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ORIGINAL ARTICLES

Achievement Gap in Reading Is Present as Early as First Grade and Persists through Adolescence

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Objectives To determine if differences between dyslexic and typical readers in their reading scores and verbal IQ are evident as early as first grade and whether the trajectory of these differences increases or decreases from childhood to adolescence.

Study design The subjects were the 414 participants comprising the Connecticut Longitudinal Study, a sample survey cohort, assessed yearly from 1st to 12th grade on measures of reading and IQ. Statistical analysis employed longitudinal models based on growth curves and multiple groups.

Results As early as first grade, compared with typical readers, dyslexic readers had lower reading scores and verbal IQ, and their trajectories over time never converge with those of typical readers. These data demonstrate that such differences are not so much a function of increasing disparities over time but instead because of differences already present in first grade between typical and dyslexic readers.

Conclusions The achievement gap between typical and dyslexic readers is evident as early as first grade, and this gap persists into adolescence. These findings provide strong evidence and impetus for early identification of and intervention for young children at risk for dyslexia. Implementing effective reading programs as early as kindergarten or even preschool offers the potential to close the achievement gap. *(J Pediatr 2015;■:■-■).*

Developmental dyslexia is the most common neurobehavioral disorder in children, affecting 17%-21% of school-age population.[1,2] Dyslexia is also the most comprehensively studied of the learning disabilities, affecting 80% of all children identified as learning-disabled.[3] First described over a century ago, dyslexia is defined as an unexpected difficulty in reading for an individual's chronological age or intelligence.

At its core, dyslexia is a problem with a component of spoken language, phonological processing: that is, getting to the elemental sounds of speech, affecting both spoken and written language. As dyslexic children progress in school, given good instruction, reading accuracy often improves; however, lack of fluency (the ability to read not only accurately, but rapidly and with good intonation) persists and remains a lifelong problem. The landscape in dyslexia is changing rapidly. For example, in 2014 the Congressional Committee on Science, Space, and Technology held a hearing on "The Science of Dyslexia," and many new state laws now urge recognition of dyslexia.[4,5] For the last decade, school policies have often emphasized that all children should be reading by third grade, a policy that perhaps has contributed to the delay of dyslexia diagnosis until after third grade.[6]

Here we report findings demonstrating that the achievement gap in reading between typical and dyslexic readers is evident as early as first grade and persists. We demonstrate further that typical and dyslexic readers do indeed differ in the trajectories of their reading scores and verbal IQ over time, from childhood to adolescence. Of particular importance, we demonstrate that such differences are not so much a function of increasing disparities over time but instead because of differences already present in first grade between typical and dyslexic readers.

Methods

The data for this report came from the Connecticut Longitudinal Study, a sample survey of Connecticut children entering public kindergarten.[1,7-10] The analyses presented here involve data from the 414 individuals who were first assessed in first grade and followed annually. Of the participants, 55.2% are females and 44.8% males. The sample contains Caucasians (84.3%), African Americans (11.2%), Asians (0.9%), Hispanics (2.0%), and other children with unknown ethnicity (1.6%). This sample from Connecticut was similar to the racial and ethnic composition of the nation at the time of the study.[11]

WISC-R	Wechsler Intelligence Scale for Children-Revised
WJ	Woodcock-Johnson Psycho-Educational Test Battery

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Table I. Variable estimates from a growth model of WJ reading components

	Typical	Dyslexic
Passage comprehension		
Mean intercept μ_0	.293 (.047)*	−1.170 (.071)
Mean slope μ_s	.421 (.006)*	.490 (.012)
Variance intercept σ_0^2	.612 (.047)	.288 (.061)
Variance slope σ_s^2	.007 (.001)	.008 (.002)
Covariance σ_{0s}	−.054 (.006)	−.009 (.012)†
χ^2 (df)		221 (90)
BIC		5326
Word identification		
Mean intercept μ_0	.286 (.044)*	−1.236 (.079)
Mean slope μ_s	.398 (.005)*	.463 (.011)
Variance intercept σ_0^2	.584 (.049)	.448 (.078)
Variance slope σ_s^2	.006 (.001)	.008 (.002)
Covariance σ_{0s}	−.051 (.005)	.035 (.009)
χ^2 (df)		577 (90)
BIC		2935
Word attack		
Mean intercept μ_0	.307 (.059)*	−1.232 (.057)
Mean slope μ_s	.345 (.007)‡	.339 (.014)
Variance intercept σ_0^2	.928 (.084)	.093 (.039)
Variance slope σ_s^2	.007 (.001)	.011 (.002)†
Covariance σ_{0s}	−.062 (.008)	−.001 (.008)†
^{2} (df)		669 (90)
BIC		7003

BIC, Bayesian information criterion.
SEs are in parentheses. N_1 (typical) = 335, N_2 (dyslexic) = 79. Dyslexia based on achievement and discrepancy definitions at third grade. All parameter estimates are derived from data in z-scores from the first measurement occasion.
*Significant difference (typical ≠ dyslexic).
†Parameter with $P > .05$.
‡Nonsignificant difference (typical = dyslexic).

Measures

Annually from 1st to 12th grade, participants completed 3 reading subtests from the Woodcock-Johnson Psycho-Educational Test Battery (WJ).[12] In addition, at grades 1, 3, 5, 7, and 9, participants were assessed on the Wechsler Intelligence Scale for Children-Revised (WISC-R).[13] In the current analyses, we consider the 4 verbal components of the WISC-R (vocabulary, information, comprehension, and similarities) as well as the reading subtests from the WJ (passage comprehension, word identification, and word attack).

Dyslexia was evaluated using a composite of the word reading subtests from the WJ battery (reading cluster, a composite of passage comprehension, word identification, and word attack) and the full-scale IQ score from the WISC-R. Dyslexia was determined if a participant's score was below 90 on the reading cluster score or if there were a difference of 1.5 SDs between the IQ and the reading cluster score, a difference that refers to the standardized residuals calculated from the regression of IQ on the reading scores. It is well established that reading and dyslexia occur along a normal distribution,[8] and similar results would be obtained whether the discrepancy is set at 1 or 1.5 SD. If participants met criteria for dyslexia in either grade 2 or grade 4, they were classified as dyslexic; if not, they were classified as typical.

To examine changes in the target variables across the grades, we used growth curve models (equivalent to multilevel or hierarchical linear models) that include grade as the underlying time dimension.[14-16] Details of the growth

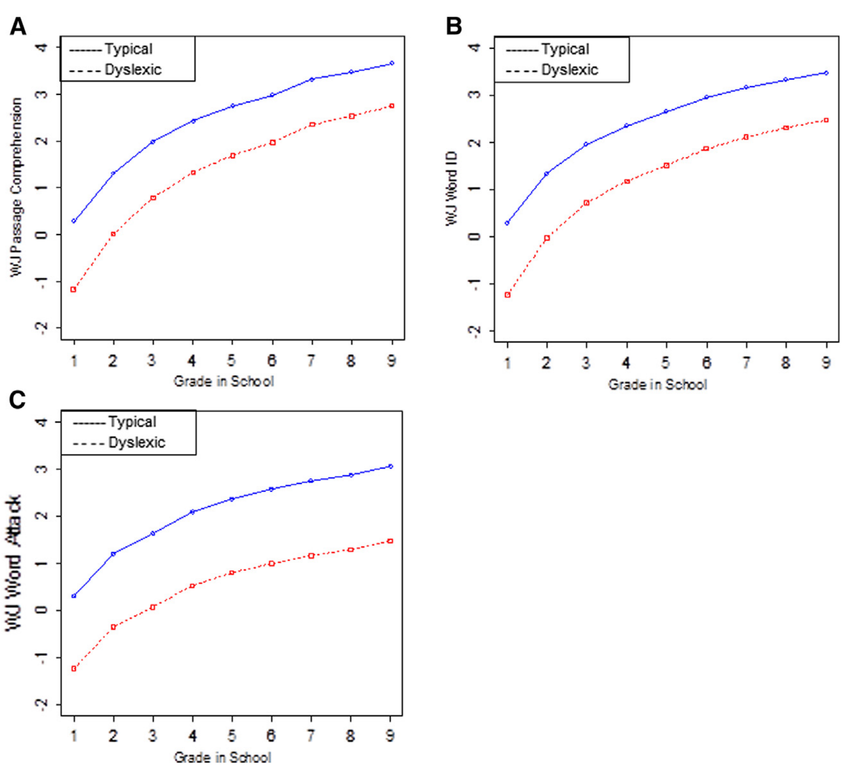

Figure 1. Smoothed predicted trajectories of reading across grades for both reading groups. **A**, Passage comprehension. **B**, Word identification. **C**, Word attack.

curve methods are found in the Appendix (available at www.jpeds.com).

Results

Changes in Reading Scores over Time

For all analyses, we transformed the data into z-scores, based on the first measurement occasion. This transformation allowed us to put all measures into a common metric and to evaluate change in terms of SD units from first grade. In the first set of analyses, we examined differences in reading between typical and dyslexic readers using the reading subtests from the WJ battery[12] (ie, word identification and word attack [decoding nonsense words]). In addition, we also included a measure of reading comprehension (passage comprehension) to examine the potential negative impact of dyslexia on reading comprehension. We employed a growth curve model and compared a linear model (ie, equal changes across grades) with a model allowing for nonlinear changes across grades (ie, latent coefficients for the slope). Across all reading subtests, this latter model showed a much better fit relative to a linear specification. Next, we evaluated differences between typical and dyslexic readers using a multiple-group model following an increasingly relaxed sequence: (1) full invariance (same parameters across both groups); (2) different mean of intercept and slope; (3) different variances and covariances; (4) different slope coefficients; and (5) different residuals. Table I includes results from these analyses.

Across all reading subtests, typical readers had higher initial scores at first grade than dyslexic readers. The slopes for passage comprehension and word identification, however, were slightly larger for the dyslexics, whereas for word attack, the slopes were similar between groups. The resulting trajectories from these models are presented in Figure 1, A-C, for passage comprehension, word identification, and word attack, respectively. Across all subtests, dyslexic readers show substantially lower reading scores in first grade than typical readers do, and their trajectories never join those of the typical readers. To illustrate, the difference in passage comprehension scores between both groups at first grade is 1.46 SD units. This difference decreases slightly across grades but remains as almost 1 SD in ninth grade. A similar pattern is evident for word identification. In sum, because of the initial achievement gap in first grade, the trajectories of dyslexic readers never catch up with those of the typical readers, even for subtests such as passage comprehension and word identification, on which they have slightly faster rates of change than typical readers.

Changes in Verbal IQ over Time

In the next set of analyses, we examined the changes in each of the verbal components of IQ (ie, vocabulary, information, comprehension, and similarities subtests; WISC-R).[13] As we did for the reading subtests, we implemented a growth curve model and compared linear with nonlinear changes across grades (ie, latent slope coefficients). Across all verbal components, the nonlinear model showed a much better fit relative to a linear specification. Next, we fitted a multiple-group model to evaluate differences between typical and dyslexic readers. For each of the 4 verbal components, the best fitting model was one in which the intercept and slope means as well as variances and covariances were allowed to differ between typical and dyslexic readers. Results from this best-fitting model across all verbal components are reported in Table II. We also fitted a single-group model using group as a covariate. The results from this model confirmed those from the multiple-group approach.

The first section of Table II represents parameter estimates for the Vocabulary IQ subscale. These estimates indicate initial vocabulary scores (at first grade) for the 2 groups of readers ($\mu0$ = .244, and −.596, for typical and dyslexic, respectively). Of particular importance, the slope estimates were reliably different from zero for both groups (μs = .623, and .519), indicating evidence for changes in vocabulary scores from first to ninth grade for both groups. Both the intercept and slope showed statistical differences between groups, with higher values for typical relative to dyslexic readers. The variance estimates were also different from

Table II. Variable estimates from a growth model of IQ verbal components

	Typical	Dyslexic
Vocabulary		
Mean intercept μ_0	.244 (.053)*	−.596 (.115)
Mean slope μ_s	.623 (.008)*	.519 (.017)
Variance intercept σ_0^2	.514 (.065)	.711 (.164)
Variance slope σ_s^2	.010 (.002)	.012 (.004)
Covariance σ_{0s}	.021 (.008)	.035 (.017)
χ^2 (df)		46.9 (26)
BIC		5334
Information		
Mean intercept μ_0	.252 (.057)*	−.626 (.090)
Mean slope μ_s	.685 (.010)*	.576 (.021)
Variance intercept σ_0^2	.646 (.076)	.293 (.099)
Variance slope σ_s^2	.017 (.002)	.024 (.006)
Covariance σ_{0s}	.027 (.009)	.052 (.017)
χ^2 (df)		68.3 (26)
BIC		5568
Comprehension		
Mean intercept μ_0	.176 (.057)*	−.280 (.117)
Mean slope μ_s	.620 (.008)*	.509 (.019)
Variance intercept σ_0^2	.521 (.073)	.639 (.165)
Variance slope σ_s^2	.004 (.001)	.014 (.005)
Covariance σ_{0s}	.010 (.008)†	.026 (.020)†
χ^2 (df)		76.5 (26)
BIC		5708
Similarities		
Mean intercept μ_0	.261 (.055)*	−.550 (.126)
Mean slope μ_s	.438 (.008)‡	.418 (.015)
Variance intercept σ_0^2	.513 (.069)	.860 (.196)
Variance slope σ_s^2	.006 (.001)	.004 (.003)†
Covariance σ_{0s}	−.017 (.008)	−.010 (.018)†
χ^2 (df)		119.4 (26)
BIC		5341

SEs are in parentheses. N_1 (typical) = 335, N_2 (dyslexic) = 79. Dyslexia based on achievement and discrepancy definitions at 3rd grade. All parameter estimates are derived from data in z-scores from the first measurement occasion.
*Significant difference (typical ≠ dyslexic).
†Parameter with $P > .05$.
‡Nonsignificant difference (typical = dyslexic).

zero, denoting variability in both initial scores and changes over grades across individuals within each of the groups. These results indicate that both groups showed improvements in vocabulary scores across the nine grades. However, because of initial differences in first grade and the different rates of change, the disparity in vocabulary scores increases throughout the grades. This is visualized in Figure 2, A (Vocabulary), which displays the predicted scores from the curve models for each of the groups. Typical readers have higher scores at first grade and slightly faster rates of change than dyslexic readers, resulting in group trajectories with initial gaps that expand over time.

The next sections in Table II include results for information, comprehension, and similarities. In all cases, the intercept estimates (values in first grade) are statistically larger for typical than dyslexic readers. The slope estimates are also statistically higher for typical readers for information and comprehension, and not different across groups for similarities. For all verbal subsets, and regardless of the between-group differences, the slopes are positive. The resulting pattern of trajectories is consistent: positive changes across grades with a slightly diverging trajectory between both groups, except for similarities, for which the trajectories remain parallel over time (Figure 2, B-D, for information, comprehension, and similarities, respectively).

Discussion

Our findings demonstrate that an achievement gap appears as early as first grade in dyslexic readers and persists. This finding has important implications. If the persistent achievement gap between dyslexic and typical readers is to be narrowed, or even closed, reading interventions must be implemented early, when children are still developing the basic foundation for reading acquisition. The persistent achievement gap poses serious consequences for dyslexic readers, including lower rates of high school graduation,[6] higher levels of unemployment,[17] and lower earnings because of lowered college attainment.[18] Implementing effective reading programs early, even in preschool and kindergarten, offers the potential to reduce and perhaps even close the achievement gap between dyslexic and typical readers and bring their trajectories closer over time.

The argument for the benefits of early intervention is not new. It has been cast in terms of educational achievement

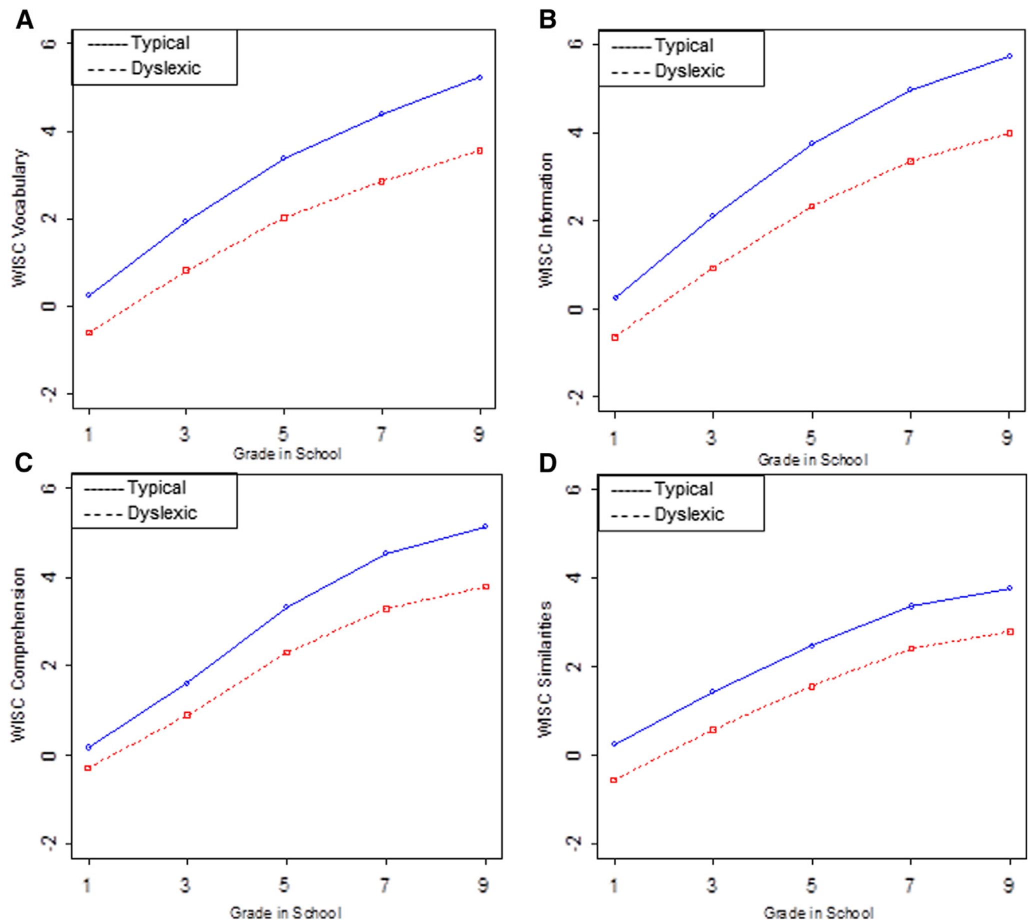

Figure 2. Smoothed predicted trajectories of verbal IQ components across grades for both reading groups. **A**, Vocabulary. **B**, Information. **C**, Comprehension. **D**, Similarities.

as well as financial returns. Heckman et al,[17] for example, have shown the benefits of high-quality preschool programs in a range of areas. These findings have been further replicated recently in a different population.[18] Often not taken into consideration in education policy is not only the possibility that the achievement gap between dyslexic and typical readers may already be apparent in very early grades, but also the awareness that, even when the trajectory of reading improves over time (as our data indicate), the gap does not narrow. Now, examination of our longitudinal data indicates that the achievement gap is already present at first grade and points to the overwhelming influence of the large early difference accounting for the persistence of this difference. In other words, although the gap may not become wider over time, because of early disparities, it persists. Interventions at later grades may decrease or prevent the gap from widening, but will not overcome the already existing differences in early grades. These data are consistent with prior reports of the general lack of substantial improvement in reading if interventions are delayed until after the first grade.[19]

Our data provide strong evidence of the need for early intervention in dyslexic children, beginning in kindergarten, first grade, or even earlier, perhaps in preschool. Even though such early interventions are just starting to be applied, at least one recent report suggests that preschool reading interventions are effective and available.[20]

Solid evidence from a number of lines of investigation[21,22] indicates that dyslexia is best conceptualized as a weakness in phonology (ie, getting to the sounds of spoken words) affecting initially spoken language, and then, print. This finding raises the possibility of using spoken language measures to identify children at risk for dyslexia, even before they are expected to read. In order to read, children must be able to pull apart the sounds of spoken language so that they can go on to attach the letters of a word to the sound it represents; hence, children learn to sound out words.

In sum, our data indicate that the achievement gap between typical and dyslexic readers is evident as early as first grade, and this gap persists into adolescence. Identifying students at risk for dyslexia and then implementing effective reading programs as early as kindergarten or even preschool offers the potential to close the achievement gap. ■

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Appendix

Details of Growth Curve Modeling

A basic curve model for a variable Y measured over time ($t = 1$ to T) on the same individual (n = 1 to N) can be written as

$$Y[t]_n = y_{0n} + A[t] \cdot y_{sn} + e[t]_n, \quad (1)$$

where y_0 represents an individual's initial level, A[t] contains the basis coefficients that specify the timing or shape of the curve, y_s represents the slope, or the individual change over time, and e[t] represents the unobserved error of measurement. This model includes sources of individual differences in the level and slope, whose terms can be decomposed at a second level as

$$y_{0n} = \mu_0 + e_{0n}, \text{ and}$$

$$y_{sn} = \mu_s + e_{sn}, \quad (2)$$

where the level and slope scores have fixed group means (μ_0 and μ_s) and residuals (e_{0n} and e_{sn}), and these residuals have variance components (σ_0^2, σ_s^2, and σ_{0s}) but are assumed to have zero means and to be normally distributed.

The basis coefficients can take specific values to represent alternative hypotheses of growth. For example, linear change can be tested with equation (1) and basis coefficients that represent linear changes, as $A[t] = 0, 1, 2, \ldots, t-1$. Alternatively, some of these coefficients can be freed to be estimated from the data, as to represent unequal changes across occasions (grades in our data), as $A[t] = 0, ?_1, ?_2, \ldots, t-1$, where "$?_t$" represents an estimated coefficient.

Group Comparisons

To evaluate hypotheses about differences between groups, the model just described can be extended by a covariate that represents the group or through multiple-group analyses. The former approach is an extension of the previous model with an exogenous, or "extension," variable on the curve.[1,2] In such a case, the equations for the level and slope (equation 2) can be written as

$$y_{0n} = \gamma_{00} + \gamma_{0x} \cdot G_p + e_{0n} \text{ and}$$

$$y_{sn} = \gamma_{s0} + \gamma_{sx} \cdot G_p + e_{sn}, \quad (3)$$

where the level and slope scores now have fixed group intercepts (γ_{00} and γ_{s0}), and regression coefficients (γ_{0x} and γ_{sx}), representing the effect of the group variable G (for group $g = 1, 2, \ldots$, G) on the level and slope. This model follows the same formulation than what are termed hierarchical, multilevel, or random-effects models[3-5] and is suited to examine differences across the groups regarding the intercept and the slope.

The multiple-group approach consists of fitting the same model from equation (2) separately to each of the groups. The resulting model can be written as

$$Y[t]_n^{(g)} = y_{0n}^{(g)} + A[t]^{(g)} \cdot y_{sn}^{(g)} + e[t]_n^{(g)}, \quad (4)$$

where $g = 1, 2, \ldots$, G, represents the group. This multiple-group approach allows the examination of differences between groups in any of the model parameters, not just intercept and slope. In the present report, we use both approaches to examine differences across groups based on various dyslexia criteria.

Trajectories of Reading and IQ Scores

In this report we compared the trajectories of reading scores and of verbal intelligence over time between typical and dyslexic readers. Specifically, we examined the extent to which the reading subtests and verbal components of IQ differed between both groups from first to ninth grade. For the reading subtests (ie, passage comprehension, word identification, and word attack), the findings reveal that dyslexic readers have lower scores at first grade and slightly higher rates of change than typical readers, with the exception of word attack, for which such rates are similar. As a consequence, the reading trajectories show initial differences between groups and lines that, despite the slight differences for some subtests, never converge over time. It is important to note that despite maintaining differences in the scores across grades, both groups, dyslexic, as well as typical readers, showed increasing trajectories over time. Furthermore, these findings indicate that, across all four measures of verbal IQ (ie, vocabulary, information, comprehension, and similarities), dyslexic readers had lower scores at first grade. For vocabulary, information, and comprehension, dyslexic readers had lower rates of change than typical readers; for similarities, the rates of change were similar across groups. As a consequence, the trajectories of components of verbal IQ in dyslexic readers showed a slight divergence from those of the typical readers or, as for the similarities subscale, parallel courses over time. That is, their scores in all components of verbal IQ and reading subtests improved across grades.

Matthew effects have been described in the literature as a consequence of dyslexics' reading difficulties, which over time result in increasing disparities in reading compared with typical readers.[6,7] Because of the connection between reading and IQ,[8-11] especially its verbal components, this pattern of increasing disparities is postulated for IQ as well. Although the data show some increasing differences over time between dyslexic and typical readers in components of verbal IQ (vocabulary, information, comprehension), these differences are generally small compared with the initial disparities. These data indicate that dyslexic readers do not catch up with typical readers through ninth grade primarily because of differences observed as early as first grade.

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