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Reading and Math Achievement in Children With Dyslexia, Developmental Language Disorder, or Typical Development: Achievement Gaps Persist From Second Through Fourth Grades

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Abstract

We examined how children ($N = 448$) with separate or co-occurring developmental language disorder (DLD) and dyslexia performed on school-based measures of academic functioning between second and fourth grades. Children were recruited from 1 school district in the U.S. state of South Carolina via classroom screenings and met common research criteria for DLD and dyslexia. Growth curve models were used to examine the overall form of growth and differences between groups. Children with DLD and/or dyslexia in second grade showed early and persistent deficits on school-administered measures of reading and math. In second grade, children with typical development (TD) scored significantly higher than children with dyslexia-only and DLD-only, who did not differ from each other. Children with DLD+dyslexia scored significantly lower than all other groups. Only small differences in growth rates were observed, and gaps in second grade did not close. Despite lower academic performance, few children (20%–27%) with dyslexia and/or DLD had received specialized support services. Children with DLD-only received services at less than half the rate of dyslexia-only or DLD+dyslexia despite similar impacts on academic performance. Evidence of significant and persistent functional impacts in the context of low rates of support services in these children—especially those with DLD-only—highlights the need to raise awareness of these disorders.

Keywords

dyslexia, developmental language disorder, academic performance, reading, math

Dyslexia and developmental language disorder (DLD) are highly prevalent, language-based learning disorders that place children at risk for poor reading comprehension and broader academic difficulties. Children with dyslexia have significant difficulties reading and spelling words that are not explained by general intellectual disability or lack of formal reading instruction (Kearns et al., 2019; Lyon et al., 2003; Miciak & Fletcher, 2020). In contrast, children with developmental language disorder (DLD; see also specific language impairment[1]) have persistent language difficulties that affect communication or learning, are unlikely to be resolved by age 5, and are not associated with a known biomedical condition (Bishop et al., 2016). DLD is defined in terms of oral language skill, which can include semantics, syntax, morphology, and/or discourse level skills such as conversation or understanding and telling stories (Bishop et al., 2016; Tomblin et al., 1997). DLD and dyslexia are different disorders, which frequently co-occur (Catts et al., 2005; McArthur et al., 2000); however, few studies of either disorder account for this overlap.

Epidemiological studies show that most children with DLD—whether it occurs alone or in combination with word reading difficulties—have not been identified prior to the study and have not received speech language services (Norbury et al., 2016; Tomblin et al., 1997). Similar arguments have been made related to the under-identification of children with dyslexia (Phillips & Odegard, 2017). It might seem intuitively clear that such children should be identified and provided with academic and/or clinical support. However, this is premised on the notion that these unidentified children are, in fact, experiencing difficulty in school.

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In the United States, eligibility for special education services depends on the presence of a disability in 1 of 13 categories covered by the Individuals with Disabilities Education Act and on evidence that they need special education supports to make appropriate progress in school. Although DLD and dyslexia fall under different eligibility categories—dyslexia is one of multiple categories of "specific learning disability" and DLD is one of multiple communication disorders that fall under the eligibility category of "speech or language impairment"—the disorders often co-occur, and evidence suggests that the same children often move between these two eligibility categories (Sun & Wallach, 2014).

Existing research on functional outcomes typically relies on samples of individuals who *have already* been identified (e.g., Conti-Ramsden et al., 2018; Olofsson et al., 2015) and therefore can't address this issue. Furthermore, children with comorbid DLD and dyslexia are overrepresented in clinical contexts, relative to those with only one disorder (Catts et al., 2005), and those with comorbid DLD and dyslexia may be expected to experience more significant effects on academic performance (Snowling et al., 2019). As a result, we cannot rule out the possibility that although many children meet criteria that researchers often use to identify DLD or dyslexia, these children are not, in fact, facing meaningful academic challenges even though they might in the future. This leaves a critical gap. Specifically, we don't know whether additional support is merited for the group of children who meet criteria for one or both disorders but are not currently identified as such.

In this study, we examined functional academic performance for children with dyslexia and DLD, taking advantage of measures of academic achievement that are used and administered by school systems and that align with state curricular expectations for reading and math. We recruited children following class-wide screenings to reduce the possibility that clinical referrals would bias the sample. We classified children with dyslexia and/or DLD using criteria commonly found in the research literature, which are often more inclusive than the criteria used by schools to identify children. Finally, we specifically considered the impact of dyslexia and DLD both separately and when they co-occurred. This approach allows us to address the critical question about the extent to which DLD and dyslexia, separately or comorbidly, have adverse effects on academic performance.

DLD and Dyslexia: Theoretical Context

As predicted by the simple view of reading (SVR; Hoover & Gough, 1990; Hoover & Tunmer, 2022), both DLD and dyslexia convey risk to the development of reading comprehension skills, which relies on strong word reading abilities (a problem for children with dyslexia) and strong linguistic comprehension skills (a problem for children with DLD). The SVR also suggests that children with weak skills in both domains (i.e., children with combined DLD + dyslexia) will usually experience the greatest impact on reading comprehension. However, the impact of DLD and dyslexia on overall reading performance may be realized to differing extents across reading development, given the changing influence of word reading and oral language skills on reading comprehension. In the early school years, word reading makes the largest contribution to reading comprehension, whereas in later school years, after most children have developed fluent word reading abilities and the texts used for instruction are more complex, broader language skills account for more variance in reading comprehension (Adlof et al., 2006; Foorman et al., 2018). To illustrate, Foorman and colleagues reported that the unique contribution of decoding to reading comprehension dropped from 14% in first grade to 9% in third grade. Across the same time period, the unique effect of language skill increased from 8% to 37%. Practically speaking, the focus of reading instruction and assessment also shifts across grades. In the early grades, the focus of instruction is on word reading, and assessments to measure progress in building foundational reading skills and word reading fluency are common. Before children are fluent readers, comprehension is supported through oral language activities. As children establish reading fluency, comprehension of complex texts becomes the primary focus of instruction and assessment. Thus, the reading difficulties experienced by children with dyslexia may be observable in the early grades as they struggle to build fluency. In contrast, although weak oral language skills may be present in early grades, resulting difficulties with reading comprehension may not be observable until later (Catts et al., 2012; Fong & Ho, 2019; Lipka et al., 2006; see also Psyridou et al., 2020). For example, Catts et al. (2012) reported that 70% of students with a kindergarten diagnosis of DLD experienced reading difficulties by 10th grade but 40% of those emerged in fourth grade or later. Children whose reading difficulties emerged by second grade generally struggled with word reading. Finally, during later school years, much of the language is learned by reading. Therefore, any disorder that affects reading could impact the rate of growth of language skills such as vocabulary (Duff et al., 2015; Hoover & Tunmer, 2022).

Although DLD and dyslexia are distinct disorders, they often co-occur (Catts et al., 2005; McArthur et al., 2000; Snowling et al., 2019). That is, within samples of children identified as dyslexic, some, but not all, children can be identified as having co-occurring language impairment; likewise, within samples of children with DLD, a wide range of word reading abilities can be observed, ranging from impaired to above average. The rate of co-occurrence has varied across studies, with higher rates of co-occurrence typically found in studies that recruit from pre-existing caseloads than in community-based samples (Dewey, 2021). Thus far, most research focused on the comorbidity of DLD and dyslexia has addressed theoretical questions about the cognitive underpinnings of DLD and dyslexia (see Adlof, 2020 for review). For example, many studies have examined whether these groups can be distinguished based on cognitive factors such as phonological processing (Bishop & Snowling, 2004; Bishop et al., 2009; Catts et al., 2005; Ramus et al., 2013; Snowling et al., 2019). Only a few of these studies have used a longitudinal design. Overall, these longitudinal studies find that in preschool and primary grades, children with dyslexia-only and children with DLD-only show similar levels of phonological deficit relative to TD controls, but the DLD-only group shows improved phonological processing over time, whereas the dyslexia-only group does not (Bishop et al., 2009; Catts et al., 2005; Snowling et al., 2019). At this time, the causal mechanisms that distinguish the DLD and dyslexia subgroups remain unclear, and there is growing recognition that these profiles arise from multiple interacting factors (Astle & Fletcher-Watson, 2020; Catts & Kamhi, 2017; Snowling et al., 2019).

Functional Impacts of DLD and Dyslexia

Insights about the nature of DLD and dyslexia have not been matched to date by similar gains in understanding of the functional impact of separate versus co-occurring DLD and dyslexia, including impacts on academic performance. This is important because negative effects on functional outcomes are important to determining whether dyslexia and/or DLD are associated with adverse impacts on academic performance, and if so, to what extent. Furthermore, it is not clear what the prognosis would be for a child who meets criteria for one or both of these disorders in the early school years. Understanding functional academic impacts is also crucial to the rationale for further research about these populations. Many studies report academic, social, and vocational impacts for either DLD (Brownlie et al., 2007; Conti-Ramsden & Durkin, 2012; Conti-Ramsden et al., 2009, 2013, 2018; Durkin et al., 2009; Snow, 2019; Snowling et al., 2001; Tomblin, 2014; Voci et al., 2006) or dyslexia (Daniel et al., 2006; Eloranta et al., 2019; McGee et al., 2002; Olofsson et al., 2015; Richardson, 2015; Willcutt et al., 2007), but these studies have not accounted for the frequent co-occurrence of the disorders. This means that conclusions drawn about one disorder may be affected by the presence of children in the study who also have the other disorder. Moreover, the existing research on functional impacts of DLD or dyslexia has usually involved children who have already been identified by schools or private clinics. This approach is likely to overrepresent children who meet criteria for both subgroups (Catts et al., 2005), which could lead to a distorted view of academic outcomes for children with only one disorder.

A recent example of a study that did consider comorbidity of DLD and dyslexia in relation to academic outcomes comes from Snowling and colleagues (2020), who examined reading comprehension performance in 8- and 9-year-old children with dyslexia-only, DLD-only, DLD+dyslexia, or TD. The children in the disorder groups had been recruited to the study at 3.5 years of age on the basis of a family history of dyslexia or low preschool oral language skills, and reclassification of groups as having DLD or dyslexia was determined on the basis of composite scores on standardized word reading and language assessments administered by the researchers at the 8-year-old assessment point. Reading comprehension at age 8 and 9 years was assessed with a researcher-designed task (Snowling et al., 2009). The mean reading comprehension scores of children with dyslexia-only were moderately but not significantly different from the TD group ($d = 0.51$ and .60 at 8 and 9 years, respectively). The DLD-only group had significantly worse reading comprehension than both the TD and dyslexia-only groups. The reading comprehension scores of the DLD+dyslexia group ($d = 1.79$ compared to TD at age 8, and 2.06 at age 9) were marginally worse than those of the DLD-only group ($d = 1.56$ compared to TD at both time points), and at age 9 years, their deficits began to approximate an additive combination of the deficits of the dyslexia-only and DLD-only groups. The current study builds on this evidence base by using school-administered measures of both reading and math achievement examined from second through fourth grades (when students are approximately 8–10 years of age) in a large, community-based sample.

Dyslexia and DLD Defined in Research and Educational Contexts

Studies investigating the nature of DLD and dyslexia have identified children based on criteria that are often more inclusive than the group of children who are identified by schools as needing educational supports. This is evidenced by very low rates of academic identification and clinical referral for children with DLD in disorder prevalence studies, which reported rates of service ranging between 17.7% (Zhang & Tomblin, 2000) and 39% (Norbury et al., 2016). This may, in part, be because schools often rely on referral models for identification of DLD (where symptoms must be noticed before an evaluation is initiated) and use arbitrary test score cutoffs that are more stringent than those used in research contexts (Adlof, 2020; Fulcher-Rood et al., 2018; Spaulding et al., 2012). It is possible that children who would meet the criteria for dyslexia or DLD using the more inclusive, research-based criteria are having academic difficulties that are not being recognized. Alternatively, it may be that these students, while they meet criteria for DLD or dyslexia used in research contexts, are not facing substantial academic challenges. To date, most studies of academic outcomes use samples of children who have been clinically referred or school identified. Children are presumably more likely to be flagged as needing additional support if they are having functional difficulties in academic or social contexts. This introduces a circularity when evaluating whether DLD and/or dyslexia impact academic outcomes; those with academic difficulties will be oversampled if study recruitment focuses on children who are already receiving services. In addition to differences in cutoffs, researchers often use different measures than those used by schools to measure academic progress, which may or may not align with current curricular expectations. The advantage of school-based measures is their ecological validity: They are designed to evaluate student performance relative to current curricular expectations on skills valued by the schools. Our study assessed reading and math performance on a school-administered assessment, the Measures of Academic Progress (MAP; Northwest Evaluation Association [NWEA], 2013), from second through fourth grades. The MAP is widely administered in the United States; the manufacturer reports that norms include data from 24,500 schools in 5,800 districts (NWEA, 2021). It is administered by schools to assess student progress on aspects of academic performance that are defined as functionally important by schools. For example, a recent survey of teachers indicated that many of them use MAP reading assessment data to provide differentiated instruction to individual students and to plan classroom reading instruction (January & Ardoin, 2015). More recently, analyses of MAP data were used to project the impact of school closures on academic achievement during the COVID-19 pandemic (Kuhfield & Tarasawa, 2020).

Impact of DLD and Dyslexia Across the Curriculum

Given the importance of language across a range of academic skills, one might expect that children with language-based disorders of dyslexia and/or DLD would experience difficulty across the curriculum. Supporting this idea, previous studies of children with DLD or dyslexia have shown difficulties in curricular areas including English, math, and science as well as overall grade point average (Conti-Ramsden et al., 2002; Willcutt et al., 2007), but again, these studies have not considered comorbidities. In this study, we considered the impact of DLD and dyslexia on reading and math outcomes. Practically speaking, reading and math are the first academic outcomes assessed in many regions, including the state where this study was conducted. In fact, there is reason to believe that math abilities are affected in both dyslexia and DLD. Previous studies of children with dyslexia have observed deficits in counting and number fact fluency (Boets & De Smedt, 2010; Moll et al., 2015; Vukovic et al., 2010). Those with comorbid reading and math disorder have particular difficulties with phonological storage that are not found in the math disorder only group (Peng et al., 2012). Similarly, children with DLD have also demonstrated difficulties with mathematics (Alt et al., 2014; Cross et al., 2019; Durkin et al., 2015; Fazio, 1996; Snowling et al., 2021), including difficulties with counting and number facts (Cowan et al., 2005; Fazio, 1996; Nys et al., 2013; but see Kleemans et al., 2011) as well as mathematical problem solving when problems are embedded in narrative contexts (Bjork & Bowyer-Crane, 2013; Cowan et al., 2005; Pimperton & Nation, 2010). Language-based interventions support the development of word problem skill (Fuchs et al., 2020, 2021), which is consistent with other evidence that language supports mathematical development over time (Peng et al., 2020; Spencer et al., 2020). In this study, math scores on the MAP served as a second measure of academic achievement that is important to overall academic success. Although not examined in this study, we would also anticipate that DLD and/or dyslexia would impact other curricular areas, including social studies and science.

Study Purpose and Design

The current study aims to address gaps in the existing literature about academic growth in children with dyslexia and/or DLD. Several unique features allow us to make a novel contribution to the literature about outcomes for children with these disorders. First, this study utilized classroom-wide screenings to recruit a representative sample that also accounts for the co-occurrence of dyslexia and DLD. Second, our study uses the Measures of Academic Progress (MAP; NWEA, 2013) to measure academic progress. The MAP is a computer adaptive test administered by schools to benchmark students' level of achievement in reading and math. MAP scores are reported in equal interval units that allow comparison of student performance within and between grades (January & Ardoin, 2015). Third, the current study analyzes longitudinal data from the MAP between second through fourth grades, a critical period in which the academic demands shift. To our knowledge, no previous published studies have considered reading or math outcomes for children with separate versus co-occurring DLD on school-administered measures. Our study addresses two questions using growth curve models to examine differences between groups in second grade and the overall form of growth between second and fourth grades.

RQ1. Do children with DLD and/or dyslexia experience academic deficits in second grade that are evident on a global, school-based measure of academic performance, that is, the MAP? We specifically ask: Are there intergroup differences in (a) reading and (b) math at the intercept?

RQ2. Do children with DLD and/or dyslexia experience differences in patterns of growth on a global, school-based measure of academic performance, such as the MAP? We specifically ask: Are there intergroup differences in form of growth of: (a) reading and (b) math between second and fourth grades?

We ran analyses both with and without a nonverbal IQ covariate included in the models. In the past, clinical and research identification of language or reading impairment has required IQ scores that were within normal limits (Catts et al., 2005; Gallinat & Spaulding, 2014; Miciak & Fletcher, 2020). Yet, children with DLD or dyslexia continue to score significantly lower than control groups on measures of nonverbal IQ even when their scores are within normal limits. This may be particularly relevant to the study of math because nonverbal IQ has been found to be a significant predictor of mathematical performance (Hornung et al., 2014; Jõgi & Kikas, 2016; Peng et al., 2019). Durkin et al. (2015) found that nonverbal IQ, rather than language skill, predicted mathematics performance in children with SLI. Additionally, nonverbal IQ has been found to be a significant early predictor of future reading comprehension (Adlof et al., 2010; Fuchs et al., 2012; Hayiou-Thomas et al., 2021), perhaps because of the increasing importance of reasoning skills for drawing inferences and comprehending complex texts (Tighe & Schatschneider, 2014). Therefore, it is of interest whether potential group differences are maintained for reading and math after controlling for nonverbal IQ. The findings were similar across both analyses. The results reported in the main manuscript include the nonverbal IQ covariate; models without the nonverbal IQ covariate are included in the supplemental materials.

Regarding reading, we predicted that participants with dyslexia-only would exhibit lower reading scores at the intercept compared to students with DLD-only due to the instructional focus on developing word reading skills in the early grades (Foorman et al., 2018), which are impaired in dyslexia. We also hypothesized that students with DLD would show a lower rate of reading growth than students with dyslexia-only or typical development (TD) because of the increasing reliance on language ability in reading comprehension (e.g., Adlof et al., 2006; Foorman et al., 2018; Kent et al., 2017). Thus, the developmental shift from "learning to read" to "reading to learn" was predicted to have different impacts on the dyslexia-only and DLD-only groups. Regarding math, we hypothesized that TD students would perform the highest on math at all time points, followed by students with either dyslexia-only or DLD-only, and that students with both DLD and dyslexia (DLD+dyslexia) would have the lowest scores across grades. We made no predictions about group differences in rate of growth in math.

Method

All procedures were reviewed and approved by the University of South Carolina Institutional Review Board. Upon enrollment, students completed background assessments of language, word reading, reading fluency, vocabulary, and nonverbal cognition. Prior to conducting these assessments, all research assistants received training in the administration of standardized assessments and were observed by a project coordinator who was a clinical psychologist or certified speech-language pathologist. Schools provided reports of participant performance on MAP reading and math assessments twice annually from fall of second grade through spring of fourth grade in the years 2013 to 2016.

Participants

Participants ($N = 448$) were in second grade at the time of enrollment and were enrolled in the study in waves each year for 3 years beginning in Fall 2013 and ending in Spring 2016. Participants had been part of a larger project examining language and reading development in children with DLD and/or dyslexia. All children were recruited from one school district located in South Carolina in which the median household income of families in the district is slightly lower than that of the United States overall ($65,000 vs. $67,500), and most students reside in households with two adults (70%) who have at least some college education (64%). Second-grade students in the district were screened using a classroom-based procedure which identified children to be tested for inclusion in one of the study subgroups (Adlof et al., 2017). All students in each second-grade classroom were screened at the same time. Trained research assistants administered the Listening Comprehension subtest of the Group Reading Assessment and Diagnostic Evaluation (Williams, 2001) as a screen of language abilities and the Test of Silent Word Reading Fluency (Mather et al., 2004) as a screen of word reading abilities. Students with low scores on either or both assessments were prioritized for invitation in follow-up assessments; see Adlof et al. (2017) for more details. The analyses in this study involved children with dyslexia-only ($n = 45$), DLD-only ($n = 91$), DLD+dyslexia ($n = 78$), or TD ($n = 234$) whose parents provided informed consent, who met criteria for study subgroups, and for whom the school district had MAP data available on at least one measure.

All participants were monolingual English speakers without hearing loss, motor disorder, or other diagnosed physical or medical problems that would interfere with speech or language development. Information on students' eligibility status in the National School Lunch program was available for 411 participants. In the United States, children are eligible for partial or complete funding of lunch meals if their family income is low relative to the poverty level or if they are eligible for other federal programs intended to reduce poverty. As such, it serves as a proxy measure of socioeconomic status. Of the 411 students, 234 were eligible for free meals, 24 were eligible for reduced-price meals, and 153 received full price meals. Parent-reported information about race was provided for 422 participants: 1 was American Indian (0.2%), 1 was Asian (0.2%), 132 were Black/African American (29.5%), 271 were White (60.5%), 1 was Native Hawaiian/Pacific Islander (0.2%), 6 were two or more races (1.3%), and 10 were described as "Other" (2.2%). Ethnicity was provided for only 291 participants, 7 of whom identified as Hispanic/Latino and 284 of whom identified as not Hispanic/Latino. The sample included 205 (45.8%) males and 232 (51.8%) females, with gender information not reported for 11 (2.5%) participants. The average age of the participants upon entry to the study in second grade was 7.98 years (*SD* = 0.40).

Subgrouping Measures and Criteria

Participants were classified into language/reading impairment subgroups in second grade. The Core Language Score from the Clinical Evaluation of Language Fundamentals—Fourth Edition (CELF-4; Semel et al., 2003), which provides an omnibus measure of language ability including both receptive and expressive language, was used to assess language ability. Participants with a standard score of 85 or lower on the CELF-4 Core Language composite were classified as DLD. According to the CELF-4 test manual, the internal consistency reliability of the Core Language score ranges from .94 to .95 for the ages represented in our study, and the selected cut score of 85 yields 100% sensitivity and 82% specificity for classification accuracy (Semel et al., 2003). Because this study was conducted in a region of the country where nonmainstream dialects of American English (NMAE) are common, we also administered the Diagnostic Evaluation of Language Fundamentals-Screening Test (DELV-ST; Seymour et al., 2003) to ensure that children who spoke a NMAE dialect were not incorrectly classified as having DLD on the basis of dialectal mismatch with the CELF-4 (cf. Adlof et al., 2017). Specifically, children who exhibited "some" or "strong" variation from mainstream American English on the DELV-ST also had to be classified by the DELV-ST as showing "medium-high" to "highest" risk of language impairment to remain in the DLD group for analysis. Speakers of NMAE whose DELV-ST risk status did not match their CELF-4 Core Language score were excluded from analyses.

The Basic Skills Cluster of the Woodcock Reading Mastery Tests, Third Edition (WRMT-III; Woodcock, 2011) was used to assess word reading ability. The Basic Skills Cluster includes the Word Identification subtest, which requires students to read real English words of increasing difficulty, and the Word Attack subtest, which requires them to decode English pseudowords. According to the test manual, the Basic Skills cluster reliability is .96 for second-grade students. Participants who received a standard score of 85 or lower on the WRMT-III Basic Skills Cluster were classified as meeting criteria for dyslexia. This cutoff is comparable to other studies that have used the WRMT-III (or previous versions) for identifying dyslexia (e.g., Catts et al., 2005; Joanisse et al., 2000; Siegel, 2008).

Participants who received a standard score of 85 or lower on both the CELF-4 and the WRMT-III were classified as DLD+dyslexia. Participants who scored above 85 on both assessments were classified as TD. Based on these classifications, for the CELF-4 Core Language score, the DLD-only group mean was 78.44 (*SD* = 6.31), the dyslexia-only group mean was 96.04 (*SD* = 6.39), the DLD+dyslexia group mean was 74.79 (*SD* = 8.49), and the TD group mean was 101.61 (*SD* = 9.70). For the WRMT-III Basic Skills Cluster score, the DLD-only group mean was 96.01 (*SD* = 8.56), the dyslexia-only group mean was 79.67 (*SD* = 3.68), the DLD+dyslexia group mean was 75.13 (*SD* = 6.65), and the TD group mean was 103.74 (*SD* = 10.96). The full sample mean was 91.62 (*SD* = 14.64) for the CELF-4 Core Language score and 94.77 (*SD* = 14.80) for the WRMT-III Basic Skills Cluster score.

Descriptive Measures

In addition to the subgroup classification measures, other norm-referenced assessments were administered to further characterize the subgroups in second grade. These assessments included the Expressive Vocabulary Test-2 (EVT-2; Williams, 2007), the Peabody Picture Vocabulary Test-4 (PPVT-4; Dunn & Dunn, 2007), the Test of Word Reading Efficiency-2 (TOWRE-2; Torgesen et al., 2012), and the Test of Nonverbal Intelligence-4 (TONI-4, Brown et al., 2010). We also obtained data from parents and schools on receipt of speech, language, reading, or other special education services. Parents provided this information as part of the intake questionnaire completed when students enrolled in the study in second grade. The school district provided this information based on whether the student had an Individualized Education Program (IEP) or not in the fall following the third cohort's study enrollment (Fall 2016).

Scoring Reliability

All assessments for the first cohort were double scored by trained research assistants to ensure reliability, with disagreements reconciled through discussion. For the second and third cohorts, 20% of the assessments were blind double-scored using blank protocols and audio and video recordings. Reliability was assessed as by-item agreement between scorers and was high for all assessments: 93.5% for CELF-4, 92% for DELV-ST, 96.8% for WRMT-III, 97.0% for TOWRE-2, 99.5% for EVT-2, 99.8% for PPVT-4, and 95.7% for TONI-4.

Outcome Measures: Reading and Math Measures of Academic Progress

Participating students completed the MAP Reading and Math growth assessments (NWEA, 2013), in fall and spring of each academic year they were enrolled in the study. The MAP is a computer adaptive assessment administered as part of the school district's monitoring plan. As a benchmark test, the MAP is intended to reflect likely performance on external measures such as state-wide proficiency tests (Cordray et al., 2012), and in third grade, MAP scores account for 75% of variance on the Iowa Test of Basic Skills (January & Ardoin, 2015). The MAP Reading assessment measures foundational reading skills (e.g., phonics, word recognition, context clues) and comprehension and analysis of literary and informational texts. The number of items testing each skill will vary depending on each student's current level of ability. The MAP Math assessment measures number sense and operations, algebraic thinking, geometry, and measurement. Although there are different subtests/domains within each MAP test, the premise of the MAP is that scores measure a single underlying construct (i.e., reading achievement or math achievement), which reflects coordinated engagement of multiple cognitive processes. Corresponding to this premise, total scores for the MAP were used as the outcome variables in this study. These scores were computed through a Rasch item response model framework, which yields a predicted ability score based on students' responses to items of varying difficulty. Thus, scores are vertically scaled across grades to allow comparison of student performance both within and across grade levels. The test-retest reliability for the MAP is $r = .78$ to .83 (Reading) and $r = 0.77$ to 0.89 (Math) for tests administered in consecutive semesters (NWEA, 2011). The internal consistency reliability (marginal reliability coefficient) was 0.96 (Reading) and 0.92 (Math; NWEA, 2011). The MAP was administered by teachers and other educational professional at the students' school under typical testing conditions.

Analytic Approach

Growth curve modeling was used to examine the rate and form of students' change in performance on the measures of reading and math from the fall of second grade to the spring of fourth grade. Rasch scores from the MAP assessments were used in all analyses. Following recommendations for growth curve modeling presented by O'Connell et al. (2013), data were first examined for evidence of nonnormality and missing data patterns that would affect the robustness of parameter estimates. Next, unconditional growth models were constructed separately for MAP Reading and MAP Math to determine the optimal form of growth to describe change in students' scores. Linear and quadratic forms were evaluated. Conditional growth was then examined, including main effects for diagnostic classification and including nonverbal IQ (i.e., TONI-4 Index Score) as a covariate. To assess hypotheses regarding differences in growth trajectories between the TD, DLD-only, and dyslexia-only groups, interactions between diagnostic classification and growth were examined. Statistically significant interactions would indicate that growth trajectories were not consistent across the groups.

Time was centered at the first time point so that the intercept indicated students' predicted scores in the fall of second grade. Each one-unit change in time was scaled to correspond with a MAP testing window (0 = *Fall Second Grade*, 1 = *Spring Second Grade*, etc.). The dyslexia-only group was selected as the reference group for the reported conditional models to allow for direct comparison between the dyslexia-only group and the other diagnostic groups (also see Tables S3 and S4 in the online supplemental materials for group comparisons against the DLD-only diagnostic groups).

All modeling was conducted in the R environment (R Core Team, 2019) using the lme4 package (Bates et al., 2015), consistent with a mixed-effect regression approach to growth modeling (McNeish & Matta, 2018). Model fit was evaluated considering (a) normality of residuals, (b) chi-square difference testing among nested models, and (c) compatibility between visualization of modeled growth and individual student growth (O'Connell et al., 2013; Raudenbush & Bryk, 2002). Syntax used for data preparation and analysis is available at https://osf.io/zuxf7.

Nesting of time points ($i = 2{,}554$) within students ($j = 448$) within teachers ($n = 55$) within schools ($k = 11$) was examined in each model. First, intraclass correlation coefficients obtained from unconditional models were examined for evidence of substantial variation (i.e., nearing ICC $= 0.10$) at each level of nesting. Then, levels that appeared to contribute to predicting variability in the outcome were included in the modeling structure and reevaluated in the conditional framework.

Results

Descriptive Statistics

Group performance on background descriptive measures is provided in Table 1. Overall, students classified as TD had the highest average scores on all descriptive measures, while the children classified as having DLD+dyslexia achieved the lowest average scores. Students classified as dyslexia-only scored in the normal range on average on all descriptive measures except the word reading fluency measure ($M = 80.47$, $SD = 7.50$). Students classified as DLD-only achieved lower average scores on the vocabulary measures compared to the children classified as dyslexia-only but scored higher on word reading fluency ($M = 95.68$, $SD = 11.04$). Overall, this pattern of performance is consistent with that observed for the subgrouping assessments. Finally, all group means were well within the average range on the measure of nonverbal intelligence, and most children classified as DLD (90.7% DLD-only, and 93.2% DLD + dyslexia) scored within one standard deviation of the normative mean, thus meeting common research criteria for SLI.

Of children categorized as typically developing, 47% received a free or reduced-price lunch. These rates were 49%, 75%, and 73% for the dyslexia-only, DLD-only, and DLD-and-dyslexia groups respectively. According to parent report regarding students' receipt of supplemental educational services to date in second grade (Table 1), only 18% ($n = 80$) of the sample had been referred for services. Of the 214 students classified as having DLD and/or dyslexia according to study criteria, 27.1% ($n = 58$) were reported to have received services. The proportion of children in the dyslexia-only and DLD+dyslexia groups who had received supplemental educational services was over twice that of children in the DLD-only group (33% and 37% vs. 15%, respectively). Some parents who responded positively to this question included explanations that referred to response to intervention. Student enrollment in special education classrooms showed similar trends. Less than 20% ($n = 38$) of students classified as having DLD and/or dyslexia were receiving special education services, according to school report. Taken together, these descriptive results for the DLD group are similar to past epidemiologic studies of children with DLD (Norbury et al., 2016; Tomblin et al., 1997), but these prior studies did not consider whether DLD occurred alone or in combination with word reading difficulties.

Scores for MAP Reading and Math by time point and diagnostic classification are shown in Table 2. Overall, student scores increased each semester, though less change was evident from each spring to fall compared to fall to spring. Students classified as TD had the highest average scores across all time points compared to students classified with DLD and/or dyslexia. Students classified as having both DLD and dyslexia had the lowest average scores both for Reading and Math.

Missing Data and Model Considerations

Student scores for both MAP Reading and Math were normally distributed. Missing data were observed at a rate of 9.4% for Reading and 8.5% for Math across all 3 years, with more data missing in years 2 and 3 compared to year 1. For nonverbal IQ, missing data occurred at a rate of 10.5% ($n = 47$). No additional patterns of missing data were identified through examination of missingness by performance on background measures and classification status. Given that the missing-at-random (MAR) assumption was plausible, we used restricted maximum likelihood (REML) estimation to fit the models. REML is preferred to maximum likelihood (ML) to generate less biased estimates of variance parameters (Raudenbush & Bryk, 2002). For model comparisons, ML estimation was used to facilitate chi-square difference testing. With larger sample sizes and more clusters (i.e., students and schools), the difference between REML and ML is negligible (Snijders & Bosker, 2012).

Some administration errors ($n = 25$ out of 2240 datapoints) were noted in the dataset. Errors included basal and ceiling violations. Scores with violations were flagged according to the type of administration error. A best estimate for the score was then reported whenever possible, using available data. To assess the impact of including these scores in the analyses, sensitivity analyses were conducted with these values excluded. No substantial differences were identified in any of the reported results. Consequently, all data are included in the results reported in this manuscript.

Growth Analysis—Reading

The observed change in students' MAP Reading scores from fall of second grade through spring of fourth grade was best described as quadratic (see Table 3 and Figure 1A). Students tended to increase their scores by approximately 7.84 points each semester (95% CI = [7.21, 8.48], $p < .001$), though this rate of growth decreased (-0.51, 95% CI = [-0.63, -0.39], $p < .001$) over time. Significant differences in performance on MAP Reading were identified between the groups at intercept. Compared to students classified as having dyslexia-only, typically developing students scored approximately 11.69 points higher (95% CI = [8.36, 15.02], $p < .001$) on reading in the fall of second grade after accounting for scores on nonverbal IQ. Students identified as having dyslexia and DLD scored approximately 6.32 points lower (95% CI = [-10.09, -2.56], $p = .001$) than those with dyslexia-only. No significant differences in MAP Reading scores were observed between children classified as having dyslexia-only and those classified as having DLD-only (0.89, 95% CI = [-2.74, 4.51], $p = .632$).

Table 1. Prior Receipt of Supplemental Services and Descriptive Measure Scores by Qualification for Diagnosis.

	Receipt of supplemental services to date (Parent report in 2nd grade)		Instructional setting (School report in 2016–2017)		School lunch status	Expressive vocabulary[a]	Receptive vocabulary[b]	Word reading fluency[c]	Nonverbal intelligence[d]
Group	No known services	Child has received services	General education	Special education	Free or reduced-price lunch	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Dyslexia only	30 (67%)	15 (33%)	33 (73%)	7 (16%)	22 (49%)	100.84 (6.47)	103.74 (9.57)	80.44 (7.57)	100.98 (8.59)
DLD only	77 (85%)	14 (15%)	79 (87%)	7 (8%)	69 (75%)	91.35 (7.36)	92.51 (7.73)	95.87 (11.18)	99.79 (9.90)
DLD+dyslexia	49 (63%)	29 (37%)	41 (53%)	24 (31%)	22 (49%)	87.77 (8.19)	91.79 (9.44)	75.73 (11.13)	95.66 (8.31)
Typically developing	212 (91%)	22 (9%)	215 (92%)	5 (2%)	110 (47%)	104.74 (9.62)	105.78 (11.35)	103.79 (11.90)	106.36 (8.88)
Full sample	368 (82%)	80 (18%)	368 (82%)	43 (10%)	234 (57%)	97.24 (11.18)	99.07 (11.89)	94.79 (15.92)	102.42 (9.90)

Note. DLD = developmental language disorder.
[a]Expressive Vocabulary Test, 2nd Edition Standard Score.
[b]Peabody Picture Vocabulary Test, 4th Edition Standard Score.
[c]Test of Word Reading Efficiency, 2nd Edition Total Word Reading Efficiency Index Score.
[d]Test of Nonverbal Intelligence, 4th Edition Index Score.

Table 2. Mean MAP Scores by Year and Diagnostic Classification.

	MAP reading							MAP math						
Group	Fall Grade 2	Spring Grade 2	Fall Grade 3	Spring Grade 3	Fall Grade 4	Spring Grade 4	All years	Fall Grade 2	Spring Grade 2	Fall Grade 3	Spring Grade 3	Fall Grade 4	Spring Grade 4	All years
Dyslexia only	167.53 (10.35)	182.18 (12.34)	181.76 (12.54)	193.43 (12.73)	192.49 (12.14)	201.69 (10.52)	185.31 (10.58)	171.89 (9.41)	185.51 (10.25)	186.67 (9.24)	197.52 (9.47)	197.45 (9.36)	205.85 (8.58)	189.84 (8.64)
DLD only	170.84 (12.19)	183.04 (10.27)	182.45 (12.14)	191.96 (11.54)	192.81 (11.69)	200.06 (11.13)	186.16 (9.87)	172.52 (8.46)	185.30 (8.71)	185.03 (8.75)	195.53 (9.14)	195.35 (9.58)	204.19 (9.65)	189.01 (8.55)
DLD and Dyslexia	160.85 (11.37)	174.43 (11.92)	175.25 (11.40)	185.38 (12.15)	184.26 (13.39)	193.70 (11.78)	177.73 (9.84)	167.00 (8.19)	180.86 (9.63)	181.57 (9.30)	191.69 (8.26)	191.91 (9.91)	200.56 (9.67)	184.62 (8.35)
Typically developing	182.82 (14.69)	196.13 (10.78)	195.87 (13.00)	204.03 (10.77)	204.81 (12.65)	211.67 (10.54)	198.55 (11.20)	182.20 (10.14)	194.19 (8.89)	195.08 (9.62)	204.80 (9.52)	205.31 (9.47)	214.46 (9.89)	198.64 (9.03)
Full sample	175.03 (15.86)	188.30 (14.01)	188.19 (15.03)	197.30 (13.57)	197.65 (14.87)	205.31 (12.97)	191.65 (17.36)	176.58 (11.24)	189.20 (10.60)	189.89 (10.89)	199.95 (10.64)	200.23 (11.04)	209.18 (11.25)	
Sample size (*n*)	448	444	424	418	414	406		446	446	422	419	413	408	

Note. Table includes means. Standard deviations are in parentheses. MAP = Measures of Academic Progress; DLD = developmental language disorder.

Table 3. Growth in MAP Reading Controlling for Nonverbal IQ.

	Main effects				Model including interactions			
Predictors	*Estimates*	*95% CI Lower*	*95% CI Upper*	*p-value*	*Estimates*	*95% CI Lower*	*95% CI Upper*	*p-value*
(Intercept – Dyslexia only)	171.17	168.10	174.24	**<.001**	**169.34**	**165.84**	**172.84**	**<.001**
Time (semester/grade)	**7.84**	**7.21**	**8.48**	**<.001**	**8.55**	**7.64**	**9.47**	**<.001**
Time^2	**−0.51**	**−0.63**	**−0.39**	**<.001**	**−0.51**	**−0.63**	**−0.39**	**<.001**
Classification: DLD Only	0.89	−2.74	4.51	.632	3.22	−1.01	7.45	.136
Classification: DLD+dyslexia	**−6.32**	**−10.09**	**−2.56**	**.001**	**−5.69**	**−10.07**	**−1.32**	**.011**
Classification: Typical	**11.69**	**8.36**	**15.02**	**<.001**	**14.12**	**10.26**	**17.98**	**<.001**
TONI: Centered at 100	**0.20**	**0.09**	**0.31**	**<.001**	**0.20**	**0.09**	**0.31**	**<.001**
Interaction: DLD*Time					**−0.91**	**−1.76**	**−0.07**	**.035**
Interaction: DLD+dyslexia*Time					−0.25	−1.12	0.63	.580
Interaction: Typical*time					**−0.95**	**−1.72**	**−0.18**	**.015**
Random effects								
n_{Students} = 401	σ^2 = 52.68				σ^2 = 52.65			
Observations = 2,287	τ_{00} = 101.40 $_{\text{Student}}$				τ_{00} = 100.89 $_{\text{Student}}$			
	τ_{11} = 1.88 $_{\text{Student / Semester Grade}}$				τ_{11} = 1.81 $_{\text{Student / Semester Grade}}$			
	ρ_{01} = −0.41 $_{\text{Student}}$				ρ_{01} = −0.41 $_{\text{Student}}$			
	Adj. ICC = 0.63				Adj. ICC = 0.63			
	Cond ICC = 0.31				Cond ICC = 0.30			
	Marginal R^2/Conditional R^2 = .516/.822				Marginal R^2/Conditional R^2 = .519 / .823			

Note. Significant results are in bold. Estimates are provided based on the Dyslexia-only group as the reference. CI = confidence interval; IQ = intelligence quotient; ICC = intraclass correlation coefficient; DLD = developmental language disorder; TONI = test of nonverbal intelligence.

There was some evidence of interaction effects consistent with hypotheses. Students with DLD-only exhibited a slightly slower growth in their reading scores compared to students with dyslexia-only (-0.91, 95% CI = [-1.76, -0.07], p = .035). There was also an interaction between TD status and growth, indicating that students with TD grew at a slower rate compared to students with dyslexia-only (-0.95, 95% CI = [-1.72, -0.18], p = .015). No interaction was observed between time and DLD+dyslexia status.

The best-fitting random effects structure for reading accounted for student-level nesting but not nesting within teachers or schools. Both teacher-level and school-level random effects accounted for less than 1% of the variance in reading scores. Random effects for student by semester were identified, suggesting that individual students grew at different rates between each of the included time points. Overall, a slight negative association was observed between students' reading scores in fall of second grade and their growth over the 3 years of the study (ρ_{01} = -0.41). The models accounted for 82.3% of the variation in students' MAP Reading scores from fall of second grade through spring of fourth grade. The fixed effects alone explained 51.9% of the variation in students' scores. Models not including nonverbal IQ as a covariate are provided in Table S2, and models with children with DLD-only as the reference group are available in Table S3 in the online supplemental materials.

Growth Analysis: Math

Similar to MAP Reading, the change in students' MAP Math scores from fall of second grade through spring of fourth grade was best described as quadratic (see Table 4, Figure 1B). Students' scores increased by approximately 7.84 points each semester (95% CI [7.22, 8.46], p <.001). The rate of growth again decreased over time (-0.36, 95% CI = [-0.45, -0.27], p < .001). Significant differences by group were observed at intercept, as participants classified as typically developing scored approximately 7.13 points higher (95% CI = [4.51, 9.75], p < .001) on math than participants with dyslexia-only, after accounting for nonverbal IQ. Students classified as having both dyslexia and DLD scored approximately 3.44 points lower (95% CI = [-6.41, -0.46], p = .024) than those with dyslexia-only. There were no significant differences in math performance between students identified as having DLD-only compared to those with dyslexia-only (-0.33, 95% CI = [-3.20, 2.54], p = .822).

Only one potential interaction effect was observed. Students with DLD-only exhibited a slightly slower rate of growth in math across the duration of the study compared to students with dyslexia-only (-0.69, 95% CI = [-1.27, -0.11], p = .021). There was no evidence of interactions among any of the other groups.

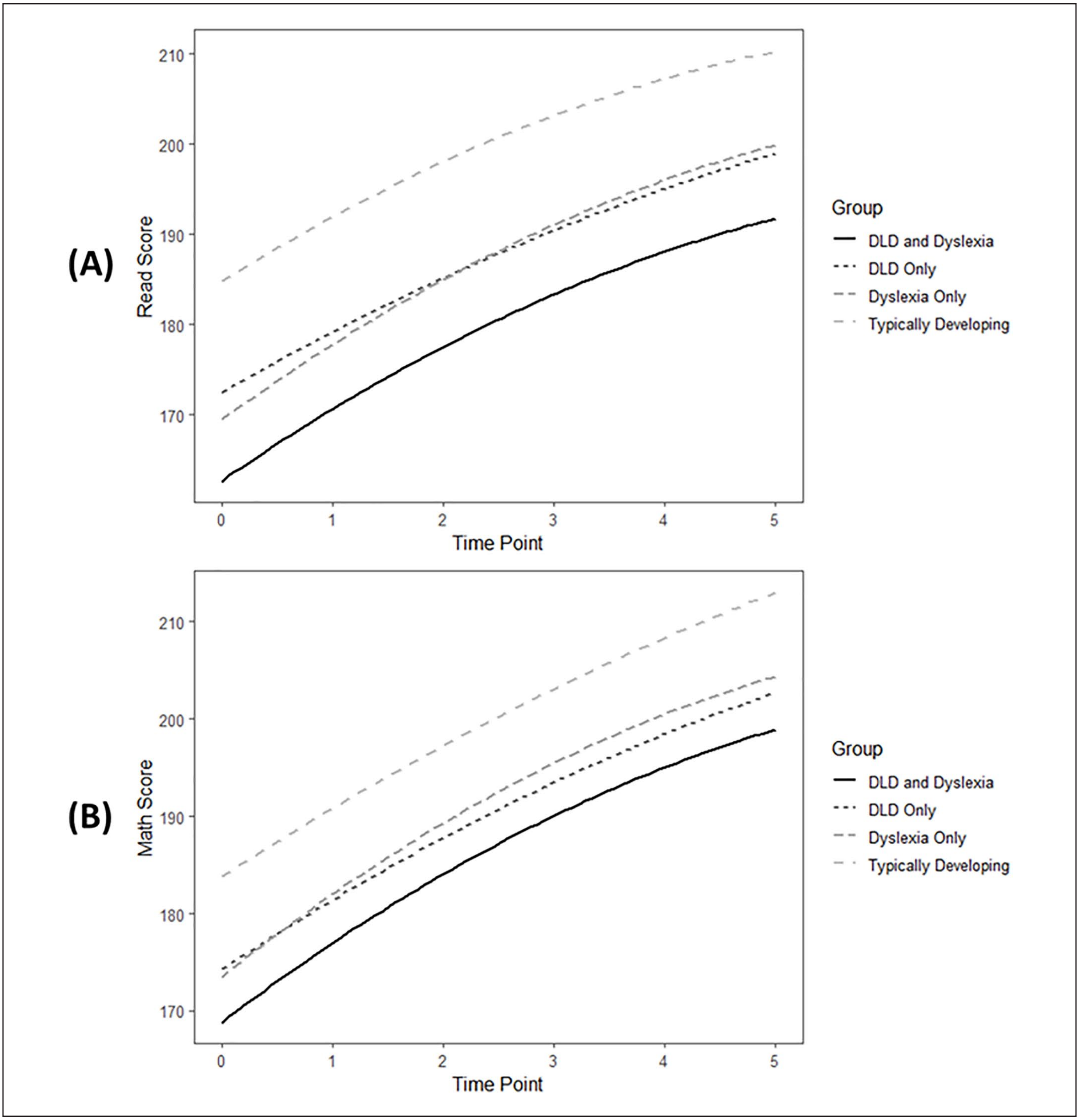

Figure 1. Growth curves depicting students' predicted MAP scores in (A) reading and (B) math from second to fourth grades by classification group.
Note. MAP = Measures of Academic Progress; DLD = Developmental Language Disorder.

The best-fitting random effects structure for math accounted for both student-level nesting and school nesting, as significant variation in math scores was attributable to both student variability and to school variability. Nesting of students within teachers' classrooms did not contribute substantially to differences in students' math scores (ICC $<$ 0.01). Random effects for student by semester were identified, suggesting again that individual students grew at different rates between each of the included time points even after accounting for school-level variation. The fixed effects alone explained 61.6% of the variation in students' MAP Math scores from fall of second grade through spring of fourth grade, with the full models accounting for 86.3% of the variation in scores. Models not including nonverbal

Table 4. Growth in MAP Math Controlling for Nonverbal IQ.

	Main effects model				Model including interaction terms			
Coefficient	*Estimates*	*95% CI Lower*	*95% CI Upper*	*p-value*	*Estimates*	*95% CI Lower*	*95% CI Upper*	*p-value*
(Intercept—Dyslexia Only)	174.27	171.47	177.07	**<.001**	173.55	170.61	176.49	**<.001**
Time (semester/grade)	**7.84**	**7.22**	**8.46**	<.001	**8.21**	**7.44**	**8.98**	**<.001**
$Time^2$	**−0.36**	**−0.45**	**−0.27**	<.001	**−0.36**	**−0.45**	**−0.27**	**<.001**
Classification: DLD Only	−0.33	−3.20	2.54	.822	0.98	−2.10	4.05	.534
Classification: DLD+dyslexia	**−3.44**	**−6.41**	**−0.46**	**.024**	−2.85	−6.03	0.33	.080
Classification: Typical	**7.13**	**4.51**	**9.75**	<.001	**7.79**	**4.99**	**10.59**	**<.001**
TONI: Centered at 100	**0.27**	**0.19**	**0.36**	<.001	**0.27**	**0.19**	**0.36**	**<.001**
Interaction: DLD*Time					**−0.69**	**−1.27**	**−0.11**	**.021**
Interaction: DLD+dyslexia*Time					−0.31	−0.90	0.29	.311
Interaction: Typical*Time					−0.35	−0.88	0.17	.190
Random Effects								
$n_{Students}$ = 401	σ^2 = 32.16				σ^2 = 32.15			
$k_{Schools}$ = 11	τ_{00} = 49.44 $_{Student / School}$				τ_{00} = 49.34 $_{Student / School}$			
Observations = 2287	5.13 $_{School}$				= 5.29 $_{School}$			
	τ_{11} = 0.32 $_{Student / School \| Semester}$				τ_{11} = 0.30 $_{Student / School \| Semester}$			
	= 0.37 $_{School / Semester}$				= 0.37 $_{School / Semester}$			
	ρ_{01} = 0.08 $_{Student / School}$				ρ_{01} = 0.09 $_{Student / School}$			
	= −0.57 $_{School}$				= −0.60 $_{School}$			
	Adj. ICC = 0.64				Adj. ICC = 0.64			
	Cond ICC = 0.25				Cond ICC = 0.25			
	Marginal R^2 / Conditional R^2 = .616 / .863				Marginal R^2 / Conditional R^2 = .616 / .863			

Note. Significant results are in bold. Estimates are provided based on the Dyslexia-Only group as the reference. CI = confidence interval; IQ = intelligence quotient; ICC = intraclass correlation coefficient; DLD = developmental language disorder; MAP = measures of academic progress; TONI = test of nonverbal intelligence.

IQ are provided in Table S2, and models with children with DLD-only as the reference group are available in Table S4 in the online supplemental materials.

Discussion

Existing research indicates that there are many children who meet criteria for DLD or dyslexia but do not receive formal academic or clinical supports (Norbury et al., 2016; Phillips & Odegard, 2017; Zhang & Tomblin, 2000). Prior to this study, however, there has been no data published that speaks to the question of whether such children experience functional difficulties in academic contexts. Moreover, dyslexia and DLD frequently co-occur, but neither studies on functional outcomes nor studies reporting under-identification for each disorder have considered separate versus co-occurring dyslexia and DLD dyslexia. The results of this study are generalizable to just such children, namely those who meet research criteria for dyslexia-only, DLD-only, or both disorders yet do not seem to have been identified by schools or clinicians as needing support.

In this study, we examined functional measures of academic performance in children who met research-based criteria for dyslexia and/or DLD between second and fourth grades. Our approach was novel because we used a community-based sample rather than recruiting primarily from those who were clinically referred or at risk because of family history. Overall academic performance was measured with reading and math achievement scores on the MAP, a widely used computer adaptive test of academic progress administered by schools to benchmark student achievement on curricular standards. Data were analyzed using a mixed-effects modeling approach to examine both initial performance in second grade and patterns of growth between second and fourth grades. We found that children with either DLD or dyslexia in second grade exhibited significantly lower performance than their typically developing peers in both reading and math achievement. Students who met criteria for both disorders showed significantly poorer performance than children with one disorder. Furthermore, growth rates were generally similar across groups, and differences in academic performance persisted through fourth grade. Regarding group differences and growth rates, similar results were obtained when nonverbal IQ was included in the model and when it was not.

The findings from this study thus provide unique evidence that children with both DLD and dyslexia who are not identified from clinical samples do exhibit lower academic achievement than their peers on measures administered by schools. Furthermore, their difficulties are not restricted to reading-related skills but also extend to another curricular areas, namely math. Academic impacts of DLD and dyslexia compound, such that the most significant effects are experienced by children who meet criteria for both disorders. These difficulties persisted across all time points in this study, from second through fourth grade. Taken together, these novel findings underscore the importance of research about identification and appropriate academic supports for students with separate and co-occurring DLD and/or dyslexia.

Longitudinal Impacts of DLD Versus Dyslexia on Overall Reading Achievement

A strength of this study is the use of the MAP to measure overall reading achievement longitudinally during a time in development when children are expected to shift from “learning to read” (i.e., to decode words) to “reading to learn.” To our knowledge, no prior studies have examined reading achievement in children with separate versus co-occurring DLD and dyslexia on school-administered measures. The MAP is a widely used, school-administered test which measures overall reading achievement for students across grade levels. Items are aligned with state content standards to measure foundational skills, including phonics and word reading, as well as higher level skills such as comprehension and analysis of literary and informational texts. As a computer adaptive test, the proportion of items of each type that each student receives will depend on their performance. The test is vertically scaled to allow for the estimation of growth over time; thus the overall reading score reflects students’ overall progress on curricular standards in reading. Based on the SVR (Hoover & Gough, 1990), we expected that children with combined dyslexia and DLD, who by definition struggle with both word reading and oral language, would experience the greatest impact on reading comprehension, which would be reflected in MAP reading achievement scores. Indeed, we found robust evidence for an additive effect, such that children who met criteria for both dyslexia and DLD had lower performance than groups of children who had only one of these disorders. Our results build on those of Snowling et al. (2020), who examined reading comprehension of 8- to 9-year-old children who had a history of preschool language difficulties or a family history of dyslexia. Snowling et al. (2020) found that children with DLD-only performed worse than children with dyslexia-only or TD on a researcher-designed measure of reading comprehension, but only marginal differences between the DLD-only and DLD+dyslexia group and nonsignificant differences between dyslexia-only and TD. The participants in the current study were also approximately 8 years old at the first measurement point. Our results indicate that when progress on overall reading standards is considered, both the dyslexia-only and the DLD-only groups exhibit deficits relative to TD, and the DLD+dyslexia group shows significantly greater impact than dyslexia-only and DLD-only.

We found that gaps in reading performance between disordered and typically developing groups in the fall of second grade persisted through the spring of fourth grade. As shown in Figure 1A, the mean MAP reading scores of the DLD-only and dyslexia-only groups in fall of third grade were similar to those of the TD group in the fall of second grade. In the DLD+dyslexia group, which had more severe reading deficits, the MAP reading scores in spring of third grade were similar to those of the TD group in the fall of second grade. Thus, the reading deficits observed in the disorder groups were educationally meaningful. Our findings for the DLD-only group extend those of Tomblin (2014), who also found a difference of approximately 1 year between children with a kindergarten history of DLD or TD language on a global reading measure administered by schools in third and fourth grades. However, Tomblin's (2014) analysis did not differentiate between DLD-only and DLD+dyslexia.

Although we hypothesized slower growth rates in reading for the DLD-only group, we found that growth rates were mostly similar across groups. We did find that children with dyslexia-only had slightly higher growth rates in MAP reading scores than children with DLD-only, but these differences were very small and not sufficient to close gaps present in second grade. This finding may be attributable to the use of an omnibus measure of reading skill, which meant that while the reasons for difficulty (i.e., word reading vs. oral language) may be different, the impact of these distinct disorders on overall reading performance remained relatively constant between second and fourth grades. However, based on previous research on late-emerging poor readers and poor comprehenders (Catts et al., 2012; Psyridou et al., 2020), we would expect gaps in comprehension—and therefore overall reading achievement—to widen for children with DLD-only and dyslexia-only at older ages. This is a question for future research.

Impact of DLD and Dyslexia Across the Curriculum

No previous studies have examined the impact of separate versus co-occurring dyslexia and DLD on academic achievement beyond reading per se. We predicted that children with DLD-only and dyslexia-only would experience additional academic challenges; therefore, we examined math scores as an available example of the effect of language-based disorders on academic performance beyond reading. We found that in fall of second grade, children with dyslexia-only and children with DLD-only had lower math performance on the MAP than their TD peers, with little difference between the dyslexia-only and DLD-only groups. The DLD+dyslexia group had lower scores than the DLD-only and dyslexia-only groups. These results parallel the finding for the MAP reading test and suggests that the deficits associated with dyslexia and DLD may have additive effects on math outcomes. However, the raw score differences for math were somewhat smaller than for reading. As shown in Figure 1B, the DLD-only and dyslexia-only groups were approximately 1.5 semesters behind the TD group in MAP math scores, whereas the DLD+dyslexia were approximately 1 year behind. In terms of growth rates for math skills, children with dyslexia-only had a slightly higher growth rate for MAP math than did children with DLD-only. No additional between-group differences were observed, and the gaps that existed in second grade for all groups with disorders persisted through fourth grade.

Importantly, while the groups differed in nonverbal IQ scores, results regarding academic performance were not solely explained by nonverbal IQ differences. In line with previous studies, nonverbal intelligence was a significant covariate in both the reading (Hayiou-Thomas et al., 2021) and math (Peng et al., 2019) models. The finding that group differences were significant both with and without the nonverbal IQ covariate in the model indicates that dyslexia and DLD contribute to academic performance in reading and math above and beyond contributions of nonverbal intelligence.

The MAP generates global measures that include a range of tasks, and the current data do not allow us to comment on whether there were different reasons for low math achievement across groups. There may be different cognitive paths that lead to similar outcomes for the DLD-only and dyslexia-only groups on a global measure of math performance. Whatever the cognitive mechanisms involved, a key takeaway from these data is that DLD and/or dyslexia have functional academic impacts that extend beyond content areas that are designated as "reading." Furthermore, these deficits persist over time.

Research vs. Clinical Categorization of DLD and Dyslexia

A critical feature of this study was community-based recruitment; participants were recruited following classroom-wide screenings. Previous studies on academic performance in children with dyslexia or DLD have generally used samples of children who are clinically referred or at-risk based on family history. However, previous research shows that most children who meet research criteria for dyslexia or DLD are not identified by schools as in need of service (Norbury et al., 2016; Zhang & Tomblin, 2000), which could affect validity of conclusions in this line of research about functional impacts. In the current sample, less than 40% of children in any of these groups had received any type of supplemental educational services based on parent report; a similar pattern, with lower overall proportions, was observed for school reports of special education services. We do not have data from schools about whether students received other supports, such as Response to Intervention (RTI) services, so reported service rates may not reflect all academic supports offered to students. Another limitation of our data is that we don't have detailed information about the specific types or amount of services children received. For this reason, we did not compare academic performance between children who were reportedly receiving services and those who were not. This is a research question for future studies. Nonetheless, despite these limitations, we are reassured that between parent-reported and school-reported data, we were successful in recruiting children who were not formally identified by schools as being in need of additional academic supports. This addresses limitations of previous studies about functional impacts of DLD and dyslexia because we are able to draw conclusions about outcomes for a range of children who meet common research criteria for DLD and/or dyslexia, not only those receiving formal academic or clinical supports. In this inclusive sample, we found evidence of meaningful intergroup differences in academic performance.

It is noteworthy that the school-reported rate of special education services was different between groups. Children who had characteristics of both dyslexia and DLD had the highest reported rates of service although even in this group, the majority did not seem to be receiving supplemental support. Parents reported similar rates of specialized services for children with dyslexia-only and DLD+dyslexia, and students with DLD-only were the *least* likely to have received any services. Thus, in this sample, children with dyslexia seemed to be more likely to receive support than children with DLD despite similar levels of impact on academic performance. Because the current study was not designed to address this question specifically, further studies are needed to confirm these findings. The pattern of results in this sample, in which children with DLD seem to be receiving lower levels of specialized support than children with dyslexia despite similar academic impacts, is in line with recent calls to raise awareness of DLD and its impacts (McGregor, 2020) and for schools to systematically monitor oral language development in similar ways as reading and math skills are monitored (Adlof & Hogan, 2019). Other research suggests that many parents and teachers have low knowledge about language disorders, decreasing the likelihood of referral (Friberg, 2006; Skeat et al., 2010). Once referred, system-wide constraints may affect whether children with DLD receive services (Fulcher-Rood et al., 2018; Selin et al., 2018). Additionally, other variables including gender, geographic location, minority status, the presence of co-occurring speech disorders, and socioeconomic status (see review by McGregor, 2020) affect the probability that children with DLD will receive services. Notably, these variables are not intrinsically related to the functional significance of the language disorder itself. Thus, our findings are consistent with other literature, which demonstrates low levels of specialized support for children with DLD (Norbury et al., 2016; Zhang & Tomblin, 2000), and highlight a need to raise awareness of DLD and its impacts on academic progress. It might be assumed that low referral rates are because children with DLD and/or dyslexia (defined in ways common to researchers) were not meaningfully affected in real world academic performance. Data from this study would strongly argue against this interpretation and would rather lend support to the idea that children with DLD and/or dyslexia should be identified and provided with adequate supports.

Conclusion

Children who met standard research criteria for dyslexia or DLD in second grade exhibited significantly lower performance than TD peers on school-administered, global measures of reading and math achievement, which persisted from fall of second grade through the spring of fourth grade. Children who met criteria for both disorders showed the lowest level of performance across all measures and time points. These findings of significant functional impacts on academic achievement support the validity of standard research criteria for dyslexia and DLD. However, the majority of children with dyslexia and/or DLD identified by the researchers had not received special education services, according to both parent and school reports. Children with DLD-only were least likely to have received services despite similar levels of academic performance relative to the dyslexia-only group in second grade. This highlights a continued need to raise awareness of this disorder and its impacts within both research and school settings. We believe that all who are interested in children with learning disabilities—researchers, practitioners, and parents—need to be aware of the role of oral language skills and the impact of DLD on academic progress.

Authors' Note

The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. Preliminary results of this study were presented at the 2018 meeting of the Society for the Scientific Study of Reading in Brighton, England.

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Author Contributions

Study conception and design: S.M.A., A.E.H., and D.M.D. Data acquisition and management: S.M.A., A.E.H. Data analysis and interpretation: L.F., S.M.A., and D.M.D. Manuscript drafting: D.M.D., A.E.H., L.F., and S.M.A. All authors contributed to critical revisions of the manuscript and approved the final submitted version.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Supplemental Material

Supplemental material for this article is available on the *Journal of Learning Disabilities* website at with the online version of this article.

Note

1. The DLD label was recently proposed as an alternative to the term *specific language impairment* (SLI; Bishop et al., 2016). SLI is defined similarly as DLD, that is, significant difficulty understanding and producing spoken language despite normal hearing and normal intellectual abilities (National Institute on Deafness and Other Communication Disorders (NIDCD), 2019), but studies of SLI have traditionally required nonverbal IQ scores to fall within normal limits (Leonard, 2014). Such studies of children with SLI can be considered to represent a subset of children with DLD.

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