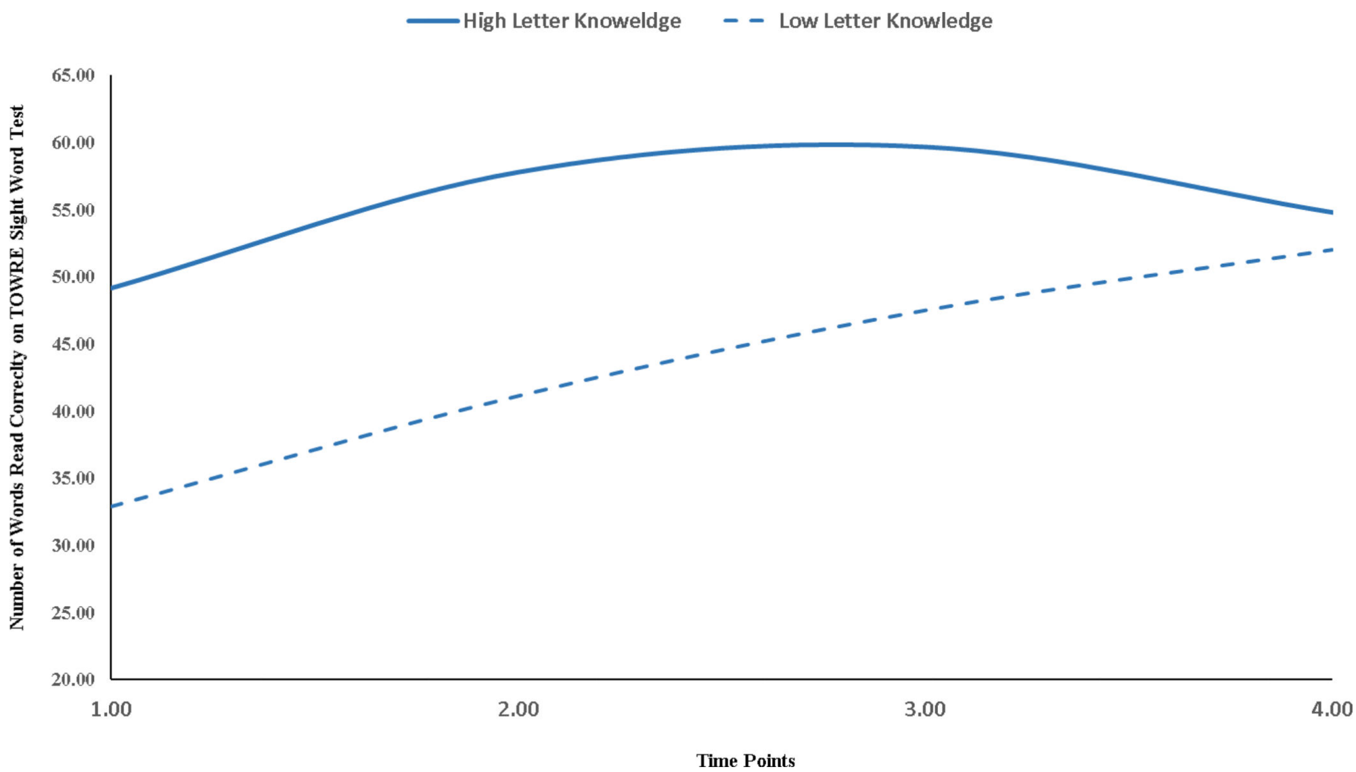

Figure 1.

Word Reading Developmental Trajectories between Groups with High Letter Knowledge (One SD above the Mean) versus Low Letter Knowledge (One SD below the Mean) in Fall of First Grade

Table 1

Descriptive Statistics of Study Measures

	N	Mean	SD	Skewness	Kurtosis	Min	Max	Percentile Rank
Gender (male)	185 (100)	-	-	-	-	-	-	-
FRL (Yes)	182 (149)	-	-	-	-	-	-	-
IEP (Yes)	178 (12)	-	-	-	-	-	-	-
Retained (Yes)	182 (15)	-	-	-	-	-	-	-
Ethnicity (Caucasian/Black/Hispanic/Others)	185 (53/83/25/77)	-	-	-	-	-	-	-
ELL (yes)	183 (14)	-	-	-	-	-	-	-
Age (at the beginning of first grade)	185	6.46	.40	1.05	1.57	5.83	8.08	-
Rapid Sound Naming	185	26.94	10.89	.003	−.55	0	52	-
Rapid Letter Naming	185	35.73	14.25	−.38	.44	0	71	-
Sound Matching	185	10.61	4.55	.18	−.62	0	20	37.75
Non-verbal Reasoning	185	6.81	4.04	1.17	1.33	0	21	34.00
Vocabulary	185	16.71	6.92	−.20	−.15	1	34	16.00
Listening Recall	185	2.28	3.12	1.06	.29	0	12	6.67[+]
Backward Digit Recall	185	5.31	4.08	.03	−1.14	0	12	14.75[+]
Processing Speed	132	8.31	2.86	−.57	.63	0	15	37.20
Word-Grade0	185	10.37	5.46	−.09	−.36	0	26	45.54
Word-Grade1	169	29.46	11.66	.13	0	1	60	58.33
Word-Grade2	165	41.98	13.37	−.36	−.12	1	69	43.68
Word-Grade3	147	50.77	12.78	−.72	.59	6	73	42.59
Word-Grade4	109	56.03	13.67	−1.07	.95	14	79	37.83
RC-Grade0	137	131.23	6.11	−.36	−.13	114.00	146.00	25.61
RC-Grade1	129	144.74	10.26	.14	−.14	119.00	170.00	35.48
RC-Grade2	146	157.53	15.43	1.25	2.37	130	224	28.99
RC-Grade3	130	166.92	16.69	.64	.22	136	214	24.78
RC-Grade4	93	180.85	22.76	.80	−.08	149	246	27.75

Note. N = the number of data points. FRL: Free/Reduced lunch status; ELL: English language learning status; Word-Grade 0–4: word reading performance at the beginning of 1st grade, the end of 1st grade, the end of 2nd grade, the end of 3rd grade, and the end of 4th grade, respectively; RC-Grade1–4: reading comprehension performance at the beginning of 1st grade, the end of 1st grade, the end of 2nd grade, the end of 3rd grade, and the end of 4th grade, respectively.

[†] indicates the average accuracy of the test.

Table 2

Correlations among Variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. Age	-																	
2. Rapid Sound Naming	.02																	
3. Rapid Letter Naming	.06	.47**																
4. Sound Matching	.10	.22**	.21**															
5. Non-verbal Reasoning	.23**	.13	.04	.18*														
6. Vocabulary	.14	.09	.19**	.21**	.15*													
7. Listening Recall	.15*	.16*	.13	.36**	.08	.29**												
8. Backward Digit Recall	.08	.19**	.24**	.38**	.17*	.27**	.34**											
9. Processing Speed	.27**	.14	.05	.16	.36**	.06	.11	.20*										
10. Word-Grade0	.05	.52**	.39**	.49**	.33**	.21**	.35**	.34**	.27**									
11. Word-Grade 1	−.15*	.36**	.26**	.44**	.10	.23**	.25**	.26**	.16	.61**								
12. Word-Grade2	−.21**	.32**	.35**	.36**	.14	.22**	.17*	.24**	.19*	.56**	.84**							
13. Word-Grade3	−.15	.41**	.37**	.33**	.20*	.16	.10	.23**	.26**	.44**	.69**	.83**						
14. Word-Grade4	−.16	.35**	.36**	.28**	.18	.13	.13	.25**	.23*	.44**	.70**	.83**	.90**					
15. RC-Grade0	−.05	−.07	−.15	.11	.03	−.06	.10	−.07	−.12	.13	.10	.10	.08	.10				
16. RC-Gradel	−.09	.33**	.28**	.42**	.20*	.24**	.27**	.21*	.21*	.59**	.80**	.73**	.69**	.64**	.15			
17. RC-Grade2	−.04	.21*	.28**	.33**	.35**	.41**	.25**	.28**	.34**	.53**	.62**	.63**	.57**	.50**	.09	.62**		
18. RC-Grade3	−.03	.23**	.20*	.37**	.32**	.46**	.26**	.17*	.28**	.43**	.51**	.49**	.51*	.45**	−.03	.53**	.71**	
19. RC-Grade4	−.05	.15	.18	.37**	.48**	.51**	.46**	.30**	.34**	.45**	.52**	.51**	.53**	.48**	.09	.50**	.72**	.78**

Note. Word-Grade 0–4: word reading performance at the beginning of 1st grade, the end of 1st grade, the end of 2nd grade, the end of 3rd grade, and the end of 4th grade, respectively; RC-Grade1–4: reading comprehension performance at the beginning of 1st grade, the end of 1st grade, the end of 2nd grade, the end of 3rd grade, and the end of 4th grade, respectively.

* $p < .05$

** $p < .01$

Table 3

Fixed and Random Effects Early Predictors of Word Reading and Reading Comprehension

Word Reading Fixed effects	Intercept (end of 1st grade)				Slope				Quadratic Term			
	coefficient	SE	T-ratio	p	coefficient	SE	T-ratio	p	coefficient	SE	T-ratio	p
Intercept	29.76**	1.20	24.79	< .001	15.12	1.16	13.06	< .001	−2.36	.45	−5.30	< .001
Age	−10.80**	2.86	−3.78	< .001	−5.13	2.87	−1.79	.08	1.40	.91	1.53	.14
Incoming Word Reading	1.11**	.29	3.90	< .001	−.63	.29	−2.19	.04	.13	.09	1.49	.15
Incoming Reading	−.18	.19	−.93	.36	.27	.19	1.39	.17	−.12	.06	−1.80	.08
Comprehension												
Domain-general Skills												
Working Memory	.91	1.73	.53	.60	−2.28	1.72	−1.33	.19	.90	.54	1.68	.10
Non-verbal Reasoning	−.45	.29	−1.56	.13	.39	.30	1.30	.20	−.03	.10	−.30	.77
Processing Speed	.32	.43	.73	.47	.94	.41	2.71	.03	−.28	.12	−2.29	.03
Domain-specific Skills												
Letter Knowledge	.61	1.60	.38	.71	6.30**	1.62	3.89	< .001	1.75**	.52	−3.35	.002
Phonological Awareness	.58	.25	2.34	.025	.12	.24	.51	.62	−.07	.07	−.95	.35
Vocabulary	.11	.16	.70	.49	.11	.16	.67	.51	−.05	.05	−1.07	.29
Random Effects	School-level Variance	Student-level Residual Variance	χ^2	BIC	School-level Variance	Student-level Residual Variance	χ^2	BIC	School-level Variance	Student-level Residual Variance	χ^2	BIC
	7.60	19.07	37.09	1877	7.60	19.07	37.09	1877	7.60	19.07	37.09	1877

Reading Comprehension Fixed effects	Intercept (end of 1st grade)				Slope			
	coefficient	SE	T-ratio	p	coefficient	SE	T-ratio	p
Intercept	145.94**	1.21	120.52	< .001	11.80	.71	16.61	< .001
Age	−8.77**	2.70	−3.25	.002	−1.21	1.89	−.64	.53
Incoming Word Reading	.97**	.27	3.61	< .001	−.26	.19	−1.38	.18
Incoming Reading	−.01	.18	−.08	.94	−.19	.13	−1.50	.14
Comprehension								
Domain-general Skills								
Working Memory	−.46	1.64	−.28	.78	.97	1.12	.87	.39
Non-verbal Reasoning	−.22	.28	−.79	.44	.51*	.20	2.52	.02

Reading Comprehension Fixed effects	Intercept (end of 1st grade)				Slope			
	coefficient	**SE**	**T-ratio**	**p**	**coefficient**	**SE**	**T-ratio**	**p**
Processing Speed	.80	.41	1.96	.78	.38	.26	1.45	.15
Domain-specific Skills								
Letter Knowledge	.26	1.52	.17	.86	.84	1.11	.76	.45
Phonological Awareness	.53	.23	2.30	.03	.04	.15	.28	.78
Vocabulary	.11	.15	.70	.49	.26*	.10	2.50	.02
Random Effects	School-level Variance	Student-level Residual Variance	χ^2	BIC	School-level Variance	Student-level Residual Variance	X^2	BIC
	9.96	77.20	40.49	2110	9.96	77.20	40.49	2110

Note. *p* value was corrected to reduce type one errors:

* $p < .025$

** $p < .005$