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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

Dawna Duff
Department of Communication Science and Disorders, University of Pittsburgh

Alison Eisel Hendricks
Department of Communicative Disorders and Sciences, University at Buffalo

Lisa Fitton
University of South Carolina - Columbia, fittonl@mailbox.sc.edu

Suzanne M. Adlof
University of South Carolina - Columbia, sadlof@mailbox.sc.edu

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Dawna Duff

Department of Communication Science and Disorders, University of Pittsburgh

Alison Eisel Hendricks

Department of Communicative Disorders and Sciences, University at Buffalo

Lisa Fitton

Suzanne M. Adlof

University of South Carolina, Department of Communication Sciences and Disorders

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Correspondence to

Suzanne M. Adlof, sadlof@mailbox.sc.edu

University of South Carolina, Department of Communication Sciences and Disorders, 1705 College Street, Suite 220, Columbia, SC 29208

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Author Contributions

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

Abstract

We examined how children (n=448) who met research criteria for separate vs. co-occurring DLD and dyslexia performed on school-based measures of academic functioning in reading and math between second and fourth grades. 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 all other groups, children with DLD+dyslexia scored significantly lower than all other groups, and children with dyslexia-only and DLD-only did not differ from each other. Only small differences in growth rates were observed, and gaps in second grade did not close. Few children (20-27%) meeting research criteria for dyslexia and/or DLD had received specialized support services. Children with DLD-only received services at less than half the rate of the dyslexia groups, despite similar levels of academic performance. Evidence of significant and persistent functional impacts on academic achievement support the validity of standard research criteria for dyslexia and DLD. Low rates of reported support services in these children—especially those with DLD-only—highlight the need to raise awareness of these disorders.

Dyslexia and developmental language disorder (DLD) are highly prevalent, language-based learning disorders that both 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 (Lyon et al., 2003). In contrast, children with developmental language disorder (DLD; see also specific language impairment[1]) have language difficulties that affect communication or learning, are unlikely to be resolved by age five, 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. Thus, DLD and dyslexia have distinct cognitive profiles. Importantly, though, they also frequently co-occur (Catts et al., 2005, McArthur et al., 2000).

Dyslexia and DLD are both reported to have a long-term impact on functional outcomes. For example, adults with a history of DLD have been reported to have more restricted employment opportunities (Conti-Ramsden & Durkin, 2012), more limited social experiences with peers (Tomblin, 2014), poorer quality of friendships and higher levels of social anxiety (Conti-Ramsden et al., 2013; Voci et al., 2006), higher risk of victimization in the forms of bullying and sexual abuse (Brownlie et al., 2007), and higher risk of involvement in the legal system (Snow, 2019). Similarly, individuals with dyslexia have increased risk of depression, lower self esteem, lower social functioning, and higher rates of unemployment in adulthood (Eloranta et al., 2019). Academically, children who are identified as having DLD are also at risk for a range of academic difficulties, including lower grades (Snowling et al., 2000), lower overall academic attainment (Conti-Ramsden et al., 2009; Durkin et al., 2009) and a higher risk of functional illiteracy (Tomblin, 2014), compared to typically developing peers. Similarly, children identified as having dyslexia experience lower grades and lower ratings of academic success by youth and teachers (Wilcutt et al., 2007) and lower rates of high school completion (Daniel et al., 2006, McGee et al., 2002). Of those who attend university, students with a history of dyslexia have lower grades and passing rates (Richardson, 2015) and express less confidence in notetaking and reading (Olofsson et al., 2015). These challenges have long term implications: language related disorders are estimated to significantly decrease both labor force participation and wages in adulthood (Cronin et al., 2020).

Reported differences in academic outcomes motivate efforts to identify children with dyslexia or DLD as early as possible and to provide intervention in an attempt to promote academic success. However, there are limitations in the existing literature, which we outline below. These limitations complicate the apparently straightforward conclusion that DLD and dyslexia negatively impact academic performance and point to a need for clearer information about academic achievement in children with dyslexia or DLD.

First, the group of children identified as having DLD or dyslexia in research contexts tend to be more inclusive than the group of children who are identified by schools as needing educational supports. This is evident in very low rates of academic identification and clinical referral for such children, relative to prevalence studies, which reported rates of service ranging between 17.7% (Zhang & Tomblin, 2000) to 39% (Norbury et al., 2016). One possibility is that children who would be classified as having dyslexia or DLD (using these more inclusive criteria) are having academic difficulties, but these needs are not being recognized by the schools. Alternatively, it may be that these students, while they meet criteria for DLD or dyslexia as used in research contexts, are not facing substantial academic challenges. Directly related to this, many studies of academic outcomes use samples of children who have been clinically referred, or school identified. Presumably, children are 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 are likely to be oversampled if study recruitment focuses on children who are already receiving services. This could lead to a distorted sense of the academic impact for the group as a whole. Specifically, this recruitment approach limits our ability to answer questions about those who meet research-based criteria for these disorders, but who are not identified by schools as being in need of additional supports. This information is a critical requirement in order to inform decisions about whether to invest in efforts to identify and intervene for these children. In the current study, children were recruited via classroom wide screenings. Children who were at risk of dyslexia and/or DLD based on these screenings received further diagnostic assessments to determine if they met research-based criteria for dyslexia and/or DLD. This method allowed us to include children with DLD and/or dyslexia who were receiving services, and those who were not. This results in a sample of children with DLD and/or dyslexia that are representative of these groups.

A second complication to the discussion about academic outcomes in these groups is rooted in the high co-occurrence of these disorders. As described earlier, although DLD and are distinct disorders (Catts et al., 2005; Ramus et al., 2013) they often co-occur (McArthur et al., 2000). Prior studies of school academic outcomes in children with dyslexia or DLD have not accounted for their frequent co-occurrence. This is an important limitation, because conclusions drawn about one disorder may be affected by the presence of children in the study sample who also had the other disorder. In principle, a failure to account methodologically for the co-occurrence of DLD and dyslexia could lead to a distorted view of academic outcomes for children with only one of these disorders. This is not merely a hypothetical risk. McArthur and colleagues (2000) found that approximately half of children who were clinically referred for dyslexia also had impaired language, and approximately half of children with DLD also had dyslexia. Rates of comorbidity of DLD and dyslexia were lower for children drawn from an epidemiologic sample (Catts et al., 2005). This suggests that samples recruited from clinical sources may over-represent children who meet criteria for both subgroups. Thus, when studies don't clearly account for the comorbidity of dyslexia and DLD, this interacts with the previously noted challenges regarding studies that sample from children who have been previously referred. The current study recruited children through classroom screenings and sampled children with dyslexia only and DLD only, as well as children with both disorders. This allowed us to consider these groups separately in our analyses, and to draw conclusions about the effect of each disorder both separately and together.

A further complexity in interpreting data on academic outcomes in children with DLD and/or dyslexia relates to the nature of measures used to assess academic functioning. Measures administered by researchers may or may not align with current curricular expectations or academic success in the classroom. For example, administration of standardized or researcher designed measures of nonword reading, word recognition, vocabulary, and reading comprehension can provide insight into specific cognitive process that may contribute to academic difficulties. However, they may or may not reflect the functional difficulties- or successes- that children are experiencing in the classroom. This is because academic performance involves the coordination of multiple cognitive processes, used across academic domains. Thus, academic success is related to, but not the same as, performance on tests of individual processes. Our study uses the Measures of Academic Progress (MAP; Northwest Evaluation Association (NWEA), 2013) to measure academic progress. The MAP is administered by schools to benchmark student performance on aspects of academic performance that are defined as functionally important by the school. We believe that the ecological validity of this measure is a strength of this study.

Fourth, when considering academic achievement for students with dyslexia and/or DLD, it is necessary to consider the changing importance of word reading and broader language skills at different stages of reading development. Within the Simple View of Reading (SVR; Hoover & Gough, 1990), word reading and broader comprehension skills are considered as distinct dimensions. The Simple View predicts that children with co-occurring DLD and dyslexia should be affected more than children with either disorder alone. There is also a developmental shift in the skills that contribute most strongly to reading comprehension (Adlof et al., 2006; Foorman et al., 2018). Word reading is the instructional focus in early school years and makes the largest contribution to reading comprehension. In contrast, broader language skills account for more variance in reading comprehension in later school years. Therefore, children with dyslexia who have slow or inaccurate word reading in the early grades should experience reading comprehension difficulties in the early grades; if these persist, they may interfere with children's ability to acquire new information from text. Children with DLD are particularly at risk of comprehension related disorders. This is presumed to be especially challenging in older grades, as text becomes more complex and more demanding of broader language skills. Thus, children with dyslexia and DLD are expected to have different developmental trajectories of reading. These differences are especially likely to be evident during the critical period in academic development in which students transition between learning to read and reading to learn. The current study aimed to examine academic outcomes longitudinally across just this juncture, between 2nd and 4th grades.

Further, we examine performance across two curricular areas. DLD and dyslexia are each expected to impact performance across academic disciplines. 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. However, there is more information about the impact of dyslexia and DLD on reading than other curricular areas. Previous studies of children with dyslexia have observed deficits in counting and number fact fluency (Moll et al., 2015; Boets & de Smedt, 2010; Vukovic et al., 2010). Children with DLD have also demonstrated difficulties with mathematics (Alt et al., 2014; Cross et al., 2019; Durkin et al., 2015; Fazio,1996), 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). Importantly, these prior studies have not considered the impacts of separate vs. co-occurring dyslexia and DLD. Additionally, in the late elementary school grades, written texts become an increasing source of new knowledge acquisition, and there is an increasing reliance on reading and writing activities to deliver information and assess performance in all academic content areas. Thus, there is reason to believe that the impact of these disorders on math and may change across the school grades. The data in this study allow us to examine the impact of dyslexia and DLD on math as well as reading performance from 2nd to 4th grades.

Finally, children with DLD or dyslexia often score significantly lower than control groups on measures of nonverbal IQ, even when nonverbal IQ is within normal limits (Gallinat & Spaulding, 2014). This is particularly relevant to the study of math because nonverbal IQ has been found to be a significant predictor of mathematical performance across several studies (Hornung et al., 2014; Jogi & Kikas, 2015; Peng et al., 2019). Durkin and colleagues (2015) also report that nonverbal IQ, rather than language skill, predicted mathematics performance children with SLI (Durkin et al., 2015). 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., 2020), 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.

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. This includes a representative sample that accounts for the co-occurrence of dyslexia and DLD and use of ecologically valid measures of academic growth across content domains. To our knowledge, no previous published studies have considered reading or math outcomes for children with separate vs. co-occurring DLD on school-administered measures. Our study addresses two questions using growth curve models to examine differences between groups in 2nd grade and the overall form of growth between 2nd and 4th grades.

1. Do children with DLD and/or dyslexia experience academic deficits in 2nd grade that are evident on a global, school-based measure of academic performance, i.e., the MAP? We specifically ask: Are there intergroup differences in (a) reading and (b) math at the intercept?
2. Do children with DLD and/or dyslexia experience differences in 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 2nd and 4th grades?

With regard to reading, we predicted that participants with dyslexia-only would exhibit lower reading scores at the intercept compared to students with DLD-only because early reading relies heavily on decoding-specific skills (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 (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

Participants

Participants (*n*=448) were in second grade at the time of enrollment and were enrolled in the study in waves each year for three years beginning in Fall 2013 and ending in Spring 2016. Participants had been part of larger project examining language and reading development in children with DLD and/or dyslexia. All children were recruited from one school district located in [State]. 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 (Author et al., Year). 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 were monolingual English speakers, without hearing loss, motor disorder, or other diagnosed physical or medical problems that would interfere with speech or language development. 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 Caucasian (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%). The sample included 205 (45.8%) males and 232 (51.8%) females, with gender information not reported for 11 (2.5%) participants.

Procedures

Upon enrollment, students completed background assessments of language, word reading, reading fluency, vocabulary, and nonverbal cognition. 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 2013-2016. All procedures were reviewed and approved by the University of [State] Institutional Review Board.

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, this cut score 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 dialect (cf. Author et al., Year). 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 in order 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. 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 cut-off 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.

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 IEP or not in the fall following the third cohort's study enrollment (Fall 2016).

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 Reading assessment measures foundational reading skills (e.g., phonics, word recognition, context clues) and comprehension and analysis of literary and informational texts. The MAP Math assessment measures number sense and operations, algebraic thinking, geometry, and measurement. The MAP assessments are computer adaptive interim assessments and were administered as part of school district's progress monitoring plan. Scores for each subtest (i.e., Reading and Math) are 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 facilitate evaluation of growth and academic development across grades.

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 Grade 2 to the spring of Grade 4. Rasch scores from the MAP assessments were used in all analyses. Following recommendations for growth curve modeling presented by O'Connell and colleagues (2013), data was first examined for evidence of non-normality 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 diagnostic classification to evaluate potential differences in trajectory between each of the identified groups, and including nonverbal IQ (i.e., TONI-4 Index Score) as a covariate. Time was centered at the first time point so that the intercept indicated students' predicted scores in the Fall of Grade 2. Each one-unit change in time was scaled to correspond with a MAP testing window (i.e., 0 = Fall Grade 2, 1 = Spring Grade 2, 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 (but see supplementary Tables S3 and S4 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), employing 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 will be made available in the supplemental materials.

Nesting of time points (i = 2554) within students (j = 448) within schools (k = 11) was examined in each model. Teacher-level nesting (n = 55) was also considered, but classrooms did not account for significant variation in either MAP Reading or Math scores. This may be because students moved classrooms each year, reducing the longitudinal impact of any individual teacher above and beyond the school in which the child was enrolled.

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). 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.

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). 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.

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 Estimation

Student scores for both MAP Reading and Math were normally distributed. Missing data was 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).

Growth Analysis – Reading

The observed change in students' MAP Reading scores from fall of grade 2 through spring of grade 4 was best described as quadratic (see Table 3 and Figure 1A). Students tended to increase their scores by approximately 7.84 points each semester (p <.001), though this rate of growth decreased (-0.48, 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 (p <.001) on reading in the fall of grade 2, after accounting for scores on nonverbal IQ. Students identified as having dyslexia and DLD scored approximately 6.32 points lower (p =.001). No significant differences in MAP Reading scores were observed between children classified as having dyslexia only and those classified as having DLD only (95% CI = -2.74 to 4.51, p = .632).

There was some evidence of interaction effects. Students with DLD only exhibited a slightly slower growth in their reading scores compared to students with dyslexia only (-0.91, 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, 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 school nesting, as school accounted for less than 1% of the variance in reading scores. Additionally, 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 grade 2 and their growth over the three years of the study ($\square_{01} = -0.41$). The models accounted for 82.3% of the variation in students' MAP Reading scores from fall of grade 2 through spring of grade 4. The fixed effects alone explained 51.9% of the variation in students' scores. Models not including nonverbal IQ as a covariate are provided in supplementary Table S2, and models with children with DLD-only as the reference group are available in supplementary Table S3.

Growth Analysis – Math

Similar to MAP Reading, the change in students' MAP Math scores from fall of grade 2 through spring of grade 4 was best described as quadratic (see Table 4, Figure 1B). Students' scores increased by approximately 7.84 points each semester (p <.001). The rate of growth again decreased over time (-0.36, p <.001). Significant differences by group were observed at intercept, as participants classified as typically developing scored approximately 7.13 points higher (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 (p =.024). There were no significant differences in math performance between students identified as having DLD only compared to those with dyslexia only (95% CI = -3.20 to 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, p = .021). There was no evidence of interactions among any of the other groups.

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. Additionally, the model included random effects for student by semester, 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 grade 2 through spring of grade 4, with the full models accounting for 86.3% of the variation in scores. Models not including nonverbal IQ are provided in supplementary Table S2, and models with children with DLD-only as the reference group are available in supplementary Table S4.

Discussion

DLD and dyslexia are different disorders, which frequently co-occur. In this study, we examined academic performance in 2nd through 4th grades, in children who met common research criteria for dyslexia and/or DLD. We examined reading and math scores on a global, school-based measure of academic performance, the MAP. The MAP has high validity because it is used by schools to benchmark student achievement on parameters deemed important by schools themselves. Participants were identified via classroom wide screenings, so our results apply both to children who have been identified as being in need of additional academic support, and those who have not. Further, we separately considered those who had one disorder, and those who had both. Data was analyzed using a mixed-effects modeling approach to examine both initial performance in 2nd grade and patterns of growth between 2nd and 4th grades.

Key results from this study are as follows: children who met standard research criteria for dyslexia or DLD in 2nd grade exhibited significantly lower performance than their typically developing peers on school-administered, global measures of reading and math achievement. There were no significant differences in performance between the dyslexia- only and DLD-only groups in second grade, and children who met criteria for both disorders showed significantly poorer performance than children with one disorder. In terms of patterns of growth, growth rates in both reading and math were similar across groups, although children with dyslexia-only had slightly higher growth rates in MAP reading scores than children with DLD-only or TD and slightly higher growth rates in MAP math than children with DLD only. However, these differences in growth were very small, and not sufficient to close gaps present in 2nd grade. Lower levels of performance for all disorder groups persisted from fall of second grade through the spring of fourth grade. None of these findings were solely attributable to differences in nonverbal IQ across groups because nonverbal IQ was included as a covariate in the model. These results are novel and important because they allow a direct comparison across children with one or both disorders, and because the sample includes children who haven't been referred for additional academic support as well as those who have.

With respect to reading, one key finding is that in second grade, students meeting research criteria for either dyslexia or DLD had lower performance on school-based reading measures (such as the MAP) than children with TD. These results can be interpreted within the SVR (Hoover & Gough, 1990), in which reading comprehension is the product of language comprehension and word recognition skills. By definition, children with dyslexia are impaired in word recognition, and children with DLD are impaired in foundational language skills. Interestingly, the performance on the MAP reading assessment, a global assessment of overall reading ability, was similar for the DLD-only and dyslexia-only groups in second grade. While there are different reasons for reading difficulties in dyslexia and DLD, reading performance on the MAP was affected to a similar extent in this sample as early as second grade. Children who met criteria for both dyslexia and DLD had lower performance than groups of children who had only one of these conditions. Again, this is congruent with the SVR because these children experience two disadvantages with respect to reading comprehension, namely word reading and language comprehension.

Another key finding in this study concerned the rate of growth in reading performance across language and reading subgroups. Longitudinal data was collected during a time in development when children are expected to shift from "learning to read" (i.e., to decode words) to "reading to learn". With respect to reading achievement, we hypothesized that children with dyslexia-only would initially score lower than their peers with DLD-only on school-administered, global reading assessments because of their word reading difficulty, but that their rate of reading growth would be faster than children with DLD-only because of strong language skills in the dyslexia only group. There was partial support for this hypothesis. Although there were no significant differences between the dyslexia-only and DLD-only groups in second grade, children with dyslexia-only had slightly higher growth rates in MAP reading scores than children with DLD-only and, somewhat unexpectedly, children with TD. However, these small differences in growth rate were not sufficient to close the gap that was present in second grade. More importantly, the reading gaps that existed in second grade for children in all three disorder groups persisted through fourth grade.

With respect to math, we found that in second grade, children with dyslexia had lower math performance on the MAP than their TD peers, as did children with DLD. Parallel to the findings for reading, there was little difference between the dyslexia-only and DLD-only groups on the MAP Math scores, so both groups were affected to a similar extent. The MAP generates global measures which include a range of tasks, and the current data does not allow us to comment on whether there were different reasons for low math achievement across groups. However, previous research (Cross et al., 2019; Alt et al., 2014, Boets & de Smedt, 2010; Vukovic, Lesaux & Sigel, 2010) does suggest that the different cognitive profiles in dyslexia and DLD impact different aspects of math performance (e.g. math fluency, word problems). Thus, 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. The DLD+dyslexia group had lower scores than the DLD-only and dyslexia-only groups. This result parallels the finding for the MAP reading test and suggests that the deficits associated with dyslexia and DLD may have additive effects on math outcomes. 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 et al., 2020) 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.

These results about intergroup differences are important because they indicate that DLD and dyslexia each do impact academic performance, even for those who are not identified as being in need of additional academic supports. In fact, in this sample, less than 40% of children in any of these groups had received any type of supplemental educational services; a similar pattern, with lower overall proportions, was observed for school reports of special education services. We do not have specific information about whether or when children received response to intervention (RTI) support between second and fourth grades, as RTI data was not stored in a centralized system by the school district across the years of the study. This is a direction for future research. However, 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 rates of service, but even in this group, the majority did not seem to be receiving supplemental support. Students with DLD-only were the least likely to have received any services, even though their reading and math performance was affected to a similar degree as children with dyslexia-only in 2nd grade. This is consistent with previous studies which indicates that the majority of children with DLD do not receive special education or clinical services (Zhang & Tomblin, 2000; Norbury et al, 2016).

Other research suggests that many parents and teachers have low knowledge about language disorders, decreasing the likelihood of referral (Friberg, 2006; Skeat, 2010). Once referred, system wide constraints may affect whether children with DLD receive services (Selin et al., 2018; Fulcher-Rood et al., 2018). Additionally, socioeconomic status (Whittke & Spaulding, 2018), and the presence of co-occurring speech disorders (Zhang & Tomblin, 2000) 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 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.

Conclusions

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 2nd grade. This highlights a continued need to raise awareness of this disorder and its impacts, within both research and school settings.

Endnote

[1] The DLD label was recently proposed as an alternative to the term specific language impairment (SLI; Bishop et al., 2017). Children with SLI have similar language deficits (National Institute on Deafness and Other Communication Disorders (NIDCD), 2019), but studies of SLI have traditionally required nonverbal IQ scores to fall within 1 standard deviation of the population mean (Leonard, 2014). Such studies of children with SLI can be considered to represent a subset of children with DLD.

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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)**		**Expressive Vocabulary[1]**	**Receptive Vocabulary[2]**	**Word Reading Fluency[3]**	**Nonverbal Intelligence[4]**
	No Known Services	Child Has Received Services	Regular Education	Special Education	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Dyslexia Only	30 (67%)	15 (33%)	33 (73%)	7 (16%)	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%)	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%)	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%)	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%)	97.24 (11.18)	99.07 (11.89)	94.79 (15.92)	102.42 (9.90)

[1]Expressive Vocabulary Test, 2nd Edition Standard Score
[2]Peabody Picture Vocabulary Test, 4th Edition Standard Score
[3]Test of Word Reading Efficiency, 2nd Edition Scaled Score
[4]Test of Nonverbal Intelligence, 4th Edition Index Score

Table 2

Mean MAP Scores by Year and Diagnostic Classification

	MAP Reading							MAP Math						
	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.

Table 3

Growth in MAP Reading Controlling for Nonverbal IQ

	Main Effects with NVIQ				Model Including Interactions with NVIQ			
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**
Nonverbal IQ: 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 = 2287	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	= 0.516 / 0.822			Marginal R^2 / Conditional R^2	= 0.519 / 0.823		

Note. Estimates are provided based on the Dyslexia-Only group as the reference.

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	= 0.616 / 0.863			Marginal R^2 / Conditional R^2	= 0.616 / 0.863		

Note. Estimates are provided based on the Dyslexia-Only group as the reference.

Supplemental Materials

S1. *Growth of MAP Reading Without Nonverbal IQ*

S2. *Growth of MAP Math Without Nonverbal IQ*

S3. *MAP Reading Controlling for Nonverbal IQ - Reference is Children with DLD-Only* (comparable to Table 3)

S4. *MAP Math Controlling for Nonverbal IQ - Reference is Children with DLD-Only* (comparable to Table 4)

Table S1

Growth of MAP Reading Without Nonverbal IQ

	Main Effects Model				Model Including Interaction Terms			
Predictors	*Estimates*	*95% CI Lower*	*95% CI Upper*	*p-value*	*Estimates*	*95% CI Lower*	*95% CI Upper*	*p-value*
(Intercept – Dyslexia Only)	171.55	168.52	174.59	**<.001**	169.66	166.20	173.13	**<.001**
Time (semester/grade)	**7.76**	**7.16**	**8.36**	**<.001**	**8.47**	**7.60**	**9.34**	**<.001**
$Time^2$	**-0.48**	**-0.60**	**-0.37**	**<.001**	**-0.48**	**-0.60**	**-0.37**	**<.001**
Classification: DLD Only	0.20	-3.41	3.82	0.913	2.33	-1.88	6.54	0.278
Classification: DLD+Dyslexia	**-7.48**	**-11.20**	**-3.76**	**<.001**	**-6.86**	**-11.19**	**-2.53**	**.002**
Classification: Typical	**12.65**	**9.42**	**15.89**	**<.001**	**15.24**	**11.47**	**19.00**	**<.001**
Interaction: DLD*Time					-0.80	-1.61	0.01	.052
Interaction: DLD+Dyslexia*Time					-0.23	-1.07	0.61	.590
Interaction: Typical*Time					**-0.97**	**-1.69**	**-0.24**	**.009**
Random Effects								
n_{Students} = 448	σ^2 = 52.68				σ^2 = 52.65			
Observations = 2554	τ_{00} = 111.50 Student				τ_{00} = 110.88 Student			
	τ_{11} = 1.84 Student / Semester Grade				τ_{11} = 1.76 Student / Semester Grade			
	ρ_{01} = -0.42 Student				ρ_{01} = -0.42 Student			
	Adj. ICC = 0.65				Adj. ICC = 0.65			
	Cond ICC = 0.32				Cond ICC = 0.32			
	Marginal R^2 / Conditional R^2 = 0.500 / 0.825				Marginal R^2 / Conditional R^2 = 0.503 / 0.826			

Table S2

Growth of MAP Math Without 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)	174.70	171.80	177.60	**<.001**	174.18	171.18	177.18	**<.001**
Time (semester/grade)	**7.86**	**7.28**	**8.44**	**<.001**	**8.15**	**7.43**	**8.87**	**<.001**
$Time^2$	**-0.36**	**-0.45**	**-0.28**	**<.001**	**-0.36**	**-0.45**	**-0.28**	**<.001**
Classification: DLD Only	-0.49	-3.37	2.39	.739	0.48	-2.56	3.51	.759
Classification: DLD+Dyslexia	**-4.91**	**-7.86**	**-1.97**	**.001**	**-4.57**	**-7.67**	**-1.46**	**.004**
Classification: Typical	**8.23**	**5.66**	**10.79**	**<.001**	8.76	6.05	11.46	**<.001**
Interaction: DLD*Time					-0.55	-1.09	0	**.050**
Interaction: DLD+Dyslexia*Time					-0.20	-0.76	0.36	.448
Interaction: Typical*Time					-0.30	-0.79	0.19	.239

Random Effects

		Main Effects Model		Model Including Interaction Terms	
n Students	= 446	σ^2	= 31.36	σ^2	= 31.15
k Schools	= 11	τ_{00}	= 53.81 Student / School	τ_{00}	= 53.77 Student / School
Observations	= 2554		= 7.00 School		= 7.05 School
		τ_{11}	= 0.29 Student / School | Semester	τ_{11}	= 0.28 Student / School | Semester
			= 0.34 School / Semester		= 0.33 School / Semester
		ρ_{01}	= 0.17 Student / School	ρ_{01}	= 0.17 Student / School
			= -0.58 School		= -0.59 School
		Adj. ICC	= 0.68	Adj. ICC	= 0.68
		Cond ICC	= 0.28	Cond ICC	= 0.28
		Marginal R^2 / Conditional R^2	= 0.586 / 0.866	Marginal R^2 / Conditional R^2	= 0.586 / 0.865

Table S3

MAP Reading Controlling for Nonverbal IQ - Reference is Children with DLD-Only (comparable to Table 3)

	Main Effects Model				Model Including Interaction Terms			
Predictors	*Estimates*	*95% CI Lower*	*95% CI Upper*	*p-value*	*Estimates*	*95% CI Lower*	*95% CI Upper*	*p-value*
(Intercept – DLD only)	172.05	169.88	174.22	**<.001**	172.56	170.13	174.99	**<.001**
Time (semester/grade)	**7.84**	**7.21**	**8.48**	**<.001**	**7.64**	**6.88**	**8.40**	**<.001**
Time^2	**-0.51**	**-0.63**	**-0.39**	**<.001**	**-0.51**	**-0.63**	**-0.39**	**<.001**
Classification: Dyslexia-only	-0.89	-4.51	2.74	.632	-3.22	-7.45	1.01	.136
Classification: DLD+Dyslexia	**-7.21**	**-10.27**	**-4.15**	**<.001**	**-8.91**	**-12.47**	**-5.36**	**<.001**
Classification: Typical	**10.80**	**8.25**	**13.36**	**<.001**	**10.90**	**7.94**	**13.85**	**<.001**
Nonverbal IQ: Centered at 100	**0.20**	**0.09**	**0.31**	**<.001**	**0.20**	**0.09**	**0.31**	**<.001**
Interaction: DLD*Time					**0.91**	**0.07**	**1.76**	**.035**
Interaction: DLD+Dyslexia*Time					0.67	-0.04	1.37	.064
Interaction: Typical*Time					-0.04	-0.61	0.53	.897

Random Effects

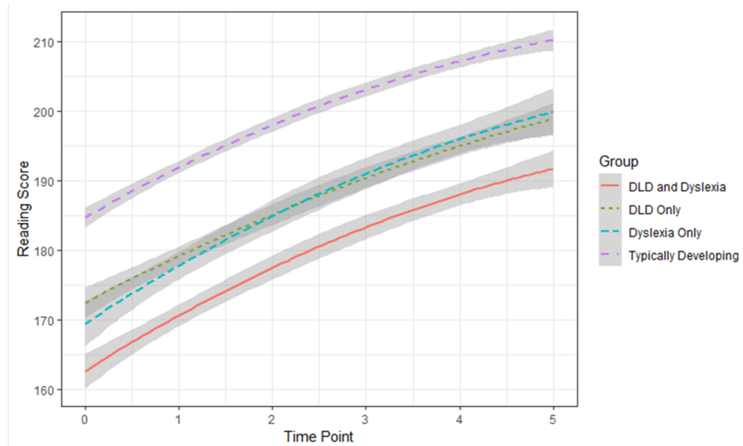
		Main Effects Model		Model Including Interaction Terms	
n Students	= 401	σ^2	= 52.68	σ^2	= 52.65
Observations	= 2287	τ_{00}	= 101.40 Student	τ_{00}	= 100.89 Student
		τ_{11}	= 1.88 Student / Semester Grade	τ_{11}	= 1.81 Student / Semester Grade
		ρ_{01}	= -0.41 Student	ρ_{01}	= -0.41 Student
		Adj. ICC	= 0.63	Adj. ICC	= 0.63
		Cond ICC	= 0.31	Cond ICC	= 0.30
		Marginal R^2 / Conditional R^2	= 0.516 / 0.822	Marginal R^2 / Conditional R^2	= 0.519 / 0.823

Table S4

MAP Math Controlling for Nonverbal IQ - Reference is Children with DLD-Only (comparable to Table 4)

	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 – DLD Only)	173.94	171.70	176.17	**<.001**	174.53	172.21	176.85	**<.001**
Time (semester/grade)	**7.84**	**7.22**	**8.46**	**<.001**	**7.52**	**6.84**	**8.21**	**<.001**
Time^2	**-0.36**	**-0.45**	**-0.27**	**<.001**	**-0.36**	**-0.45**	**-0.27**	**<.001**
Classification: Dyslexia Only	0.33	-2.54	3.20	.822	-0.98	-4.05	2.10	.534
Classification: DLD+Dyslexia	**-3.11**	**-5.53**	**-0.69**	**.012**	**-3.82**	**-6.41**	**-1.24**	**.004**
Classification: Typical	**7.46**	**5.43**	**9.49**	**<.001**	**6.81**	**4.65**	**8.97**	**<.001**
Nonverbal IQ: Centered at 100	**0.27**	**0.19**	**0.36**	**<.001**	**0.27**	**0.19**	**0.36**	**<.001**
Interaction: Dyslexia*Time					**0.69**	**0.11**	**1.27**	**.021**
Interaction: DLD+Dyslexia*Time					0.38	-0.10	0.86	.121
Interaction: Typical*Time					0.33	-0.06	0.72	.093
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 = 0.616 / 0.863				Marginal R^2 / Conditional R^2 = 0.616 / 0.863			

(A)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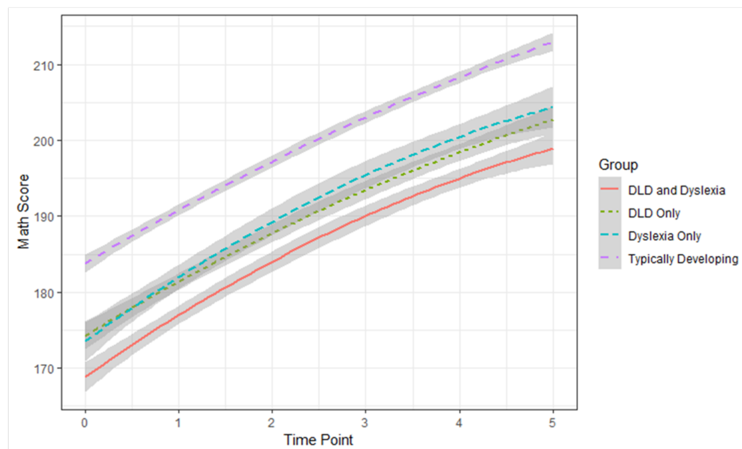
200
190
180
170
160
0
1
2
3
4
5
Time Point
Group
DLD and Dyslexia
DLD Only
Dyslexia Only
Typically Developing

(B)


Math Score
210
200
190
180
170
0
1
2
3
4
5
Time Point
Group
DLD and Dyslexia
DLD Only
Dyslexia Only
Typically Developing