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Persistence of Dyslexia: The Connecticut Longitudinal Study at Adolescence

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ABSTRACT. *Objective.* **The outcome in adolescence of children diagnosed as dyslexic during the early years of school was examined in children prospectively identified in childhood and continuously followed to young adulthood. This sample offers a unique opportunity to investigate a prospectively identified sample of adolescents for whom there is no question of the childhood diagnosis and in whom highly analytic measures of reading and language can be administered in adolescence.**

Design. **Children were recruited from the Connecticut Longitudinal Study, a cohort of 445 children representative of those children entering public kindergarten in Connecticut in 1983. Two groups were selected when the children were in grade 9: children who met criteria for persistent reading disability in grades 2 through 6 (persistently poor readers [PPR]; $n = 21$) and a comparison group of nondisabled children, subdivided into average readers ($n = 35$) and superior readers ($n = 39$). In grade 9, each child received a comprehensive assessment of academic, language, and other cognitive skills.**

Results. **Measures of phonological awareness (but not orthographic awareness) were most significant in differentiating the 3 reading groups, with smaller contributions from measures of word finding and digit-span. Academic measures that best separated good from poor readers were decoding and spelling, whereas measures of math and reading comprehension did not. Measures of phonological awareness, followed next by teacher rating of academic skills were the best predictors of decoding, reading rate, and reading accuracy. In contrast, the best predictor of reading comprehension was word finding, with digit span and socioeconomic status also contributing significantly. Using a growth curve model (quadratic model of growth to a plateau) all 3 groups demonstrated similar patterns of growth over time, with the superior group outperforming the average group, and the average group outperforming the PPR group. There was no evidence that the children in the PPR group catch up in their reading skills.**

Conclusions. **Deficits in phonological coding continue to characterize dyslexic readers even in adolescence; performance on phonological processing measures contributes most to discriminating dyslexic and average readers, and average and superior readers as well. These data support and extend the findings of previous investigators indicating the continuing contribution of phonological processing to decoding words, reading rate, and accuracy and spelling. Children with dyslexia neither spontaneously remit nor do they demonstrate a lag mechanism for catching up in the development of reading skills. In adolescents, the rate of reading as well as facility with spelling may be most useful clinically in differentiating average from poor readers.** ***Pediatrics*** **1999;104: 1351–1359;** ***dyslexia, reading, language, phonology, adolescence.***

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ABBREVIATIONS. SES, socioeconomic status; PPR, persistently poor readers; MIT, Multi-Grade Inventory for Teachers; WISC-R, Wechsler Intelligence Scale for Children—Revised; GORT-3, Gray Oral Reading Test-3; MANOVA, multivariate analyses of variance.

Faced with common complaints from parents about their child's difficulties in school while, at the same time, restrictions on their ability to refer the child to a specialist are imposed by managed care networks, pediatricians are increasingly being called on to recognize and to be involved in the diagnosis and management of reading disability or dyslexia. Within the last decade, significant scientific advances have been made that now provide a coherent theoretical framework for pediatricians to approach these most common disorders in children and adolescents. Evidence from a number of lines of investigation has converged to indicate that reading disability reflects a deficit in the language system, and furthermore, evidence indicates that an individual's inability to identify the sound structure of words (phonological awareness) represents the specific cognitive deficit responsible for dyslexia (reviews).[1–5] Phonological awareness is "an oral language skill that manifests itself in the ability to notice, to think about, or manipulate the individual sounds in a word,"[6] an awareness that all words can be decomposed into phonologic segments, one that allows the reader to connect the letter strings (the orthography) to the corresponding units of speech (phonologic constituents) they represent. In contrast, orthographic awareness refers to a way of representing spoken language by letters and spellings. Results from 2 large and well-studied populations with reading disability confirm that in young school-aged children a deficit in phonological processing represents the most robust[4,7] and specific[8] correlate of reading disability. Recent functional neuroimaging studies have demonstrated that the cognitive deficit in dyslexia is related to a pattern of brain organization different from that seen in nonimpaired readers. Specifically, this neural signature of dyslexia is characterized by underactivation in posterior brain regions (particularly the angular gyrus) and overactivation in anterior brain regions as dyslexic readers engage phonologic analysis.[9–11]

Despite these advances in understanding the underlying neurobiology of dyslexia, what remains unclear, however, is what happens over time to children with a reading disability. What are the characteristics of dyslexia as children mature into adolescence? How does the pediatrician diagnose dyslexia in adolescence? Answering these questions is critical if pediatricians are to identify dyslexia in older children, adolescents, and young adults. Studies of older children and adults are far less clear. The available evidence suggests that although adolescents and young adults with histories of dyslexia in childhood may show some improvement in phonological awareness, they continue to demonstrate deficits in reading compared with their peers who have no history of dyslexia in childhood.[12–15] These studies, however, are limited because the samples were clinic-based, diagnosed retrospectively; nonrepresentative (eg, requiring a risk factor of family history of reading problems); or restricted to either high socioeconomic status (SES) or college students. To our knowledge, there has been no modern study of a representative sample of reading disability in which the subjects were prospectively identified in childhood and continuously followed to young adulthood. In this report, the availability of a virtually intact epidemiologic sample of adolescent age whose cognitive, academic, and behavioral development has been continually and carefully monitored from school entry provides an important new dimension previously not available to studies of dyslexia. This sample offers a unique opportunity to investigate a prospectively identified sample of adolescents for whom there is no question of the childhood diagnosis and in whom highly analytic measures of reading and language can be administered in adolescence.

METHODS

Sample Selection and Group Definition

Children for this study were recruited from the Connecticut Longitudinal Study, a cohort of 445 children representative of those children entering public kindergarten in Connecticut in 1983. All subjects had to be children whose primary language was English. This cohort, assembled from a 2-stage probability sample survey, has been described in detail elsewhere.[16–19] The cohort has been followed longitudinally since enrollment, with yearly assessments of academic skills and parent/teacher behavior ratings and evaluation of intelligence every 2 years. The sample recently completed grade 12.

For the current study, 2 groups of Connecticut Longitudinal Study subjects were selected for participation when the children were in grade 9: 1) children who met criteria for persistent reading disability in grades 2 through 6 and 2) a comparison group of nondisabled children. Reading disability was defined using the Full Scale IQ score from the Wechsler Intelligence Scale for Children—Revised (WISC-R)[20] and the Basic Reading composite (Word Identification and Word Attack subtests) of the Woodcock–Johnson Psycho-Educational Test Battery.[21] At each grade, children were defined as reading disabled if their Full Scale IQ was ≥80 and their age-adjusted score on the on the Woodcock–Johnson Basic Reading composite was either 1) 1.5 standard errors below the score predicted by their Full Scale IQ (discrepancy definition); or 2) <90 (low achievement definition). Extensive research[22] has shown that both of these definitions validly identify children as reading disabled, with little evidence for differences in chronicity among subgroups of children with reading disability formed with these definitions. Persistence was indicated if a child met either or both of these definitions 4 of 5 years in grades 2 through 6. Application of these criteria resulted in a sample of 21 persistently poor readers (PPR).

The comparison group of nondisabled children did not meet the above criteria and selection was based on their mean Basic Reading composite scores in grades 2 through 6. This comparison group was further subdivided into average readers, with mean Basic Reading scores from 90 to 110 (n = 35), and superior readers with mean Basic Reading scores ≥111 (n = 39). Six children declined to participate in the study, resulting in the final sample size of 95 at their grade 9 evaluation.

The demographic characteristics of these 3 groups in grade 9 are presented in Table 1. There were no differences in age (F [2,92] <1) or sex (χ^2, [2; n = 95] <1). However, compared with their nondisabled peers, the reading disabled group had more children who were lower in SES (χ^2 [6; n = 95] = 26.89; $P < .0001$) and had an ethnic representation that included more nonwhite ethnicities (χ^2 [4; n = 95] = 17.21; $P < .002$). As expected, given the correlation of Full Scale IQ and reading achievement (.60), an analysis of variance for Full Scale IQ was significant (F [2,92] = 39.98; $P <$ .0001). Each 2-group comparison for Full Scale IQ was significant ($P < .05$), indicating that the PPR group had lower Full Scale IQ scores than the average group, who had lower scores than the superior group.

Procedures

Grade 9

In grade 9, each child received a comprehensive assessment of academic, language, and other cognitive skills. In addition, the Multi-Grade Inventory for Teachers (MIT) was completed by the teacher of the subject.[23] To reduce the data and to enhance the reliability of the cognitive assessments, composites were created by residualizing each variable on age and averaging the resultant z scores. The composites represented 5 cognitive domains: phonological awareness, orthographic awareness, word finding, rapid automatized naming, and visual–spatial skills. The phonological awareness composite included the Auditory Analysis Test[24] and a Pig Latin task.[25] The orthographic awareness composite was de-

TABLE 1. Age, SES, and Full Scale WISC-R IQ for Persistently Poor, Average, and Superior Reading Groups

Variable		Group		
		Persistently Poor	Average	Superior
n		21	35	39
Age (mo)	Mean	14.50	14.39	14.36
	SD	.54	.33	.30
Sex Male		10	18	20
	Female	11	17	19
SES* I		1	11	14
	II	6	10	17
	III	7	11	6
	IV–V	7	2	0
Race	White	12	33	36
	Black	5	2	1
	Other	4	0	2
Full scale IQ†	Mean	97.62	115.71	126.18
	SD	12.97	13.00	9.88

SD indicates standard deviation.
* Hollingshead–Redlich (1958).
† WISC-R.

rived from the Orthographic Choice[26] and Orthographic Word Likeness[27] tasks. Word finding was measured by the Peabody Picture Vocabulary Test[28] and the Boston Naming Test.[29] Rapid naming was measured by average time on the Rapid Automatized Naming.[30] Visual–spatial skills were measured by the Test of Visual Motor Integration[31] and Embedded Figures Test.[32] In addition, short-term memory was measured with the Digit Span subtest of the WISC-R and listening comprehension was measured by the Story Comprehension subtest of the Diagnostic Achievement Battery.[33] The differentiation of these cognitive domains has been supported by latent variable analyses of cognitive skills in children with dyslexia.[34]

Academic skills in grade 9 were measured using the Woodcock–Johnson Psycho-Educational Test Battery, Gray Oral Reading Test-3 (GORT-3),[35] and the Test of Written Spelling.[36] For analysis, composites were created for decoding (Word Identification and Word Attack subtests of the Woodcock–Johnson Psycho-Educational Test Battery), reading comprehension (Woodcock–Johnson Passage Comprehension and GORT-3 comprehension), and math (Woodcock–Johnson Calculations and Applied Problems). The Rate and Accuracy measures from the GORT-3 and the Spelling Quotient from the Test of Written Spelling also were analyzed.

Intelligence (verbal IQ and performance IQ) was measured with the WISC-R. The MIT yields 6 empirically-derived scales: Academic, Language, Attention, Dexterity, Activity, and Behavior.[23]

Grade 12

An individual growth curves approach was used to model changes in reading over the time span of the longitudinal study.[19] This was accomplished through the interval-based Rasch scores on the Woodcock-Johnson Basic Reading subtests in grades 1 through 12. To further characterize long-term outcomes, the students completed a confidential student survey in grade 12 addressing questions about graduation plans, reading behaviors, school conduct problems, family status, self-esteem, and extracurricular activities. The survey was completed by the student, sealed in an envelope, and turned in to the evaluator. Teachers completed an end-of-year evaluation in grade 12 that provided data about school status including placement, class ranking, special services, honors and awards, and extracurricular activities. Although students and teachers completed these surveys each year, the grade 12 data are reported here to address long-term outcomes.

Data Analysis

The 7 cognitive variables, 6 academic variables, 2 IQ variables, and 6 MIT scales obtained in grade 9 were analyzed in separate multivariate analyses of variance (MANOVAs). When the MANOVA was significant, each variable was correlated with the canonical variate (discriminant function) maximally separating the groups to assess the contribution of individual tests to the separation of the groups. This method, widely accepted as an approach to interpreting the discriminant functions computed for MANOVA, yields a set of correlation coefficients (canonical loadings). Higher correlations indicate a stronger relative relationship with group separation. All significant group effects were followed with planned comparisons of each pair of groups tested at $\alpha < .05/3 = .0167$ to control the type I error rate. To evaluate the contribution of the cognitive variables relative to teacher ratings and sociodemographic variables, multiple regression methods were used to predict 4 reading outcomes: decoding, comprehension, rate, and accuracy. These 4 outcomes are the widely used descriptors of reading ability. The longitudinal data on the Woodcock–Johnson Basic Reading composite were analyzed using a nonlinear growth curve model. Growth parameters were calculated for intercept, slope, curvature, plateau age, and plateau level. Finally, the student survey and end-of-year evaluation data were analyzed with χ^2 or analysis of variance depending on whether the variable was frequency-based or continuous.

RESULTS

Grade 9

Means and standard deviations for each dependent variable are presented in Table 2. As would be expected, the means on the 7 cognitive variables are systematically highest for the superior group and lowest for the PPR group. Similarly, the academic skill and IQ variables exhibit the same pattern indicating that the PPR group was impaired in all areas.

TABLE 2. Means and Standard Deviations for the Cognitive Variables, Academic Skills and Multigrade Inventory for Teachers Scales

Domain	Variable	Group					
		Persistently Poor		Average		Superior	
		Mean	SD	Mean	SD	Mean	SD
Cognitive	Phonological awareness	6.37	1.95	9.79	2.09	12.07	1.02
	Orthographic awareness	8.71	4.83	10.04	1.71	10.54	1.23
	Word finding	6.97	3.48	9.83	1.89	11.74	1.71
	Rapid naming	8.35	3.75	9.98	3.07	10.78	2.04
	Visual-spatial	8.11	2.49	10.12	2.52	10.90	1.83
	Digit span	6.43	2.71	8.47	2.27	11.08	2.81
	Listening comprehension	7.52	2.77	8.59	2.43	9.67	1.42
Academic skills							
	Decoding	86.36	11.54	95.40	6.15	107.87	6.56
	Rate	79.75	11.35	115.15	20.15	137.70	15.45
	Accuracy	67.85	10.45	89.00	14.15	114.35	20.10
	Comprehension	93.86	11.62	108.20	9.75	118.72	9.11
	Spelling	85.45	8.50	101.01	8.08	117.17	8.65
	Math	85.50	12.73	102.66	9.69	114.54	10.43
Intellectual							
	Verbal IQ	88.71	12.58	109.29	10.46	120.72	9.51
	Performance IQ	108.48	16.84	119.49	14.41	126.10	11.33
MIT*							
	Academic	2.56	.82	2.00	1.23	1.08	.90
	Language	1.40	.64	1.16	.84	.68	.56
	Dexterity	1.21	.79	1.00	1.07	.49	.63
	Attention	2.05	1.06	1.66	1.37	.75	.88
	Activity	1.53	.91	1.18	.66	.96	.63
	Behavior	1.52	1.66	.70	1.09	.59	1.22

SD indicates standard deviation.
* For the MIT, higher scores are indicative of poorer ratings.

Means for the MIT are in the opposite direction because higher scores are indicative of poorer ratings.

These observed differences were supported by the 4 MANOVAs. The MANOVA for cognitive variables was significant (F_{mult} [14, 172] = 7.31; $P < .0001$). The canonical correlations (Fig 1A) illustrate the substantial contribution of the phonological awareness composite to differentiating the 3 reading groups, with smaller contributions from the word finding composite and digit-span. All other coefficients were negligible, including orthographic awareness. Each of the 3 follow-up comparisons were significant at the critical level of α: PPR < average, F_{mult} (7, 47) = 7.31, $P < .0001$; PPR < superior, F_{mult} (7, 52) = 34.91, $P < .0001$; average < superior, F_{mult} (7, 65) = 10.05, $P < .0001$. The patterns of canonical correlations parallel the overall analysis. Again, the coefficients

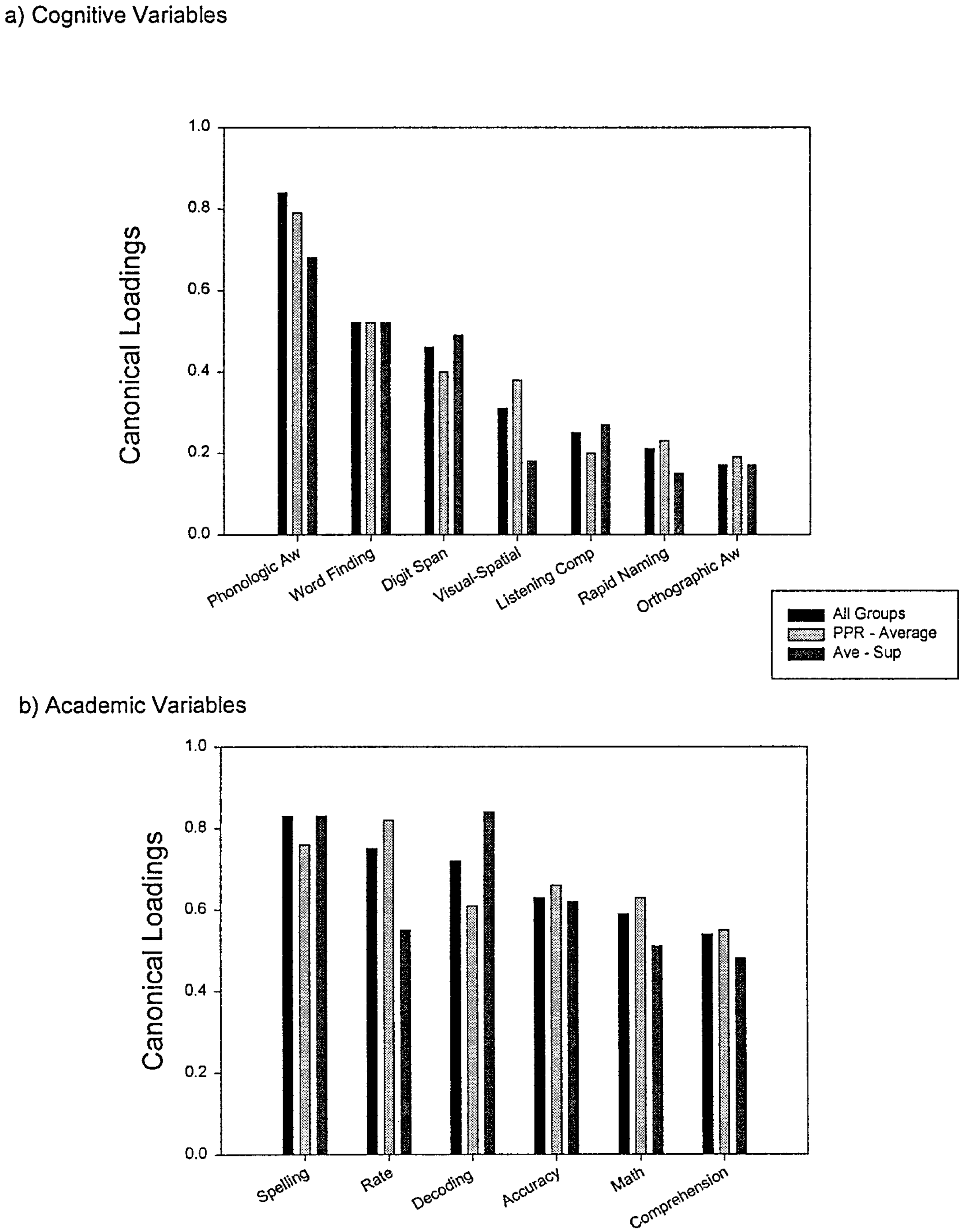

Fig 1. A, Canonical correlations for the cognitive variables. The figure illustrates the substantial contribution of the phonological awareness composite to differentiating the 3 reading groups, with smaller contributions from the word finding composite and digit-span. All other coefficients were negligible, including orthographic awareness. B, Canonical correlations for the academic variables. Canonical correlates were higher for measures involving decoding and spelling, and lower for math and reading comprehension.

The ordinates are canonical coefficients or canonical loadings and are similar to a discriminant function and represent the contribution of individual tests to the separation of the groups. Correlations vary from 0 to 1 and higher correlations indicate a stronger relative relationship with group separation.

are highest for the phonological awareness composite, with negligible contributions for the orthographic awareness composite.

The importance of phonological awareness to the identification of dyslexia in adolescence is further illustrated by the Test of Auditory Analysis Skills[24] (Fig 2). The observed differences in Fig 2, are supported by univariate analysis of variance (F [2, 92] = 52.14; $P < .0001$; Scheffe pairwise post-hoc comparisons) further indicating that PPR < average ($P < .001$); PPR < superior ($P < .001$); and average < superior ($P < .001$).

Academic Skills

The MANOVA for the measures of reading (decoding, rate, accuracy, and comprehension), math, and spelling indicated a significant group effect (F_{mult} [12, 176] = 11.03; $P < .0001$). The canonical correlations for the overall MANOVA in Fig 1B were higher for measures involving decoding and spelling and lower for math and reading comprehension. All 2-group comparisons were significant: PPR < average (F_{mult} [6, 49] = 12.30; $P < .0001$); PPR < superior (F_{mult} [6, 53] = 45.69; $P < .0001$); average < superior (F_{mult} [6, 67] = 15.45; $P < .0001$). The pattern of canonical correlations in Fig 1B was similar for the follow-up comparisons involving the PPR group and the other 2 groups, with particularly strong relationships with rate. When the average and superior readers were compared, the decoding and spelling composites had the largest canonical correlations.

A MANOVA for the WISC-R Verbal IQ and Performance IQ yielded a significant effect of Group (F_{mult} [4, 184] = 18.74; $P < .0001$). Follow-up comparisons were all significant: PPR < average (F_{mult} [2, 33] = 22.39; $P < .0001$); PPR < superior (F_{mult} [2, 57] = 60.46; $P < .0001$); average < superior (F_{mult} [2, 71] = 12.31; $P < .0001$). For each comparison, the pattern of canonical correlations showed much higher correlations with Verbal IQ (all correlations ≥ .98) than Performance IQ (all correlations ≤ .44).

The MANOVA for the MIT scales was significant (F_{mult} [12, 176] = 2.99, $P < .0008$). The canonical correlations in the overall MANOVA were higher for the Academic (.96), Attention (.79), and Language (.71) scales. Follow-up comparisons were significant for the average > superior groups (F_{mult} [6, 67] = 2.82; $P < .0165$) and PPR > superior groups (F_{mult} [6, 53] = 6.69; $P < .0001$); higher scores indicating poorer ratings. The PPR–average comparison, however, was not significant (F_{mult} [6, 49] = 1.99; $P < .13$). For the 2 significant follow-up comparisons, the pattern of canonical correlations were generally similar to the overall analysis.

Best Predictors of Academic Outcomes: Cognitive, Demographic, and Teacher Ratings

The contribution of the 7 cognitive variables, teacher ratings, and sociodemographic variables (sex, SES, maternal education) to measures of reading (decoding, rate, accuracy, and comprehension) are presented in Table 3. Preliminary analyses using the variables within the teacher rating and sociodemographic domains indicated that only the MIT Academic scale and SES had significant ($P < .01$) relationships with each reading outcome. Four separate multiple regressions were performed for each of the 4 reading outcomes using a forward stepwise selection procedure to select predictor variables from among the cognitive variables, SES, and MIT Academic scales. For decoding, rate, and accuracy, the phonological awareness composite was selected first

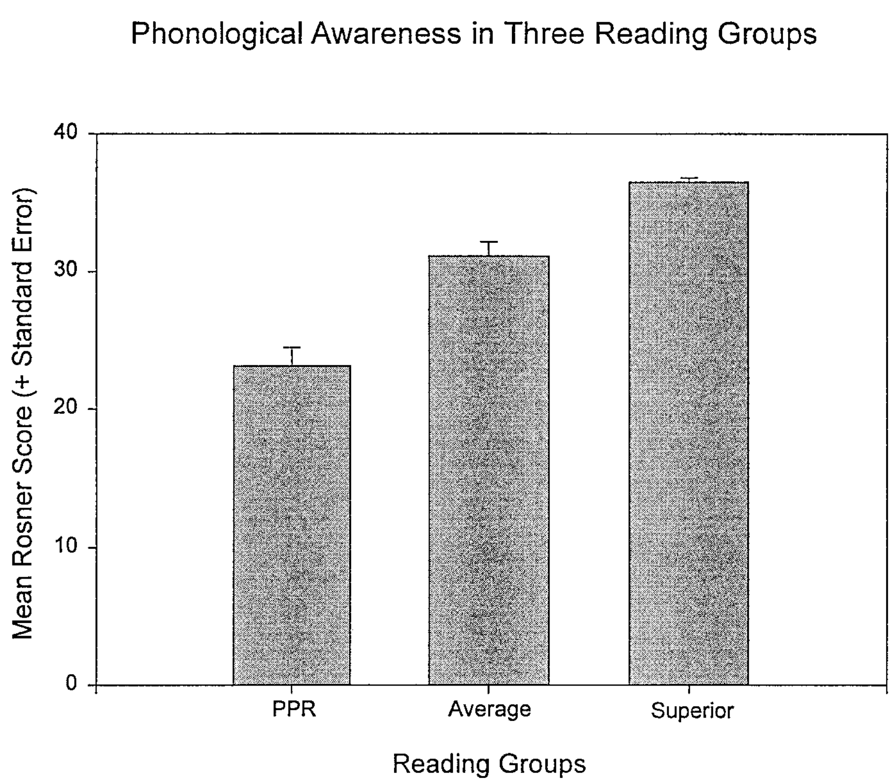

Fig 2. Phonological awareness measured on the Test of Auditory Analysis Skills.[24] Figure 2 shows the mean score (± standard error of the mean) for the 3 reading groups. The observed differences are supported by univariate analysis of variance ([2,92] = 52.14; $P < .0001$, Scheffe pairwise post-hoc comparisons) further indicating that PPR < average ($P < .001$); PPR < superior ($P < .001$); average < superior ($P < .001$).

TABLE 3. Best Predictors of Reading and Spelling Skills by Order of Selection in Regression Model

Dependent Measure	Predictor(s)	R^2
Decoding*	Phonological awareness	.74
	MIT academic	.76
Rate†	Phonological awareness	.54
	MIT academic	.64
	Rapid naming	.68
Accuracy‡	Phonological awareness	.50
	MIT academic	.60
	Rapid naming	.62
Comprehension§	Word finding	.56
	Digit span	.63
	SES	.67

* $F(2,86) = 138.21$; $P < .0001$.
† $F(3,84) = 58.52$; $P < .0001$.
‡ $F(3,86) = 46.02$; $P < .0001$.
§ $F(3,85) = 56.63$; $P < .0001$.

into the model, followed by the teacher rating of academic skills. For rate and accuracy, rapid naming was also a significant predictor. In contrast, the best predictor of reading comprehension was the word finding composite, with Digit Span and SES also contributing significantly to the regression model. It should be noted that word recognition, clearly best predicted by phonological awareness, correlated at .81 with comprehension and would have been the best predictor of comprehension had this composite been included in the model.

Longitudinal Data

The results of the grade 9 cognitive data indicate clearly that children with PPR do not outgrow their reading problem. This hypothesis was directly tested by growth curve modeling of the Woodcock–Johnson Basic Reading Composite in grades 1 through 12.

Inspection of individual growth trajectories over the 12 occasions revealed that individuals experienced growth that is more rapid over the first 6 years compared with the last 6 years, suggesting a pattern of growth to a plateau. To model this developmental pattern of reading skills in students over time, a quadratic model of growth to a plateau was fit to the data. Results from the multilevel analysis confirmed that the linear and quadratic terms were statistically significant ($t[3,92] = 36.31$; $P < .0001$ and $t[3,92] = -24.53$; $P < .0001$, respectively).

The parameter estimates for the 3 groups were compared and an estimated average growth trajectory for each of the 3 groups was constructed using the mean growth parameters for the 3 groups in Fig 3. The superior group demonstrated the highest level of reading performance at 8 years of age, the intercept. The average group demonstrated the next highest level of performance, and the PPR group performed at a lower level. The age at plateau for the superior, average, and PPR groups were 13.4, 15.4, and 15.3, respectively. Although the superior group reached plateau earlier than the other groups, the level of plateau for the superior group (535) exceeded the plateau levels of the other groups: 530 for the Average group and 510 for the PPR group. Overall, the 3 groups demonstrated similar patterns of growth over time, with the superior group outperforming the average group, and the average group outperforming the PPR group. There was no evidence that the children in the PPR group catch up in their reading skills with the results clearly fitting a deficit model.

Grade 12

Because of the large numbers of variables and relatively small sample size, the survey data are interpreted descriptively. Differences are reported as significant at the .05 level of α. We did not attempt to control for the number of variables analyzed because of the weak power of the design for these data.

On the student survey, all 95 students completed the questionnaire. Many variables did not discriminate the groups. There was no difference in legal trouble, alcohol use, tobacco use, use of stimulants, or use of other medications such as antidepressants. On the scales rating different behaviors, there were no group differences that involved dimensions of conduct, attention, and activity domains.

Students with PPR were more likely to be currently enrolled in high school and more likely to either plan to complete high school or obtain a GED. This paradoxical result occurs because of early graduation in the superior group. The PPR students were less likely to have plans to finish high school and were more likely to be placed in a lower grade. Students with PPR were less likely to get books from the library. On a reading scale involving what and why they read, students with PPR were less likely to indicate that they spent time reading. Students with PPR were more likely to have been expelled from school. They were more likely to indicate that they would like to obtain help from a professional. They were less likely to have received honors or to participate on a high school athletic team. Students with PPR were more likely to live in a household in which a divorce or separation occurred.

Teacher reports were available on 84 of the students, including 13 PPR, 33 average, and 38 superior readers. According to the teachers, children with PPR were less likely to be at grade level or on target for graduation. They were more likely to be classified for special education and to receive special services, including vocational placement. The students with PPR had significantly lower grades in English and math, and were less likely to receive awards for their schoolwork. Variables that did not differentiate the groups included days absent, times tardy, truancies, class size, school size, and withdrawals.

DISCUSSION

In this group of high school students who have been continuously and prospectively monitored since kindergarten, our findings indicate that difficulty with phonologic awareness represents the most robust characteristic of reading disability. Phonological awareness may be assessed in several different ways. One approach asks the child to count the number of sounds he or she hears in a word, for example, there are 3 sounds in the word "bat"; another asks him or her to omit a phoneme from a word (say "scar" without the "s"— "car"). The current data

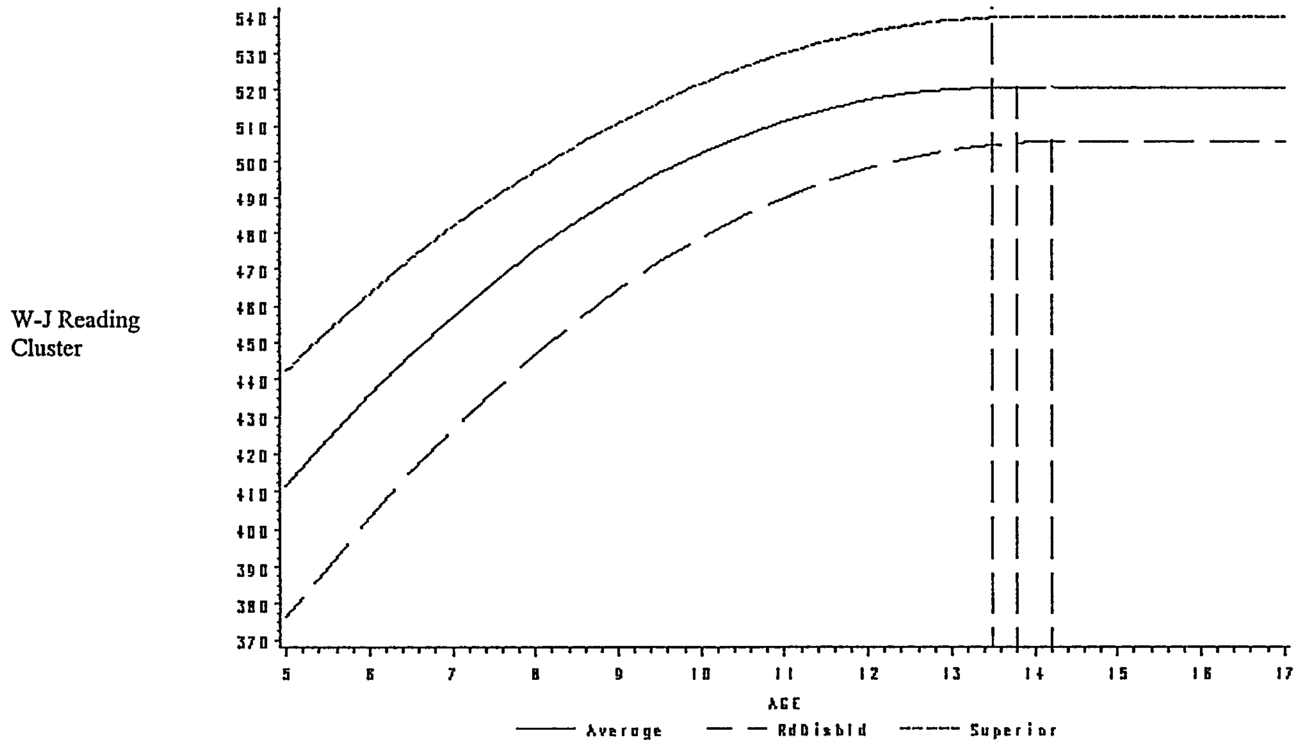

Fig 3. Individual growth curve analysis of changes in reading. The longitudinal data on the Woodcock–Johnson Basic Reading composite were analyzed using a nonlinear growth curve model using the interval-based Rasch scores on the Woodcock–Johnson Basic Reading subtests in grades 1 to 12. Growth parameters were calculated for intercept, slope, curvature, plateau age, and plateau level. The superior group demonstrated the highest level of reading performance at 8 years of age, the intercept. The average group demonstrated the next highest level of performance, and the PPR group performed at a lower level. The age at plateau for the superior, average, and PPR groups were 13.4, 15.4, and 15.3, respectively. Although the superior group reached plateau earlier than the other groups, the level of plateau for the superior group (535) exceeded the plateau levels of the other groups: 530 for the average group and 510 for the PPR group. Overall, the 3 groups demonstrated similar patterns of growth over time, with the superior group outperforming the average group, and the average group outperforming the PPR group. There was no evidence that the children in the PPR group catch up in their reading skills.

indicate that deficits in phonological coding continue to characterize dyslexic readers even in adolescence; performance on phonological processing measures contributes most to discriminating dyslexic and average readers, and average and superior readers as well. These data support and extend the findings of previous investigators indicating the continuing contribution of phonological processing to decoding words, reading rate, and accuracy and spelling as children mature and progress in school.[4,7,8,13,37–39]

Results of the growth curve analysis (Fig 3) indicate that children with dyslexia neither spontaneously remit nor do they demonstrate a lag mechanism for catching up in the development of reading skills. Such findings are consonant with a large body of literature that indicates that adults with a history of dyslexia in childhood demonstrate continuing problems in reading and spelling.[12,13,40–44] These findings extend into adolescence data previously reported on the persistence of reading disability,[18] that is, that children who were initially poor readers in the early school years remain poor readers relative to other children in the sample. This finding suggests that shortly after school entry, the reading achievement of children changes very little relative to their peers.

These results are sobering and occurred despite the fact that all 21 children in the PPR group received special education services at some point in their development. These special services, however, consisted of eclectic approaches to teaching reading that were provided in an inconsistent fashion and for relatively brief periods. The sort of systematic and highly structured programs that current research has demonstrated are necessary to teach phonologic awareness had not yet been developed when the children in this study were in grade school. We now know that phonologic awareness instruction must be taught explicitly, for example by teaching children to identify rhyming and nonrhyming word pairs, blending isolated sounds to form words, or conversely, segmenting a spoken word into its individual sounds.[45] In contrast, despite consequences for academic performance, the results are in some ways reassuring for nonacademic outcomes. Thus, student and teacher reports in 12th grade each failed to find any differences between good and poor readers on the prevalence of legal trouble or alcohol or tobacco use nor did student and teacher reports document any differences in conduct or attention problems.

On a theoretical level, the data provide important insights into how older, more experienced readers extract meaning from print. The most widely accepted current theory of reading posits 2 routes to word identification: a direct visual (orthographic) route and a more indirect, phonologically mediated route. Within such a framework, readers obtain meaning from print by 1) an orthographic route in which the letters comprising a word are mapped directly onto the reader's lexicon or internal dictionary in which meaning is accessed, or 2) a phonologically-mediated route in which letters are first mapped on to the sounds or phonology of a word and then routed to the lexicon for meaning. It is generally assumed that beginning readers use the more indirect, phonologically mediated route, whereas more experienced readers predominantly use the direct or orthographic route. It has long been assumed that once a student is past the primary grades, phonological processing is no longer critical to word identification and to reading. Our data support the view that across the life span, from childhood to adolescence, decoding words reflects primarily, phonological, rather than orthographic coding. Such findings are consonant with what is becoming overwhelming evidence that phonological mechanisms mediate word identification in all readers, whether beginners or experienced readers.[46,47]

From a clinical perspective, these data provide helpful guidelines for the primary care physician asked to evaluate and treat children and adults with dyslexia. Given the high prevalence of dyslexia, affecting perhaps 17.5% of the school-aged population,[5] recognition of its manifestations is clearly of great importance. The data presented here offer an approach to synthesizing the signs and symptoms of this most prevalent of the learning disabilities within the framework of what has been termed the phonologic deficit model of dyslexia. According to the model, a circumscribed deficit in a lower-order linguistic (phonologic) function blocks access to higher-order processes and to the ability to draw meaning from text. The problem is that the person cannot use his or her higher-order language skills to access the meaning until the printed word has first been decoded and identified. Early on, clues that a child might be dyslexic include difficulty with naming letters and then, difficulty associating the letters with the sounds of speech. As the child matures, additional clues to the diagnosis include an inability to sound out new or unfamiliar words. As children approach adolescence, a manifestation of dyslexia may be a very slow reading rate; in fact, children may learn to read words accurately, but they will not be fluent or automatic, reflecting the lingering effects of a phonologic deficit.[14] Because they are able to read words accurately (albeit very slowly) dyslexic adolescents and young adults may mistakenly be assumed to have outgrown their dyslexia. The data presented here in children followed prospectively support the notion that in adolescents, the rate of reading as well as facility with spelling may be most useful clinically in differentiating average from poor readers.

The diagnosis of dyslexia in students in secondary school and college and even graduate school represents the first step in its management. In contrast to intervention in younger students with dyslexia in which the goal is remediation, in older students with dyslexia, management is most often based on accommodation. It is important to remember that these older dyslexic students may be similar to their unimpaired peers on measures of word recognition yet continue to suffer from the phonologic deficit that makes reading less automatic, more effortful, and slow. For these readers with dyslexia, the provision of extra time is an essential accommodation. This allows them the time to decode each word and to apply their unimpaired higher-order cognitive and linguistic skills to the surrounding context to get at the meaning of words that they cannot entirely or rapidly decode. Other accommodations useful to adolescents with reading difficulties include note-takers, taping classroom lectures, using recordings for the blind to access texts and other books they have difficulty reading, and the opportunity to take tests in alternate formats, such as short essays or even orally.[5]

In many ways, this study was designed to minimize some of the methodological problems in previous studies. Thus, in contrast to retrospective studies in which there is always concern about the reliability of the diagnosis in childhood, these data exploit the availability of the prospectively diagnosed and monitored representative sample survey followed from kindergarten entry to young adulthood to investigate the relationship between the diagnosis of dyslexia in early school years and current performance at adolescence. At the same time, there are clearly limitations of this study as well. Perhaps the most salient limitation is that the number of subjects with dyslexia is limited by the base rate of dyslexia in the sample population. In a similar way, the number of children from low socioeconomic strata are dependent on the sample survey, which by design sampled children without regard to social strata. Finally, although we imposed few exclusionary criteria on our sample, one was that subjects had to be children whose primary language was English, and so our data should not be extrapolated to populations of children whose primary language is not English.

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