Multiple component remediation of developmental reading disabilities: A Controlled factorial evaluation of the influence of IQ, socioeconomic status, and race on outcomes

Multiple-Component Remediation for Developmental Reading Disabilities: IQ, Socioeconomic Status, and Race as Factors in Remedial Outcome

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Abstract

Results from a controlled evaluation of remedial reading interventions are reported: 279 young disabled readers were randomly assigned to a program according to a 2 × 2 × 2 factorial design (IQ, socioeconomic status [SES], and race). The effectiveness of two multiple-component intervention programs for children with reading disabilities (PHAB + RAVE-O; PHAB + WIST) was evaluated against alternate (CSS, MATH) and phonological control programs. Interventions were taught an hour daily for 70 days on a 1:4 ratio at three different sites. Multiple-component programs showed significant improvements relative to control programs on all basic reading skills after 70 hours and at 1-year follow-up. Equivalent gains were observed for different racial, SES, and IQ groups. These factors did not systematically interact with program. Differential outcomes for word identification, fluency, comprehension, and vocabulary were found between the multidimensional pro- grams, although equivalent long-term outcomes and equal continued growth confirmed that different pathways exist to effective reading remediation.

Keywords

treatment, dyslexia, response to intervention, intervention, reading

The prevalence of reading acquisition failure in the U.S. school-age population continues to be a major social and political concern. Although improvements have been observed since the nation's original 1992 report card, the National Assessment of Educational Progress (NAEP) in 2007 estimated that 34% of fourth-grade children are significantly below average in reading skills (U.S. Department of Education: National Center for Education Statistics, 2007). When these figures are examined according to socioeconomic status (SES) and ethnic group, the results are even more troubling: 50% of children from low-income families read below a basic level, as opposed to 21% of higher income children. By ethnic group, 54% of children who are African American, 51% of children who are Hispanic, and 23% of children who are European American read below the basic level on the NAEP.

If unresolved, the problem of reading acquisition failure will limit the future potential of more than 10 million American youth (National Reading Panel [NRP]—Report of the Subgroups, 2000; Snow, 2002). If the above trends continue, there will be an ever-expanding academic gap according to SES and ethnic grouping. In this article, we evaluate the efficacy of three reading intervention programs with a particular interest in assessing response to intervention by young impaired readers who differ in race, IQ, and SES.

Developmental reading disability (RD) is a term applied to those children who unexpectedly fail to learn to read, whether defined on the basis of significant reading under- achievement or relative to expectations based on IQ, age, or grade level (Fletcher, Morris, & Lyon, 2003). Recently, there has been an increasing number of well-controlled research reports that have focused on critical component for the effective remediation of children with RD and of those at risk for not acquiring fluent reading skills and good reading comprehension. Progress has been achieved in identifying the critical components of effective early reading instruction (Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg, 2001), particularly for teaching basic literacy skills. Although much remains to be investigated with regard to the instruction and measurement of higher order reading fluency and comprehension skills (Biancorosa & Snow, 2006; NRP, 2000), considerable recent progress has been made in this area as well, particularly for children within the range of normal reading development (Guthrie et al., 2004, 2007; Wigfield et al., 2008; Williams, 2005; Williams et al., 2005, 2007). Issues related to teaching higher order reading skills to children with RD have been discussed in recent years (Gersten, Fuchs, Williams, & Baker, 2001; Johnston, Barnes, & Desrochers, 2008).

Much of the early intervention work on reading disabilities investigated disabled readers of average IQ and SES. Decades of reliance on IQ-achievement discrepancies in identifying children with RD resulted in the relative exclusion of children with lower IQs and significant reading underachievement from research. Despite increasing recognition that IQ and the IQ-achievement discrepancy do not reliably discriminate children who will respond well to reading intervention (Shaywitz, Morris, & Shaywitz, 2008; Stage, Abbott, Jenkins, & Berninger, 2003; Vellutino, Scanlon, & Lyon, 2000), an implicit assumption persists that children without the advantages of an average to above-average IQ and access to an enriched environment will not respond to the verbally mediated interventions that are effective with struggling readers of average IQ and SES.

Post hoc analyses of early intervention outcomes for 128 at-risk first graders revealed that Verbal IQ was a minor contributor to word identification skills relative to specific reading- related language predictors like phonological processing, rapid naming, and orthographic skills (Stage et al., 2003). Indeed, ratings for attention provided greater prediction power than Verbal IQ in this analysis. This study identified three language-related processing deficits that characterized at-risk children in different combinations: deficits in phono- logical processing skills, slow rapid naming, and deficient orthographic processing skills. Those at-risk children with two or three of these language-processing deficits did not grow as quickly in varied reading skills as at-risk children with relatively intact language skills. Any of these processing deficits was sufficient to slow the growth of word identification skills in intervention, regardless of the child's IQ at entry (Stage et al., 2003).

Other studies confirm that first graders with and without reading achievement/IQ discrepancies do not show a differential response to early intervention (Vellutino et al., 1996). Similarly, longitudinal data from Francis, Shaywitz, Stuebing, Shaywitz, and Fletcher (1996) revealed no real differences in rate of reading growth among first- through ninth-grade students, whose reading achievement was and was not discrepant from IQ. To date, however, the relative contributions of IQ and demographic variables like SES and race have never been studied prospectively in a balanced factorial design to determine their relevance in predicting reading intervention outcomes.

Results from three decades of research describe a small set of core deficits in language development and in more global processing abilities that appear consistently associated with reading disabilities, particularly the most severe cases. A majority of children with developmental RD are characterized by deficits in phonological processing that are demonstrated at both sublexical and lexical levels of processing. Such children exhibit a range of defining deficits in their explicit awareness of, and ability to manipulate, the sound structure of spoken words (Snowling & Hulme, 1993, 2005). Phonological difficulties are known to persist into adulthood for individuals with histories of RD (Shaywitz et al., 1999) and have led both to concerns about their amenability to remediation (e.g., Wagner, Torgesen, & Rashotte, 1994) and to incentives to conduct rigorous research on intervention and prevention for phonologically based reading disabilities (Lyon & Moats, 1997).

A failure to acquire rapid, context-free, word identification skills appears to be a highly reliable indicator of most cases of severe RD (Fletcher, Lyon, Fuchs, & Barnes, 2007). Results from some intervention studies suggest that a failure to parse a syllable into sub-syllabic units may underlie the difficulties in acquiring an alphabetic decoding strategy and in developing stable word identification and attack skills (Lovett, Warren-Chaplin, Ransby, & Borden, 1990). Because these children do not spontaneously segment spoken syllables into smaller units, they have no basis for (a) segmenting orthographic (spelling) patterns corresponding to these units; (b) extracting rules for their synthesis; or (c) using them to decode a new word by analogy to a known word (Gaskins, Downer, & Gaskins, 1986; Lovett et al., 1994). Such deficits in word recognition processes are also thought to contribute to many forms of poor comprehension (Fletcher et al., 2007; Perfetti, 1992).

Many impaired readers are also characterized by deficits in naming speed and a profile of reading comprehension and fluency problems (Wolf, 2007). Extensive evidence from different paradigms and a growing number of languages now suggests that naming-speed deficits (NSD) may represent a second core deficit in reading disability. Some researchers have described naming speed problems as largely independent of phonological skills (Clarke, Hulme, & Snowling, 2005; McBride-Chang & Manis, 1996; Wolf & Bowers, 1999) and more predictive of RD than phoneme awareness in transparent and logosyllabic orthographies (L. H. Tan, Spinks, Eden, Perfetti, & Siok, 2005). Other researchers have contended that naming-speed deficits are related to central phonological processing deficits (Compton, DeFries, & Olson, 2001; Schatschneider, Carlson, Francis, Foorman, & Fletcher, 2002; Vukovic & Siegel, 2006; Wagner et al., 1997.)

Regardless of their independence, naming-speed deficits may be related to problems of dysfluency at several possible levels of print-to-speech mapping. Wolf and Bowers (1999, 2000) describe three potentially interrelated ways in which deficits in the processes underlying letter-naming speed may contribute to word-reading speed problems and to reading acquisition failure: (a) by slowing and/or preventing the development and amalgamation of rapid connections between and among orthographic, phonological, and semantic processes at sublexical and word levels (Ehri, 1997); (b) by limiting the quality of representation of common orthographic patterns in memory (Bowers, Golden, Kennedy, & Young, 1994); and (c) by increasing the amount of repeated practice needed to form all types of high-quality representations involved in reading (Collins & Levy, 2008; Levy, 2001; Levy, Abello, & Lysynchuk, 1997). Wolf and Katzir-Cohen (2001) discuss reading fluency as a developing process that is shaped by contributions from phonological, orthographic, semantic, syntactic, and morphological processes. Recent work has high- lighted the interdependence of fluency and comprehension growth in the development of reading skill (Collins & Levy, 2008; Klauda & Guthrie, 2008).

Another learning deficit, in strategy learning and executive functioning, is considered an important part of reading acquisition failure. Research with children with RD has produced several reports demonstrating particular difficulties in executive processing and the acquisition of self-regulatory strategies, and these problems appear to exist independent of their phonological processing difficulties (Swanson & Saez, 2003; Swanson & Siegel, 2001). These aspects of metacognitive function are important in the context of understanding children's lack of transfer and generalization failures (Harris, Graham, & Pressley, 1992) during reading acquisition and reading remediation. It has been suggested that even when children with RD have received strategy instruction, they may remain novices because they fail to transform simple strategies into more efficient forms (Swanson, Hoskyn, & Lee, 1999). Strategy acquisition, application, and self-monitoring are critical to acquisition of effective word identification and reading comprehension strategies. Strategy use and evaluation are components of reading development that become increasingly significant as the child acquires greater reading skill.

Remediating core deficits. A number of well-controlled research studies have been reported focusing on the remediation of reading problems in the early elementary grades (Foorman, Francis, Fletcher, Schatschneider, & Mehta, 1998; Scanlon & Vellutino, 1997; Torgesen, Wagner, & Rashotte, 1997a; Torgesen, Wagner, Rashotte, Lindamood, et al., 1999; Vellutino et al., 1996). Converging evidence indicates that significant improvement can be attained on speech-based and phonological reading measures (Foorman et al., 1998; Lovett et al., 1994; Olson, Wise, Ring, & Johnson, 1997; Torgesen, Alexander, et al., 2001; Torgesen, Wagner, Rashotte, Alexander, & Conway, 1997; Torgesen, Wagner, Rashotte, Lindamood, et al., 1999; Vellutino et al., 1996), confirming that phonologically based decoding and early reading skills are clearly "teachable aspects of reading for most children" (Moats & Foorman, 1997, p. 188).

Despite the improvements observed in children's phono- logically based word attack and decoding skills, training gains do not always generalize to word identification, text reading, fluency, and comprehension skills. In fact, generalization of remedial gains has proved a formidable hurdle (Lovett, Ransby, Hardwick, Johns, & Donaldson, 1989; Torgesen, Alexander, et al., 2001; Torgesen, Wagner, Rashotte, et al., 1997), particularly to long-term fluency and comprehension. Other research has characterized transfer-of-learning difficulties in RD as specific to printed language learning; they are not evident on other learning tasks with similar cognitive demands but no phonological processing requirements (Benson, 2000; Benson, Lovett, & Kroeber, 1997).

Torgesen et al. (1997a) suggested that the generalization problem reflects the complexity of the processing impairments seen in more severely disabled readers. In one of the most influential intervention studies to date, Torgesen et al. (1997a, Torgesen, Alexander, et al., 2001) found that poor readers made dramatically significant gains in phoneme awareness and word attack but were essentially unchanged in fluency.

Many questions remain concerning whether or not processing-speed and fluency deficits are amenable to current treatment methods and whether intervention should focus on connected-text, word-level, and/or underlying, sublexicallexical processes (e.g., letter-pattern recognition). Some fluency training efforts have targeted the word level and have shown gains in connected text reading, fluency, and comprehension measures (Levy, 2001; A. Tan & Nicholson, 1997), but in general, addressing fluency at the sublexical and lower processing level has received relatively little attention. For years, the assumption was that greater accuracy in alphabetic decoding would generalize to improved fluency; increasing evidence, however, failed to support this assumption (Torgesen, Rashotte, & Alexander, 2001).

Relatively more evidence is available concerning the effectiveness of remediation directed to the core deficit in strategy learning and metacognitive control. Meta-analyses have revealed that children with RD are closer in performance to their non-disabled peers when intervention programs include explicit strategy instruction (Swanson et al., 1999). The strategy deficits of children at risk for reading acquisition failure encompass all aspects of reading for meaning, expository text comprehension, and written expression. There is growing recent evidence that low-achieving readers can make gains in reading comprehension with systematic instruction and practice on reading comprehension strategies (Mason, 2004; Vaughn et al., 2000). In fact, explicit strategy training and metacognitive instruction can provide an important component of effective remediation for RD in the acquisition of both decoding accuracy and reading comprehension skills.

Evidence from our Toronto site provides strong empirical support for this speculation (Lovett, Lacerenza, Borden, et al., 2000). When phonological reading interventions were combined with the teaching of specific word identification strategies, and these strategies were implemented, practiced, and evaluated using self-directing dialogue, severely disabled readers demonstrated superior outcomes and steeper learning curves than when they received an equal amount of intervention in phonological or strategy training conditions separately. The combined intervention conditions were associated with the greatest generalization of treatment gains for this sample of children with severe RD.

The assessments and interventions included in this study address the multidimensional nature of reading skills and the heterogeneous profiles of disabled readers. Focus is placed on the need for multiple-component interventions for RD, the need to remediate the core deficits that limit reading acquisition, and the importance of facilitating the development of word identification and decoding skills, reading fluency, and reading comprehension abilities. Multidimensional approach to the study of RD and its effective remediation was undertaken within a factorial design that addresses the following questions:

1. Do multiple-component remedial reading interventions produce greater gains than those targeting phonological reading processes alone?
2. Do multiple-component interventions with different metacognitive and language emphases differ from each other in their effect on reading growth and reading outcomes for children with RD?
3. Do remedial outcomes and rate of growth differ for struggling readers who vary in socioeconomic status, race, and IQ?
4. Do struggling readers demonstrate remedial growth on all dimensions of reading skill (decoding accuracy, reading rate, comprehension)?
5. Are intervention-related gains maintained on 1-year follow-up?

Method

Study Overview

This study was a controlled evaluation of different reading remediation programs offered to children within public schools. Study participants included second- and third-grade children initially referred by their teachers. Selection was based on a screening assessment using explicit criteria to define RD. The study design involved random assignment of small groups of struggling readers, and their teachers, to one of four remediation conditions. The factorial design of the study attempted to develop four randomly assigned groups of struggling readers, such that each group included equal numbers of Caucasian and Black students, of students with average or below-average family socioeconomic situations, and of students with average or below-average IQ. Groups of four children from each sample were taught one of four remedial programs (PHAB + CSS, MATH + CSS, PHAB + WIST (PHAST), PHAB + RAVE-O; conditions described below) by trained teachers for 70 contact hours during the school year. All children were evaluated at the beginning (0 hours), in the middle (35 hours), at the end of the 70 hours of instruction, and at 1-year follow-up.

Participants

Participants were initially recruited in three large metropolitan areas (Atlanta, Boston, and Toronto) on the basis of teacher identification as struggling readers. General inclusion criteria consisted of the following: English as a first and primary language, age between 78 months (6 years 6 months) and 102 months (8 years 6 months), grade level at first or second grade at time of screening, and normal hearing and vision. Nine hundred fifty-eight children were referred (see Figure 1). Children were further selected from this pool based on their performance on a screening battery that included the *Kaufman Brief Intelligence Test* (K-BIT; Kaufman & Kaufman, 1990), *Woodcock Reading Mastery Test–Revised* (WRMT-R; Woodcock, 1987), the *Wide Range Achievement Test–3* (WRAT-3; Wilkinson, 1993), and a brief demographic and history form completed by their parents. Children were excluded if they had repeated a grade, achieved a K-BIT Composite score below 70, or had a serious psychiatric or neurological illness. The co-occurrence of a disorder common in RD populations (e.g., ADHD) did not exclude a child. The goal in excluding children who were repeating a grade was to control for the amount of previous educational experience of the children. In practice, however, this was not an issue because at every site, very few children referred to the project were repeating a grade.

Socioeconomic status. A parent/guardian was asked to complete a questionnaire that included basic demographic information used to evaluate socioeconomic status and ethnicity. SES data from all sites were derived using two American SES scales (Entwisle & Astone, 1994; Nakao & Treas, 1992) and one Canadian SES scale (Blishen, Carroll, & Moore, 1987; Edwards-Hewitt & Gray, 1995). Our goal was to develop an index for systematically identifying children's families as average to above-average SES (classified as Aver- age SES) or below-average SES (Low SES). To this end, a systematic evaluation of the reliability and concordance of the different scales and their combination was undertaken and the results used to classify the children (see Cirino et al., 2002). The particular differences or actual levels of SES provided by the scales were not as critical as an accurate ranking of children.

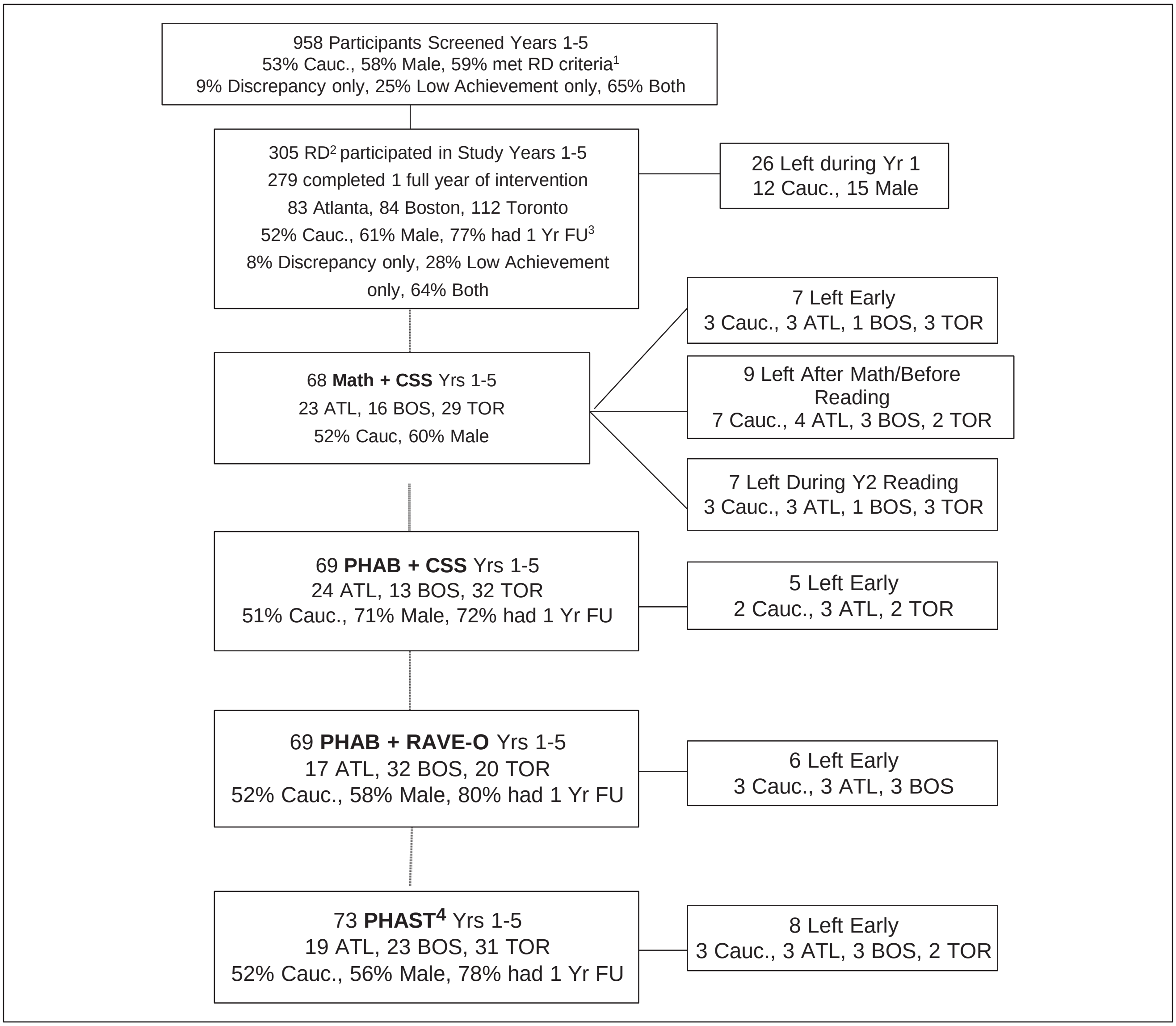

Figure 1. Participant screening, selection, attrition, and final sample who completed 70 hours of remediation

[1]Out of 911 participants with K-BIT Composite scores greater than 69 and from whom K-BIT and all screening reading scores were obtained.

[2]Plus 10 non-reading-disabled participants.

[3]162 participants out of the 211 who completed 1 year of reading intervention (and not including MATH + CSS participants).

[4]PHAST = PHAB + WIST

RD = reading disability; CSS = Classroom Survival Skills; PHAB = Phonological Analysis and Blending/Direct Instruction; PHAST = Phonological and Strategy Training; RAVE-O = Retrieval, Automaticity, Vocabulary, Engagement with language, and Orthography; Cauc. = Caucasian; FU = follow-up; ATL = Atlanta; BOS = Boston; TOR = Toronto.

Selection Criteria for Inclusion in Remediation

Neither universally accepted nor universally validated criteria for defining samples or subtypes of RD children exist (Morris et al., 1998). The current study used a sampling strategy and measurement model that allowed for the objective testing of different conceptual (categorical vs. dimensional), definitional, and subtype models of RD and comparison of the inter- action of such classification results with treatment outcomes.

The K-BIT Composite standard score was used in screening as an index of intellectual ability, and reading levels were measured using one or more of the following indices: (a) a Reading total score calculated by averaging the standard scores of the WRMT-R Passage Comprehension, WRMT-R Word Identification, WRMT-R Word Attack, and WRAT-3 Reading subtests; (b) the WRMT-R Basic Skills Cluster score; and/or (c) the WRMT-R Total Short Scale score. These different options were used to increase the heterogeneity of the samples' reading profiles.

Table 1. Demographic Data of Those Who Were Included in Growth Models (n = 279)

	MATH + CSS			PHAB + CSS			PHAB + RAVE-O			PHAST Demographic		
	ATL	BOS	TOR	ATL	BOS	TOR	ATL	BOS	TOR	ATL	BOS	TOR
Total *n*	23	16	29	24	13	32	17	32	20	19	23	31
Average age (mos.) at BL	94.56	96.76	92.46	94.32	95.02	91.17	93.84	92.48	89.80	94.02	97.29	93.45
Average IQ	89.09	93.00	91.24	89.29	95.08	90.68	89.94	96.55	87.05	88.47	96.61	90.57
IQ *SD*	11.13	13.24	10.86	12.49	10.77	9.13	9.41	14.27	7.52	8.90	14.20	8.51
BL Reading avg.	76.60	78.90	76.84	77.83	79.40	77.60	81.00	80.44	78.95	78.01	83.18	77.24
BL Reading avg. *SD*	9.89	8.08	9.48	9.91	9.39	7.46	5.07	7.54	5.73	8.81	9.02	6.27
Ethnicity												
Caucasian	6	11	17	5	9	21	4	11	17	6	8	21
Black	17	4	12	19	4	10	12	4	12	13	10	9
Socioeconomic status												
Average	9	8	17	12	5	15	12	14	10	9	12	10
Low	14	7	12	12	8	16	4	15	10	10	6	20
IQ												
Average	10	10	13	9	9	15	9	19	8	7	11	17
Low	13	5	16	15	4	16	7	10	12	12	7	13

IQ score = *Kaufman Brief Intelligence Test* (K-BIT) Composite IQ; Reading avg. = average of scores on *Woodcock Reading Mastery Test–Revised* (WRMT-R) Word Attack, Word Identification, and Passage Comprehension and *Wide Range Achievement Test–3* (WRAT-3) Reading at baseline (BL); CSS = Classroom Survival Skills; PHAB = Phonological Analysis and Blending/Direct Instruction; RAVE-O = Retrieval, Automaticity, Vocabulary, Engagement with language, and Orthography; PHAST = Phonological and Strategy Training; ATL = Atlanta; BOS = Boston; TOR = Toronto.

Children were included in the study if they met criteria for either a Low Achievement (LA) or an Ability-Achievement Regression Corrected Discrepancy (DISC) determination of a reading disability (Fletcher et al., 1994). The LA criteria required that a child's K-BIT Composite standard score was greater than 70, and at least one of their reading standard score indices was 85 (approx. the 16th percentile) or less. The DISC criteria required that at least one of the child's reading standard score indices was at least one standard error of the estimate (approximately 13 standard score points) below their regression-predicted reading score. This was calculated using the K-BIT Composite standard score and an average .60 correlation between the reading and IQ scores. This classification resulted in a broadly defined sample of children with reading problems.

Of the 958 referred children, 565 children met one of these inclusion criteria: 64% met both LA and DISC RD criteria, 8% met only the DISC criteria, and 28% met only the LA criteria. Consistent with previous findings, 72% met the DISC criteria, and 92% the LA criteria.

The study used a 2 × 2 × 2 factorial design, with Race (Caucasian, Black), IQ (Average = ≥90, Below Average = 70–89), and Socioeconomic Status (Average, Low) as critical sampling factors. The study attempted to obtain at least eight ($n = 8$) children in each factorial cell (total $n = 64$) for each of the four remediation program conditions (total study goal $n = 256$). No site was allowed to provide more than five (of the 8) children in any cell in any remediation condition. The final number of participants from each of the three cities was nearly comparable, with Atlanta, Boston, and Toronto contributing 31%, 29%, and 39% of the sample, respectively. Both socioeconomic groups and IQ levels were fairly evenly represented in all three cities. Twice as many participants from Atlanta were Black as opposed to White, and the reverse pattern was evident in Toronto.

These criteria and sampling requirements resulted in 305 children who were enrolled in one of the four remediation groups, with 279 completing the 70 hours of remediation and relevant remediation-related evaluations. These 279 children are the focus of this report (see Note 1). Table 1 describes the actual final sample for each condition and the basic screening and pre-intervention results for each remediation sample.

Measures

Both nationally normed, standardized, and experimental measures were used (Cirino et al., 2002; Lombardino et al., 1999) to increase sensitivity in monitoring change. This battery was given before remediation began (time 0), immediately following 35 hours of remediation (time 35), at the end of 70 hours of remediation (time 70), and at 1-year followup. Because there was little information concerning the performance of young children with RD on these measures, we performed an extensive test–retest evaluation on a sub- sample of 78 children from the 1st year of this study to evaluate their reliability, the impact of practice effects, and their relationship to other related measures. These results, reported in detail in Cirino et al. (2002), indicated that overall test reliability for this group of impaired readers was good, practice effects were minimal, and the experimental and nationally normed measures showed the expected relationships. Because of the extensiveness of the standardized and experimental evaluations conducted in this study, only results from the standardized, nationally normed reading measures will be reported here, although many of the experimental measures (see Cirino et al., 2002, for listing) showed similar findings.

Woodcock Reading Mastery Test–Revised. Three subtests of the WRMT-R (Form G; Woodcock, 1987) were used: noncontextual word reading (Word Identification), non-word decoding (Word Attack), and a cloze comprehension measure (Passage Comprehension). The Basic Skills Cluster score is the composite of Word Identification and Word Attack; the Total Reading–Short Form is the composite of Word Identification and Passage Comprehension.

Wide Range Achievement Test–3. The WRAT-3 (Wilkinson, 1993) measures both individual letter identification and word reading (Reading), the writing of letters and words to dictation (Spelling), and the timed solving of oral and writ- ten mathematical problems (Arithmetic). The inclusion of this measure was partly to assist with assessing preachievement abilities, so as to help address floor effects on other measures for low-performing children.

Reading efficiency test. Word Reading Efficiency and *Non- word Reading Efficiency* (Torgesen, Wagner, & Rashotte, 1997b) were the research versions and predecessor of the *Test of Word Reading Efficiency* (TOWRE; Torgesen, Wagner, & Rashotte, 1999). The *Word Reading Efficiency* measure included two lists of 104 real words (lists A & B) that increased in difficulty. The *Nonword Reading Efficiency* measure included two lists of 63 pronounceable non-words (lists A & B). The mean number of words read on both forms in 45 seconds provided a measure of reading rate. Grade-level normative data from the research version were used to compute standard scores (Torgesen, 1996).

Gray Oral Reading Test–III (GORT; Wiederholt & Bryant, 1992). This is a test that requires the child to orally read paragraphs of increasing difficulty and then answer comprehension questions. Oral reading rate and accuracy are both evaluated. This measure was completed only at preassessment (time 0) and postassessment (time 70) points.

Teacher and Program Fidelity Considerations

Two of the most difficult features to control in reading intervention research are teacher background and consistency and quality of program implementation, which frequently interact. Moats (1994, 2004) has argued eloquently for the necessity of ensuring that all teachers meet an appropriate level of competence and for ongoing monitoring and feedback to ensure consistent quality of instruction. All teachers in this study were hired specifically to go into one or two schools in a city and provide any of the four instructional programs being evaluated. This helped to control for some of the teacher-specific variance in background and motivation that occurs when using a school's own teachers or when embedding teachers within only one intervention condition, thus allowing for a confound between teacher-specific and program-specific effects. The allocation of teachers to all instructional conditions allowed teachers to be based at a specific school and multiple instructional groups from that school to be randomly assigned to different conditions. Another rationale for having all teachers teach all four intervention programs was that three conditions were based on the same core component (PHAB), which, when taught by the same teacher, would guarantee better consistency for that component, allowing the unique components of each of the intervention programs to better differentiate themselves. Concerns about cross-condition contamination are complex because the programs were designed to share half of their components but also to have unique aspects built on those shared components.

The teachers in the study were experienced and certified teachers, with a median of 7 years of teaching experience, and most teachers already having, or in the process of obtaining, graduate degrees in education. All were trained a priori to a level of specified competence during an intensive week- long training program held at the Toronto site and were led by the developers of the intervention programs. Training activities included (a) an overview of current research related to reading development and reading disabilities, (b) direct training of each intervention and its components, (c) practice followed by immediate feedback on the skills and strategies of the interventions, and (d) questions and discussion. A senior research teacher at each site served as the teacher trainer/ mentor and provided ongoing monitoring and feedback on teachers' performances. The teacher trainer visited the research classrooms a minimum of four times over the 70 hours to view and model lessons and to support the teachers. Independent review, feedback, and corrections were provided as needed. A series of independent videotaped evaluations was also conducted for all teachers to determine if the interventions were being carried out in the prescribed manner. All teachers from all sites, and the instructional program developers, were also part of a project listserv that provided teachers the opportunity to ask the other teachers or program developers about handling specific instructional components or challenges. The listserv ensured that all teachers across sites had consistent and timely information.

To increase implementation consistency and program integrity, each intervention program had a day-to-day, explicit Scope and Sequence plan that was followed by all teachers and that allowed for integrity monitoring. Each teacher completed a daily "teacher's log," which detailed their instructional activities for each lesson period based on the Scope and Sequence; at the end of each instructional period, teachers detailed what content they had completed that day, the children in attendance, children's response to instruction, and any instructional or behavioral issues that affected instruction during that period. The teacher logs were reviewed by project staff regularly to ensure adequate progress and integrity of program requirements. Random videotaped observations of the actual instructional lessons confirmed their accuracy. In addition, a senior/lead teacher at each site observed all teachers using an observational checklist four to five times during the 70 hours of instruction and provided specific implementation feedback to individual teachers to ensure that they were following the Scope and Sequence plans and instructional program expectations, that there was no cross-intervention program contamination, and that they were actively engaged in positive instructional activities with their students. All teachers were rated on a 5-point scale with regard to their ability to follow the Scope and Sequence of the different programs and provide consistent instructional experiences for their groups of children. When evaluated, this rating did not account for significant variance in the remedial outcomes of study participants.

Any teacher unable to consistently and effectively pro- vide the different instructional programs was observed more frequently, given more support and feedback, and, if program implementation could not be achieved at expected levels, was discontinued on the project. Discontinuation happened only twice over the course of the project.

Any teacher could be randomly assigned to teach any of the four instructional programs to any of the randomly assigned groups in their city's schools. Because of this, in our data analysis modeling, we included an "instructional group" factor that captured the systematic variance involved in a specific group of children with a specific teacher in a specific school. It is unfortunate that, given the sample sizes, number and types of groups taught by specific teachers, and more general design considerations, it was not possible to achieve a complete factorial design that could easily partition teacher- or school-effect variance from the results.

The rationale and outline of the teacher training and mentoring procedures used in all of our intervention research are described in detail in a recent publication (Lovett et al., 2008). Additional information on training and implementation of the RAVE-O Program components can be found in Wolf et al. (2009).

Remediation program design

Participants with similar single-word reading levels (WRMT- R and WRAT-3 Reading raw scores) were assigned to an instructional group of four children, and these groups were randomly assigned to one of four intervention programs (see detailed descriptions below). Seventy treatment sessions were conducted within each program during the academic school year. Children were typically seen in a pull-out format for 60 minutes a day, 5 days a week. Because we were in multiple cities, school districts, and schools, we allowed previous and current curricula to vary randomly to better evaluate the generalizability of our specific program results.

The intervention design included five components (PHAB, WIST, RAVE-O, CSS, MATH) that were combined, two at a time, into four different treatment programs. Two programs were control or contrast conditions (MATH + CSS; PHAB/DI + CSS, which became PHAB + CSS) and two represented experimental, multidimensional treatment programs (PHAB/DI + WIST, which became PHAST; PHAB/DI + RAVE-O, which became PHAB + RAVE-O). Every intervention program devoted equal time to its two components. The PHAB in each reading intervention aver- aged 30 minutes of instructional time in every lesson. This was exactly true for PHAB + CSS and for PHAB + RAVE-O. On average, across the 70 instructional hours of PHAST, exactly half of the instructional time was devoted to PHAB teaching. The distribution of phonological training changed, however, over the course of the 70-hour program. In the early parts of the program, 45 minutes would be devoted to PHAB training and 15 minutes to WIST training; in later parts of the program, the instructional balance shifted such that 15 minutes would be devoted to PHAB and 45 minutes to the strategy training activities of WIST. The phonological parts of the program served as a framework on which the word identification strategies were scaffolded in PHAST.

Remediation Program Components

The Classroom Survival Skills component (CSS). The CSS control component was used twice in the present design. The CSS control treatment was paired with the phonological component, PHAB, and with the alternate treatment control program, MATH. Participants received the same amount of intervention time and professional attention as those in the multiple-component reading programs, but they received no direct reading remediation in CSS. The CSS lessons, 30 minutes in length, trained classroom etiquette, life skills, and organizational strategies, with an emphasis on academic problem solving and self-help techniques. Parts of the program were developed using lessons adapted for research purposes from the *Skills for School Success* program (Archer & Gleason, 1991).

In terms of experimental design, the inclusion of a CSS component ensures that any reading effects obtained for the PHAB + CSS condition are due just to the PHAB component. When this condition is compared to the PHAST (PHAB + WIST) or the PHAB + RAVE-O conditions, it allows for a direct comparison of the additional effect of the WIST and RAVE-O components above and beyond the PHAB component alone. In this design, the treatment programs' effectiveness may be attributed to specific program content rather than to involvement in an active academic intervention program or to the benefits of receiving individual attention from an experienced special education teacher.

The Mathematics Program component (MATH). It has been estimated that 50% to 60% of children with RD exhibit poor mathematics performance (Badian, 1983). The MATH component thus provided an active, appropriate instructional pro- gram to teach a range of basic math concepts, number facts, computational skills, and specific problem-solving strategies through direct instruction and dialogue/metacognitive methods. The inclusion of a math program, paired with the CSS program, provides a stricter control for changes in self- esteem, perception by self and others, and motivation, as well as a more stringent control comparison for the specific effects of the experimental reading intervention programs. After the 70-hour posttreatment assessment, participants in the MATH + CSS control groups were offered a place in PHAST or PHAB + RAVE-O for ethical reasons.

Phonological Analysis and Blending/Direct Instruction component (PHAB). The PHAB program focuses on remediating basic phonological analysis and blending deficits and forms a foundation on which the current multidimensional interventions are based. PHAB trains sound analysis and blending skills and directly teaches letter-sound and letter- cluster-sound correspondences. Content is introduced in a highly structured sequence of steps, with multiple opportunities for overlearning, until children reach a defined "mastery" criterion. The PHAB program focuses on instruction in word segmentation and sound blending skills and attempts to remediate the core phonological deficits of disabled readers, so that reliable letter-sound knowledge and effective decoding and word identification skills can be acquired. The program uses many elements of direct instructional materials developed by Engelmann and his colleagues at the University of Oregon, specifically, the Reading Mastery Fast Cycle I/II Program (Engelmann & Bruner, 1988).

Word Identification Strategy Training component (WIST; Lovett et al., 1994). The WIST program instructs children in the acquisition, use, and monitoring of four different word identification strategies: (a) word identification by analogy, (b) seeking the part of the word that you know, (c) attempting variable vowel pronunciations, and (d) "peeling off" prefixes and suffixes in a multisyllabic word. Every WIST lesson begins with instructional time devoted to the prerequisite skills necessary to use the strategies effectively. This skill-building part of the lesson includes learning and practicing 120 key word patterns (Gaskins et al., 1986), learning different vowel pronunciations, and learning variant vowel combinations (ea, oo, ow, ie) and affixes (pre, re, un, ing, ly, ment). Most of the lesson is reserved for explicit WIST strategy instruction and application, with some discussion of explicit metacognitive issues such as strategy implementation, strategy choice, and self-monitoring. The WIST pro- gram emphasizes explicit training of the specific WIST strategies and extensive dialogue-directed practice with their implementation. In addition, the program teaches a system of metacognitive mnemonics to help the children acquire general routines important to effective strategy application and evaluation (e.g., the SAME [select, apply, monitor, evaluate] Plan).

PHAST program (PHAB + WIST; Lovett, Lacerenza, & Borden, 2000). Research findings from the Toronto site have demonstrated the efficacy of a sequential combination of phonologically and strategy-based interventions (Lovett, Lacerenza, Borden, et al., 2000) and lend support to an integration of these approaches into a single intervention program. Called PHAST for "The Phonological and Strategy Training Program," this program uses PHAB's program of phonological remediation as a framework on which each of the four WIST strategies are introduced and scaffolded. By 70 hours of intervention, children acquire a phonological letter-sound decoding strategy ("Sounding Out"), a word identification-by-analogy strategy ("Rhyming"), a strategy for separating affixes in multisyllabic words ("Peeling Off"), a strategy for seeking familiar parts of unfamiliar words ("I Spy"), and a strategy for attempting variable vowel pronunciations ("Vowel Alert"). Thus, the PHAST program allows evaluation of a multidimensional intervention that addresses phonological core deficits, orthographic and morphological components, and the more general strategy learning deficiencies associated with RD.

RAVE-O program (Retrieval, Automaticity, Vocabulary, Engagement with language, and Orthography; Wolf, Miller, & Donnelly, 2000). The RAVE-O program extends traditional emphases on phonological decoding processes to incorporate systematic emphases on four other targeted linguistic systems, critical to fluent comprehension. These include orthography, semantics, syntax, and morphology. The program directly addresses processes potentially underlying weaknesses in subtypes of children with RD who exhibit NSD and fluency problems (see Katzir, Kim, Wolf, Morris, & Lovett, 2008; Wolf & Bowers, 1999). Based on theoretical accounts of reading fluency and comprehension (Wolf & Katzir-Cohen, 2001), RAVE-O's basic premise is that the more the child knows about a word (i.e., phonemes, orthographic patterns, semantic meanings, syntactic uses, and morphological roots and affixes), the faster the word is decoded, retrieved, and comprehended. Children learn a group of core words each week that exemplify these critical linguistic principles and learn daily to make explicit connections across these linguistic systems. Core words are first introduced with their multiple meanings, and then each word's phoneme-level information is connected to its orthographic patterns. Children learn orthographic "chunks" in multiple and creative formats, including specifically designed computerized games that include varying rates of presentation (Wolf & Goodman, 1996).

A range of metacognitive strategies enables children to segment the most common orthographic and morphological units in words. For example, the strategy called "Ender Benders" helps children quickly recognize common morpheme endings that change (that is, "bend") the word's meaning. Daily dual instruction in vocabulary and explicit retrieval strategies serves to enhance semantic growth and the speed and accuracy of lexical retrieval, often problematic in children with RD. Fluent comprehension for connected text is addressed through metacognitive comprehension strategies implemented with a series of specially written RAVE-O Minute Stories, whose controlled vocabulary incorporates the phonemic and orthographic patterns, multiple meanings, and varied syntactic contexts of core words.

Results

Success of Randomization

Random assignment to intervention condition was designed to ensure equivalent mean baseline skills at the beginning of the intervention year. Multivariate analysis of variance did not indicate significant differences between the four groups at baseline in mean K-BIT or WISC-III IQ scores, or on standardized reading measures (WRMT, WRAT, GORT, TOWRE). Overall F tests for group differences were significant, however, for key measures of baseline reading-related skills (Word Blending, Elision, and Test of Word Finding). In all cases, PHAST group means were significantly higher than those for the PHAB + RAVE-O condition. However, differences for remediation condition become nonsignificant when analyses are run controlling for baseline phonological processing skills (Elision + Word Blending raw scores).

Data Analysis Strategy

Individual growth curve methodology was used to analyze changes on each reading measure and the correlates of these changes over the course of the 70-hour remediation and at 1-year follow-up. See Table 2 for unadjusted standard score results for all reading measures at all time points and Table 3 for the unadjusted raw score results for all outcome measures at all time points. Separate models were constructed to analyze growth and outcomes at the 70-hour posttest and at the 1-year follow-up. The 1-year follow-up models did not include the children participating in the MATH + CSS control group who crossed over following the 70 hours of remediation into one of the multicomponent reading remediation programs for ethical reasons, therefore affecting the overall sample size and total variance estimates and making direct comparisons with the 70-hour outcome results difficult. Post hoc analysis of the MATH + CSS group's response to the PHAB + RAVE-O or PHAST remediation program allowed for a within-study replication evaluating the effect of these two remediation programs.

Individual growth parameters were estimated using SAS- Proc Mixed and restricted maximum likelihood (REML) estimation procedures. In addition to time (0-hour baseline; 35-hour, 70-hour posttest; 1-year follow-up) being nested within individual children, individual children were nested within instructional group (groups of four children taught together) and intervention condition (four remediation pro- grams), with IQ (low, average), SES (low, average), and race (Black, Caucasian) as primary factors within the design. Age and initial levels (baseline) of phonological processing and rapid naming were used as covariates. Because of the complexity of this four-level model, the process and results of model building will be described only for prototypical reading outcome measures, with results from the most parsimonious final models summarized for the remaining variables.

All continuous predictors and covariate variables were grand-mean centered at either the 70-hour posttest or the 1-year follow-up depending on the analysis. Using this approach, the intercepts in these models represented the children's expected performance at the end of the remediation program or 1 year later. Specifically, the intercept is the CSS + Math (control) children's expected level—so that estimates for the intervention conditions represent raw score differences (increases) for the remediation program groups, as compared to the control children's mean. Changes over time, or slope, in these models represent mean incremental change in raw scores from one time point to the next, and an interaction with slope suggests different rates of change depending on the children's characteristics. Initial analysis focused on children's change over the course of the remediation programs. In general, various models evaluating linear growth with random or fixed intercepts or slopes were evaluated, along with curvilinear components to assess whether the outcome measure or academic skill plateaued over time. The model with random intercepts and growth (slope) terms will be typically presented unless otherwise noted. If significant variance was revealed in the individual intercepts and slopes in the unconditional model, then conditional model building evaluated the extent that outcomes, or rates of change, varied for instructional conditions or teaching group, as well as for factors such as IQ, SES, race, age, or a child's initial phonological processing or rapid naming abilities, and various interaction terms. Predictors/covariates with mean parameter values that did not differ from zero in these models were dropped in order to develop the most parsimonious models. Changes in model fit were also evaluated by examining chi-square differences in –2 residual log-likelihood (LL) estimates in nested models.

Table 2. Achievement Measures: Unadjusted Standard Score Means and Standard Deviations for Each Outcome Measure at Each Testing Point

Outcome Measure	Baseline		35 Hours		70 Hours		1 Yr Follow-Up	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
WRMT-R Word Attack								
PHAST	74.01	10.58	80.51	11.32	83.01	9.92	81.20	11.15
PHAB + RAVE-O	75.03	8.06	83.17	9.04	84.45	9.75	84.76	12.61
PHAB + CSS	72.40	9.64	77.06	11.03	77.88	12.02	75.84	15.83
MATH + CSS	73.09	11.39	74.00	13.94	73.07	15.22	78.21	14.29
Word Reading Efficiency Nonwords								
PHAST	81.76	5.56	89.59	9.48	86.27	7.34	85.65	10.69
PHAB + RAVE-O	80.28	3.19	85.61	6.85	88.12	7.59	88.14	11.05
PHAB + CSS	79.79	4.37	81.39	4.29	83.20	4.88	82.11	10.11
MATH + CSS	80.32	3.83	84.26	6.61	83.00	6.92	83.05	9.96
WRMT-R Word Identification								
PHAST	78.29	10.00	80.41	10.52	83.27	10.42	81.27	11.74
PHAB + RAVE-O	79.63	7.81	80.65	9.16	83.81	8.20	82.15	11.77
PHAB + CSS	77.86	10.53	78.99	11.00	80.48	11.31	75.93	14.96
MATH + CSS	78.40	10.55	78.09	12.05	77.69	13.46	77.46	14.42
WRAT-3 Reading								
PHAST	80.48	9.04	82.12	9.44	86.97	10.16	87.16	11.30
PHAB + RAVE-O	77.94	5.75	80.00	8.22	85.29	9.63	89.38	11.05
PHAB + CSS	77.93	8.72	79.12	8.04	81.32	8.81	82.16	12.96
MATH + CSS	78.82	9.05	78.75	9.90	77.85	11.27	84.21	12.54
Word Reading Efficiency Real Words								
PHAST	69.86	9.98	76.31	12.74	81.21	12.44	81.15	15.43
PHAB + RAVE-O	68.43	7.32	74.93	10.04	80.97	10.98	84.12	15.01
PHAB + CSS	68.32	9.47	72.94	11.10	77.77	12.40	76.76	16.73
MATH + CSS	67.69	6.75	72.41	9.96	75.65	12.09	76.44	15.73
WRMT-R Passage Comprehension								
PHAST	77.86	9.55	81.01	10.82	82.86	10.64	81.77	12.46
PHAB + RAVE-O	76.68	10.98	79.39	10.17	82.21	10.26	82.48	12.99
PHAB + CSS	76.43	12.02	78.80	10.60	79.61	11.24	78.18	15.52
MATH + CSS	77.04	11.91	75.90	14.32	76.32	14.64	78.35	13.46
GORT Oral Reading Quotient								
PHAST	74.22	8.62	—	—	77.38	9.98	79.69	14.60
PHAB + RAVE-O	75.33	7.63	—	—	81.73	10.51	80.37	13.74
PHAB + CSS	74.64	7.20	—	—	77.66	11.87	77.32	14.36
MATH + CSS	73.20	9.47	—	—	75.32	10.96	75.48	13.33

WRMT-R = *Woodcock Reading Mastery Test–Revised*; WRAT-3 = *Wide Range Achievement Test–3*; CSS = Classroom Survival Skills; PHAB = Phonological Analysis and Blending/Direct Instruction; RAVE-O = Retrieval, Automaticity, Vocabulary, Engagement with language, and Orthography; PHAST = Phonological and Strategy Training.

A final model will be reported that is the most parsimonious conditional model in which only primary factors of focus (IQ, SES, race) and significant fixed effect terms from the fully conditional model were retained. It should be noted that maximum likelihood (ML) estimation procedures were used during earlier model building but that final estimates were obtained using REML. The decision to include random terms for slope and intercept was determined a priori. Random terms for slope were dropped only for untenable models. Slightly different best reduced models did characterize different outcome measures; over- all, however, a highly consistent pattern of results was revealed. In general, after taking into account the influence of instructional condition and teaching group, these predictors reduced the intercept or outcome variance by another 10% to 25%. Contrasts focused on outcomes (intercepts), investigating whether the interventions resulted in different final levels of performance following remediation, or if the rates of change (slopes) or deceleration in growth (quadratic) varied as a function of treatment condition (intervention condition by slope interaction and intervention condition by quadratic interaction, respectively).

Table 3. Achievement Measures: Unadjusted Raw Score Means and Standard Deviations for Outcome Measures at Each Testing Point

	Baseline		35 Hours		70 Hours		1 Yr Follow-Up	
Outcome Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
WRMT-R Word Attack								
PHAST	3.26	4.09	8.46	6.04	11.68	6.67	15.28	7.66
PHAB + RAVE-O	1.74	2.24	8.22	5.03	11.65	6.20	16.95	8.70
PHAB + CSS	1.49	2.19	5.47	4.66	7.49	5.36	12.41	8.56
MATH + CSS	2.22	3.01	4.77	4.18	5.77	5.47	13.31	7.71
Word Reading Efficiency Nonwords								
PHAST	4.00	4.54	11.45	8.79	7.42	5.22	13.33	9.47
PHAB + RAVE-O	1.77	1.88	6.66	5.82	8.07	4.99	13.08	9.61
PHAB + CSS	1.34	1.73	3.50	2.97	4.98	3.81	9.10	8.39
MATH + CSS	2.40	2.80	5.96	4.92	4.14	3.94	9.93	6.85
WRMT-R Word Identification								
PHAST	21.51	13.49	30.47	14.37	38.51	12.41	48.22	11.20
PHAB + RAVE-O	16.65	11.01	27.25	11.50	35.70	10.34	47.32	11.12
PHAB + CSS	17.01	12.63	25.75	13.65	32.21	13.24	41.33	15.77
MATH + CSS	17.33	11.88	25.41	13.39	29.15	14.73	43.04	14.00
WRAT-3 Reading								
PHAST	20.36	3.51	22.25	3.89	25.03	4.16	27.30	4.35
PHAB + RAVE-O	18.43	2.53	21.19	3.15	23.84	3.42	27.72	3.98
PHAB + CSS	18.23	3.60	20.52	3.45	22.31	3.44	25.25	4.87
MATH + CSS	18.87	3.12	20.57	3.35	21.12	4.00	26.28	4.47
Word Reading Efficiency Real Words								
PHAST	14.79	10.80	21.15	12.76	25.80	12.31	36.89	13.18
PHAB + RAVE-O	10.41	7.65	16.50	9.59	22.49	10.61	36.08	12.51
PHAB + CSS	11.46	9.70	16.04	11.32	20.72	12.44	31.16	15.37
MATH + CSS	11.39	7.64	16.04	10.18	19.18	11.95	31.88	13.93
WRMT-R Passage Comprehension								
PHAST	10.16	6.97	15.89	8.78	19.68	8.12	25.61	8.52
PHAB + RAVE-O	7.59	6.30	13.01	7.17	17.74	7.61	25.33	9.01
PHAB + CSS	7.86	6.83	12.96	8.01	15.87	8.44	22.93	10.40
MATH + CSS	8.15	5.93	12.03	8.44	14.71	8.85	23.00	8.70
WRAT-3 Spelling								
PHAST	17.35	2.70	18.96	2.87	20.33	2.64	21.89	2.62
PHAB + RAVE-O	16.99	1.87	18.42	1.82	19.48	1.98	21.68	2.30
PHAB + CSS	16.69	2.67	17.90	2.41	19.10	2.85	20.80	3.11
MATH + CSS	16.66	2.60	18.07	2.63	18.37	3.13	21.15	2.88
WRAT-3 Arithmetic								
PHAST	18.07	3.43	19.90	2.94	21.15	3.69	25.14	4.39
PHAB + RAVE-O	17.48	3.17	19.71	2.59	20.76	2.81	23.62	3.38
PHAB + CSS	17.16	3.65	19.00	4.18	20.43	3.94	23.69	4.27
MATH + CSS	17.96	3.14	20.10	3.54	21.21	3.79	23.47	3.93

WRMT-R = *Woodcock Reading Mastery Test–Revised*; WRAT-3 = *Wide Range Achievement Test–3*; CSS = Classroom Survival Skills; PHAB = Phonological Analysis and Blending/Direct Instruction; RAVE-O = Retrieval, Automaticity, Vocabulary, Engagement with language, and Orthography; PHAST = Phonological and Strategy Training.

Three orthogonal contrasts were specified. The first contrast was the overall contrast between the reading intervention programs and the control condition (MATH + CSS)—that is, were the reading intervention programs beneficial? The second contrast compared the multidimensional interventions to the phonological-only control program (PHAST and PHAB + RAVE-O vs. PHAB + CSS)—that is, did the multiple-component models produce different results from the phonological control program? The third contrast was between the two multidimensional interventions (PHAST vs. PHAB + RAVE-O)—that is, did the two multiple-component interventions differ from each other? The 1-year follow-up models included only the three active reading interventions because the MATH + CSS group was not included. Two program contrasts were available in these models: the contrast between the multidimensional interventions and the phonological-only control program (PHAST and PHAB + RAVE-O vs. PHAB + CSS) and the contrast between the two multidimensional interventions (PHAST vs. PHAB + RAVE-O).

Nonword Reading Models (WRMT-R Word Attack; TOWRE NWRE)

Results of the first conditional model using Word Attack raw scores as the outcome measure at 70-hour posttest revealed significant fixed effects for intervention condition and for instructional group (both *p*s < .001) and a significant interaction between the linear growth term and instructional group ($p < .05$). Adding these fixed effects to the model decreased random variance around the intercept by 60%. These results indicate that outcomes at the end of intervention (the intercept) differed across intervention conditions, and both outcome and rate of change over time (the slope/linear growth) differed by teaching groups. Significant variability remained for the intercept and slope, however, indicating that additional predictors of these parameters were needed for a more complete model.

In the most parsimonious model (Table 4), 70-hour post- test outcome continued to be significantly different across intervention condition ($p < .001$). Outcome and rate of linear growth were also significantly ($p < .001$) affected by teaching group. Outcome and growth rates were not different for the factors of IQ, race, or SES. Outcome was significantly affected by both initial phonological processing and rapid naming ($p < .001$), but growth rate was only affected by initial rapid naming ($p < .05$). The inclusion of baseline measures of phonological processing and rapid naming reduced unexplained variance around the intercept by an additional 27%, as compared to the first conditional model with instructional condition and teaching group alone.

Individual outcome contrast comparisons using model- based means estimates revealed significant differences between the three reading programs and the MATH + CSS control condition and between the two multidimensional programs and the phonological control condition. PHAST and PHAB + RAVE-O were associated with superior out- comes to the PHAB + CSS condition. Post hoc comparisons indicated that the PHAB + CSS condition was associated with better outcomes on this measure than the MATH + CSS program. Significant differences in WRMT-R Word Attack 70-hour posttest scores were not found between the two multidimensional programs. Contrasts comparing differences in the rate of skill growth between treatment groups were nonsignificant.

At 1-year follow-up, the first conditional model again revealed significant outcome differences for intervention condition and teaching group ($p < .01$) and a significant interaction between intervention condition and rate of linear growth ($p < .01$). Although outcomes continued to be differentiated by intervention condition and teaching group 1 year later, continued change in long-term growth was still being affected by intervention condition.

In the most parsimonious 1-year follow-up model, long- term outcomes were still being affected by intervention condition ($p < .01$) and teaching groups ($p < .05$), and growth rates were different for the intervention conditions ($p < .01$). One-year outcomes showed significant effects for initial phonological processing and naming speed ($p < .01$), whereas growth showed a marginal interaction with initial naming speed ($.05 < p < .06$). The effects of baseline naming speed on skill growth were somewhat attenuated by the end of the follow-up year ($p = .06$). The addition of these base- line covariates reduced the amount of unexplained variance in the intercept by only 8.6% at the 1-year follow-up.

At 1-year follow-up, outcomes ($p < .01$) and rates of linear growth ($p < .05$) were significantly different between the two multidimensional programs and the phonological-only control condition. The contrast between the PHAST and PHAB + RAVE-O reflected a faster rate of skill growth for students in the PHAB + RAVE-O condition ($p < .03$) after 1 year and a marginally better mean outcome score ($.05 < p < .10$).

For the TOWRE Nonword Reading Efficiency (NWRE) measure (see Table 5), intervention condition ($p < .001$), teaching group ($p < .01$), and initial phonological processing skills and rapid naming speed, but not SES, IQ, or race, significantly affected outcome scores at 70-hour posttest. No other predictors contributed to posttest scores or skill growth on Nonword Reading Efficiency.

Students participating in one of the multidimensional reading interventions did not outperform math or phonological control students on Nonword Reading Efficiency; results for the

PHAST and PHAB + RAVE-O interventions were not significantly different. At the 1-year follow-up, students receiving the two multidimensional interventions out- performed the phonological control on the TOWRE NWRE. To be elaborated in a future study, baseline phonological processing and rapid naming skills remained strongly associated with outcome scores at follow-up as well.

Summary for Nonword Reading Models

At the end of 70 hours of instruction, students participating in the multidimensional intervention programs (PHAST, PHAB + RAVE-O) demonstrated significantly stronger word attack skills, and these differences continued to be evident on follow-up testing 1 year later. The phonological-only control program was significantly stronger than the math control program. Teaching groups affected both rates of skill growth (slope) and outcome scores (intercept) at the end of intervention, but these effects were attenuated by follow-up 1 year later. Significant curvilinear growth suggests that the rate of change, overall, slowed somewhat over time. Outcomes (at 70 hours or follow-up) were not differentially affected by demographic factors such as ethnicity, IQ, and SES, whereas baseline levels of phonological processing and rapid naming skills affected outcome both at the end of treatment and at the 1-year follow-up. Baseline rapid naming skills affected rate of nonword reading skill growth during the year of active intervention; these effects were only marginal when follow-up scores were included in the model. PHAST and PHAB + RAVE-O were associated with equivalent but superior outcomes and steeper growth over the course of the interventions, whereas at 1-year follow-up, PHAB + RAVE-O enjoyed an advantage in continued linear growth. It is noteworthy that children receiving the two multidimensional interventions maintained their gains and demonstrated superior, continued growth a year following the 70-hour interventions.

Table 4. Significant Fixed Effects in Best Reduced Model for WRMT-R Reading Measures

	Word Attack		Word ID		Passage Comp.		Basic Skills		Total Reading	
	70 Hrs	1 Yr Follow-Up	70 Hrs	1 Yr Follow-Up	70 Hrs	1 Yr Follow-Up	70 Hrs	1 Yr Follow-Up	70 Hrs	1 Yr Follow-Up
Fixed effects										
Intervention	31.08***	6.81**	19.74***	5.89**	9.81***		28.96***	7.38***	19.46***	4.01*
Group	2.73***	1.46*	2.54***	2.02***	2.11***	2.23***	2.10***	1.72**	2.13***	2.11***
Intervention × Slope		5.06**	7.87***	6.75**	2.17[a]	4.64**	3.10*	4.92**	3.84**	5.71**
Group × Slope	1.97***		2.64***	2.22***	2.37***	2.08***	2.10***	2.01***	2.20***	2.64***
SES					5.37*	5.35*	5.41*	2.78[a]	4.36*	5.19*
IQ					4.92*					
Ethnicity			2.89[a]	2.77*						2.83*
Age					5.96*	5.28*				
BL PHON	26.44***	27.46***	22.35***	15.50***	4.74*	8.05**	36.52***	23.75***	21.82***	15.01***
BL RAN letters	16.38***	6.99**	38.62***	15.54***	26.65***	16.34***	45.00***	20.46***	46.08***	24.97***
Linear growth	10.03**	12.84***	100.23***	102.59***	43.92***	80.38***	31.96***	12.00***	60.80***	64.56***
Curvilinear growth	16.83***	52.52***	24.28***	126.76***	8.21**	24.90***	90.08***	293.41***	49.79***	150.56***
Other interactions										
BL RAN × Intervention			4.15**				2.98*		3.45*	
BL RAN × Slope	5.00*	3.65[a]								
Ethnicity × Intervention			2.64[a]	3.27*					2.28[a]	3.19*
Curvilinear × Intervention			3.17*							
SES × Intervention				3.34*						
Intervention contrasts (outcome)										
Reading Conditions vs. MATH + CSS	68.15***		52.38***		24.48***		75.00***		51.92***	
Reading Conditions vs. PHAB + CSS	25.36***	10.27**	5.97**	10.58**	4.72*		11.76***	12.39***	4.29*	5.82*
PHAST vs. PHAB + RAVE-O		3.16[a]								
Intervention contrasts (slope)										
Multicomponent vs. MATH + CSS			17.87***						7.06**	
Multicomponent vs. PHAB + CSS		4.81*	4.86*	7.63**	3.85[a]		6.71*	4.57*	4.03*	
PHAST vs. PHAB + RAVE-O		5.16*		5.74*		8.68**		5.16*		8.93**

Only *F* values with $p < .10$ are reported. SES = socioeconomic status; BL = baseline scores; WRMT-R = *Woodcock Reading Mastery Test–Revised*; CSS = Classroom Survival Skills; Reading Conditions = PHAST, PHAB + RAVE-O, PHAB + CSS; Multicomponent = PHAST, PHAB + RAVE-O; Group = teaching group; PHON = Phonology; RAN = Rapid Automatized Naming.
[a]$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

Table 5. Significant Fixed Effects in Best Reduced Model

	WRAT Reading		Word Reading Efficiency		Nonword Reading Efficiency		WRAT Spelling		WRAT Arithmetic	
	70 Hrs	1Yr Follow-Up	70 Hrs	1Yr Follow-Up	70 Hrs	1Yr Follow-Up	70 Hrs	1Yr Follow-Up	70 Hrs	1Yr Follow-Up
Fixed effects										
Intervention	22.01***	6.12**	9.49***		11.70***	3.87*	17.05***	3.56*		
Group	1.53*	1.96***	2.56***	1.70**	2.11***		2.95***	2.64***	1.46*	
Intervention × Slope	7.04***	6.49**	3.12*	4.51**		4.34*	4.70**			
Group × Slope		1.84**	2.08***	1.45*			1.72**	1.79**	1.52*	
SES	5.79*		6.01*				5.68*	5.18*	9.31**	
IQ							4.18*			
Ethnicity										
Age									10.36**	
BL PHON	17.65***	19.06***	10.89***	6.87**	12.19***	15.45***	25.56***	12.89***	11.87***	
BL RAN letters	36.69**	26.19***	37.42***	26.06***	9.11**	9.18**	36.01***	23.46***	12.76***	
Linear growth	58.56***		101.00***	362.45***	3.40[a]	42.37***	12.65***	42.88***	8.64**	
Curvilinear growth			6.38**				11.12***	15.58***	10.23**	
Other interactions										
BL PHON × Slope	2.89[a]									
Quadratic × Intervention	2.85*						2.95*			
Ethnicity × Intervention			2.72*	3.36*			3.15*	2.98[a]	3.85**	
BL RAN × Slope			15.27***	10.61***		4.22**				
IQ × Intervention							2.58*		2.65*	
BL RAN × Intervention							4.52**			
Intervention contrasts (outcome)										
Reading Conditions vs. MATH + CSS	53.03***		25.02***				44.97***			
Multicomponent vs. PHAB + CSS	9.98**	10.74***		3.91*		7.19**		6.52*		
PHAST vs. PHAB + RAVE-O	3.27[a]						3.29[a]			
Intervention contrasts (slope)										
Reading Conditions vs. MATH + CSS	15.77***		7.29**				13.73***			
Multicomponent vs. PHAB + CSS	4.28*	3.93*		4.03*		4.95*				
PHAST vs. PHAB + RAVE-O		8.76**		4.94*		4.12*				

Only *F* values with $p < .10$ are reported. SES = socioeconomic status; BL = baseline scores; WRAT = *Wide Range Achievement Test*; CSS = Classroom Survival Skills; Reading Conditions = PHAST, PHAB + RAVE-O, PHAB + CSS; Multicomponent = PHAST, PHAB + RAVE-O; Group = teaching group; PHON = Phonology; RAN = Rapid Automatized Naming.
[a]$p < .10$. $*p < .05$. $**p < .01$. $***p < .0$

Word Identification Models (WRMT-R Word Identification, TOWRE WRE, WRAT Reading)

Significant differences among intervention conditions and teaching groups were also found for Word Identification raw scores (see Table 4) at the end of 70 hours ($p < .001$). Curvilinear growth was also significant ($p < .001$), suggesting a change in growth rate over the intervention time. Mean outcome scores and growth rates did not vary systematically as a function of IQ, SES, or race. Initial phonological skills and rapid naming speed significantly affected outcome scores ($p < .001$) but not rate of skill growth. The interaction between initial naming speed and intervention condition was also significant ($p < .01$), indicating that the effect of initial naming speed varied systematically as a function of intervention condition.

Comparisons of adjusted group means indicated higher posttest means and stronger rates of skill growth for students receiving one of the three reading interventions in comparison to the MATH + CSS control condition, and for the PHAST and PHAB + RAVE-O programs relative to the PHAB + CSS control program. Significant differences in mean outcome score or growth rate between the two multidimensional reading interventions were not found.

At 1-year follow-up, significant differences in outcome score and growth rate were still evident for intervention conditions ($p < .01$) and teaching groups ($p < .001$). Initial phonological skill and rapid naming speed continued to significantly ($p < .001$) predict outcome scores as well.

Students receiving multidimensional interventions continued to demonstrate higher outcome scores ($p < .01$) and faster rates of skill growth ($p < .01$) than students receiving the phonological-only control intervention. The contrast between PHAST and the PHAB + RAVE-O programs was significant for linear slope ($p < .05$) a change from the intervention period results.

Intervention condition (all ps < .001), teaching group (all ps < .05), and initial phonological processing skills and rapid naming speed significantly affected outcome scores on both the TOWRE Word Reading Efficiency and the WRAT Reading measures at 70-hours posttest. Outcome scores on these measures were also significantly associated with SES but did not interact with instructional condition. Linear growth varied systematically as a function of intervention condition also for both measures, and as a function of teaching group on TOWRE Word Reading Efficiency.

Students participating in one of the three reading interventions outperformed math control students on these reading measures. Students in the multidimensional interventions outperformed the phonological control students on only the WRAT Reading subtest, and scores for the PHAST and PHAB + RAVE-O interventions were not significantly different from each other on any measure. Growth rate differences between the reading intervention and the math control groups were demonstrated on both WRAT Reading and the TOWRE Word Reading Efficiency measures, although students in the multidimensional reading interventions demonstrated faster skill growth than students in the phonological control condition on only the WRAT Reading.

At the 1-year follow-up, significant differences in out- come scores across intervention conditions persisted for WRAT Reading. Students receiving one of the two multidimensional interventions (PHAB + RAVE-O) outperformed phonological controls on both measures at the 1-year follow- up, demonstrating a faster rate of growth on the WRAT Reading and TOWRE WRE measures over the intervention and follow-up periods. All posttest differences in adjusted mean scores for the two multidimensional intervention groups were attenuated on follow-up assessment, although growth rate on WRAT Reading and TOWRE WRE still appeared stronger for students receiving PHAB + RAVE-O than for PHAST students. Baseline phonological processing and rapid naming skills remained strongly associated with outcome scores at follow-up as well. Teaching group effects on out- come scores were still evident on both measures, but SES was not associated with either performance on follow-up.

WRMT-R Passage Comprehension Models

Using Passage Comprehension raw score as the outcome measure at 70-hours posttest (see Table 3), significant fixed effects for intervention condition and teaching group were found for all models (see Table 4), with teaching group also predicting linear growth rate (p < .001). Outcome scores for the PHAB + RAVE-O and PHAST interventions were com- parable, and both were significantly higher than the mean out- come score for students receiving the phonological control program (p < .05), which was better than the math control program. Students participating in any reading intervention program attained a higher comprehension skill level than students in the math control condition (p < .001). Curvilinear growth was also significant (p < .01), suggesting a changing growth rate over the intervention time period. Unlike the preceding measures, two of the demographic factors (SES, IQ) predicted outcomes (p < .05) but did not interact with treatment condition or predict linear growth. Outcomes were also significantly affected by initial level of phonological skill (p <.05) and rapid naming speed (p < .001). Rate of skill growth over the intervention year was not significantly affected by intervention condition or any of the other covariates.

At 1-year follow-up, however, the effects of intervention condition on comprehension skill levels were somewhat attenuated. The association between intervention condition and outcome score was non-significant, although rate of skill growth was still significantly affected by intervention condition (p < .01). The only significant contrast was a stronger rate of growth over the 2-year period for children in the PHAB + RAVE-O program relative to that for the PHAST program. Outcome score was still affected by teaching group (p < .001), SES (p < .05), and baseline phonological skills (p < .01) and naming speed (p < .001), however, and the rate of skill growth continued to vary significantly across individual teaching groups (p < .001). None of these interacted with intervention condition or predicted growth at 1-year follow-up. The model-adjusted means estimates are presented for Passage Comprehension in Figure 2.

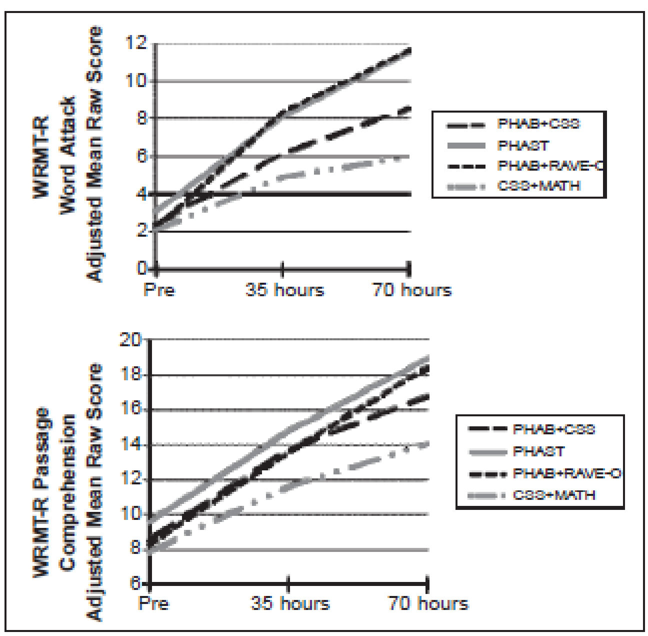

Figure 2. *Woodcock Reading Mastery Test–Revised* (WRMT-R) Word Attack and Passage Comprehension adjusted raw score by remediation condition over time

Spelling and Arithmetic Skills

Intervention condition ($p < .001$), teaching group, and initial phonological processing skill and rapid naming speed significantly affected outcome scores (see Table 5) on the WRAT Spelling measure at 70-hour posttest. Outcome scores on WRAT Spelling were also significantly associated with SES but did not interact with instructional condition. Linear growth varied systematically as a function of intervention condition and as a function of teaching group (see Table 5).

Teaching group, SES, and initial phonological processing and rapid naming speed were significantly related to posttest WRAT Arithmetic scores. There were no significant contrasts between the intervention groups in either rate of skill growth or 70-hour posttest score on WRAT Arithmetic.

Standardized Text Reading Measure

The *Gray Oral Reading Test* is reported separately because although it has a composite score (Oral Reading Quotient [ORQ]), separate scores are also available for assessment of the accuracy and rate with which connected texts are read aloud, and there is a separate score for Comprehension (see Table 6). The GORT data are also described separately because the test was not administered at the 35-hour testing point, and only 75% of the total sample of 279 participants provided pretest, posttest, and follow-up data on the GORT. The models reported below are based on an imbalanced cell distribution; older children with a higher proportion of low SES participants and a lower proportion of African American children contributed GORT data from the PHAST program relative to the PHAB + RAVE-O program. The best reduced models for the ORQ and for the three subcomponents are summarized in Table 7, as well as the associated contrasts at both 70-hour posttest and 1-year follow-up outcomes.

In the most parsimonious model, 70-hour posttest and linear growth continues to be significant for intervention condition on the ORQ and on all three component measures (all ps < .01). Teaching group also predicted outcome on all measures but was predictive of slope on only two measures (Accuracy and Rate). As with the other standardized mea- sures, initial levels of letter naming speed were a significant predictor of 70-hour posttest outcomes on all four GORT scores and also significantly predicted the amount of linear growth on the Accuracy and Rate component scores. Although IQ was related to GORT Comprehension outcomes at 70-hour posttest, IQ did not predict outcomes or slopes on the other GORT scores. Similarly, there were no significant fixed SES or race effects in these models, although SES did interact with intervention condition for Accuracy and Reading Rate scores, but not for ORQ or Comprehension.

A number of significant contrasts were revealed in these four sets of models. A significant difference was revealed between the active reading interventions and the CSS + MATH control condition for 70-hour posttest outcomes on all four GORT scores (ps < .001) and for linear growth on the Accuracy and Rate component scores (ps < .01).

Table 6. GORT-3 Raw Scores and Standardized Oral Reading Quotient (ORQ) at Each Testing Point

GORT-3 Score	Baseline		70 Hours		1Yr Follow-Up	
	M	*SD*	*M*	*SD*	*M*	*SD*
Accuracy						
PHAST	1.02	2.20	3.88	4.68	7.51	6.67
PHAB + RAVE-O	0.36	1.12	3.95	4.93	8.12	6.88
PHAB + CSS	0.15	0.47	2.54	3.94	7.02	7.17
MATH + CSS	0.11	0.41	2.31	3.50	6.12	6.36
Rate						
PHAST	0.44	0.70	2.37	3.03	4.23	4.32
PHAB + RAVE-O	0.26	0.58	1.77	2.10	4.75	4.85
PHAB + CSS	0.41	0.91	1.33	2.01	4.03	4.35
MATH + CSS	0.19	0.47	0.91	1.37	3.93	4.07
Comprehension						
PHAST	5.15	4.93	9.77	6.58	15.18	8.60
PHAB + RAVE-O	5.22	4.67	11.56	6.23	14.67	7.51
PHAB + CSS	5.02	4.27	9.66	6.38	13.51	8.39
MATH + CSS	4.46	4.75	8.04	6.44	12.15	7.93
ORQ						
PHAST	74.22	8.62	77.38	9.98	79.69	14.60
PHAB + RAVE-O	75.33	7.63	81.73	10.51	80.37	13.74
PHAB + CSS	74.64	7.20	77.66	11.87	77.32	14.36
MATH + CSS	73.20	9.47	75.32	10.96	75.48	13.33

GORT-3 = *Gray Oral Reading Test–III*; CSS = Classroom Survival Skills; PHAB = Phonological Analysis and Blending/Direct Instruction; RAVE-O = Retrieval, Automaticity, Vocabulary, Engagement with language, and Orthography; PHAST = Phonological and Strategy Training..

Contrasts comparing the two multidimensional interventions to the phonological-only control program were found on Accuracy and Rate for outcome and were also highly significant for linear growth on the Rate measure ($p < .001$) and marginally significant for Accuracy growth ($p = .06$). This contrast for ORQ was also marginal for outcome ($.05 < p < .07$) but significant for slope ($p < .05$). The third contrast, between PHAST and PHAB + RAVE-O, was significant for ORQ outcome ($p < .05$) and linear growth ($p < .01$) and for Comprehension linear growth ($p < .05$), whereas outcome was borderline ($.05 < p < .06$). The pattern of results from these models for the 70-hour posttest is presented in Figure 3. Superior outcomes and steeper learning curves were found for the two multidimensional interventions, with this advantage seen particularly on the Rate score. Superior growth on the ORQ and the Comprehension scores was found for the PHAB + RAVE-O intervention relative to the PHAST pro- gram, with better ORQ outcomes and a marginally superior outcome on the Comprehension score also associated with the PHAB + RAVE-O program.

One-year follow-up models revealed a significant effect for intervention condition in predicting outcomes on the composite ORQ ($p < .05$). Intervention condition also predicted continued growth over the follow-up year for the ORQ and the Rate scores ($p < .05$). Teaching group was highly predictive of long-term follow-up outcomes and linear growth on all four GORT scores ($p < .05$). Initial letter naming speed again predicted all four GORT measures at 1-year follow-up (*p*s $< .01$) and continued growth over time on the Accuracy and Rate scores (*p*s $< .001$). Contrasts at 1-year follow-up on the ORQ and the Comprehension score demonstrated significant, superior outcomes for the two multidimensional programs. There were no differences between the PHAST and the PHAB + RAVE-O programs in terms of follow-up outcome or growth on any of the GORT measures.

Discussion

As argued in Snow and Juel (2005), comparative intervention studies should not be considered a "horse race." Rather, we conceptualize this study as one step toward realizing Lyon's (1999) goal for reading intervention research: understanding what works best in which pro- grams for what students under which conditions. In this context, this design allows us to evaluate the relative benefits of different linguistic and metacognitive emphases in interventions for young struggling readers. The issue of whether there exist meaningful subtype × treatment inter- actions in these data will be the focus of a future report, as will additional outcome data on word identification learning, vocabulary (Barzillai, Wolf, Lovett, & Morris, 2010), and other fluency measures.

Table 7. Significant Fixed Effects in Best Reduced GORT Models

	ORQ		Accuracy		Rate		Comprehension	
	70 Hrs	1Yr Follow-Up	70 Hrs	1Yr Follow-Up	70 Hrs	1Yr Follow-Up	70 Hrs	1Yr Follow-Up
Fixed effects								
Intervention	6.93***	3.90*	8.64***		10.39***		4.93**	
Group	2.43***	2.68***	4.90***	3.56***	5.17***	4.20***	1.87**	2.86***
Intervention × Slope	6.64***	3.20*	3.77**	2.67[a]	9.14***	4.38***	3.99**	
Group × Slope		1.63*	2.10***	1.90**	3.48***	2.66***		1.47*
SES								
IQ	3.46[a]	4.05*					4.13*	
Ethnicity								
Age	37.83***							
BL PHON				5.65*				
BL RAN letters	13.99***	8.92**	13.61***	31.65***	14.34***	40.40***	9.38**	7.25**
Linear growth	38.10***		130.37***	42.63***	183.62***	63.24***	134.03***	22.86***
Curvilinear growth		5.04**		3.27[a]		11.55***		
Other interactions								
Intervention × SES			3.70**		3.72*	3.55*		
Intervention × IQ			3.83**		2.59[a]			
BL RAN × Slope			4.57*	19.13***	4.39*	26.98***		
Intervention contrasts (outcome)								
Reading Conditions vs. MATH + CSS	13.85***		16.32***		23.06***		10.25***	
Multicomponent vs. PHAB + CSS	3.47[a]	5.85*	7.87**		8.31**			3.97*
PHAST vs. PHAB + RAVE-O	4.18*						3.66[a]	
Intervention contrasts (slope)								
Reading Conditions vs. MATH + CSS			6.15**		13.00***			
Multicomponent vs. PHAB + CSS	4.95*		3.61[a]		14.56***			
PHAST vs. PHAB + RAVE-O	8.91**						5.26*	

Only F values with $p < .10$ are reported. GORT = *Gray Oral Reading Test*; ORQ = Oral Reading Quotient (standard score); SES = socioeconomic status; BL = baseline scores; CSS = Classroom Survival Skills; Reading Conditions = PHAST, PHAB + RAVE-O, PHAB + CSS; Multicomponent = PHAST, PHAB + RAVE-O; Group = teaching group; PHON = Phonology; RAN = Rapid Automatized Naming.
[a]$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

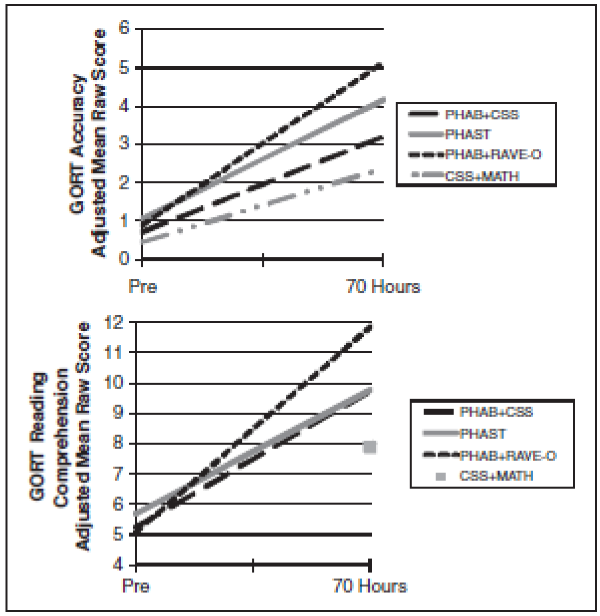

Figure 3. *Gray Oral Reading Test–III* (GORT) Text Reading Accuracy and Passage Comprehension adjusted raw by remediation condition over time (only two time points)

The present interventions are conceptualized on a continuum, including small group programming using classroom survival skills and math interventions (CSS + MATH, an alternate intervention control group), to intensive phonologically based reading intervention coupled with classroom survival skills training (PHAB + CSS, the phonological-only control), to two multiple-component reading interventions that include the same intensive phonologically based reading intervention coupled with other intervention approaches (PHAST and PHAB + RAVE-O).

The phonological-only control condition in this design can be questioned on the grounds of not equating the amount of reading instruction offered in the PHAB + CSS program versus the two multidimensional reading interventions. A deliberate decision was made to hold the amount of phono-logical intervention constant among the three active reading interventions. In this way, the present design would allow an evaluation of the specific contributions of the extra- phonological emphases present in PHAB + RAVE-O and PHAST. Previous data from our Toronto site provided a 70-hour phonological-only comparison.

Lovett, Lacerenza, Borden, et al. (2000) reported results from a crossover design comparing a double dose of PHAB/ DI with the PHAB/DI + WIST program, the precursor to the PHAST program. This study included random assignment of small groups of disabled readers to one of five conditions: PHAB/DI → WIST, WIST → PHAB/DI, PHAB/DI × 2, WIST × 2, or CSS + MATH. Each instructional sequence provided 70 hours of intervention. Superior outcomes and steeper learning curves were observed following both combined interventions, regardless of sequence. Although both the double PHAB/DI and double WIST programs yielded positive outcomes on standardized measures of word identification, decoding, and passage comprehension, greater gains were realized by children receiving both phonological and strategy-based interventions. This previous design pro- vided a 70-hour treatment intervention with the same teacher–student ratio as the present study and therefore is highly relevant to interpretation of the present results.

The multiple-component programs used in this design shared three component emphases (phonology Orthography, and morphology) and the use of metacognitive strategies but differed in specific instructional emphases on word identification and on semantic development. The PHAST program integrates phonologically and strategy-based approaches to word identification learning, focusing extra instructional attention on (a) subsyllabic orthographic patterns; (b) morphological segments; (c) variant vowel pronunciations; and (d) a program of "metacognitive decoding" in the form of direct teaching of five word identification strategies. The PHAB + RAVE-O program adds to these same phonological, orthographic, and morphological components more emphases on linguistic components involved in word knowledge, specifically, (a) semantic depth, semantic flexibility, and lexical retrieval; (b) syntactic knowledge; and (c) morphosyntactic knowledge (often conveyed using metacognitive strategies). The ultimate goals of both multiple-component programs were shared—to improve basic reading skills, to facilitate the development of independent reading, and to lay the groundwork for fluent reading comprehension. Both programs included some shared and some different emphases in intervention, and both programs provided explicit and different motivational components. Including two alternate multidimensional approaches in the present design allowed us to investigate more systematically questions concerning the contribution of different language processes to the development of word identification and reading comprehension skills.

Semantic development. The relationship between semantic growth (vocabulary) and reading comprehension is well documented (Beck & McKeown, 2006; Beck, McKeown, & Kucan, 2002; Biemiller, 1999, 2001; Moats, 2001; Stanovich, 1985); the contribution of individual differences in vocabulary knowledge to accuracy and fluency in word recognition, however, is not well understood. As Juel (2005) noted, how- ever, a critical problem in most phonics-based programming is the misguided assumption that struggling readers, particularly those with different dialects, different languages spoken in the home, and/or impoverished language backgrounds, know the meaning of the words they are trying to decode. There exists a growing body of knowledge about the contribution of different forms of linguistic knowledge to word recognition. Yates, Locker, and Simpson (2003) demonstrated that enhanced semantic knowledge improved the speed of lexical retrieval. Specifically, they found that the richer the "semantic neighborhood" for a given word (i.e., the more associated words, meanings, etc.), the faster the representation of that word was retrieved on lexical decision tasks. Wydell, Vuorinen, Helenius, and Salmelin (2003) found, in a Magnetoencephalographic (MEG) study, that processes recruited in the superior temporal cortex for reading words were significantly faster for known words than for unknown or pseudowords; this cortical region sub- serves both phonological and semantic processing. Increased semantic knowledge for a given word shortened the time that word was processed both phonologically and semantically.

The multilayered semantic emphases in the RAVE-O program allowed us to investigate these contributions to word identification, word attack, and reading comprehension. Explicit instruction in vocabulary, semantic flexibility, and lexical retrieval strategies were components unique to RAVE-O. The approach draws on the premise that more in- depth knowledge of words (e.g., multiple meanings, semantic neighborhood associates, morphosyntactic elements) facilitates both accuracy and fluency in word recognition, oral reading fluency, and the comprehension of connected text. The present test battery allowed comparison of speed and accuracy in reading and thus permitted a first step toward examining this premise in an intervention context.

As expected, the active reading interventions proved superior to the control group on all standardized reading and spelling measures at 70 hours, with the exception of the Nonword Reading Efficiency measure. The two multiple-component programs demonstrated superior 70-hour outcomes to the phonological control group on the majority of standardized measures of word identification. Significant contrasts were revealed between the multiple-component and phonological- only interventions for posttest outcomes on all WRMT-R measures, WRAT-3 Reading, and Accuracy and Rate scores on the GORT. The PHAST and PHAB + RAVE-O programs were associated with superior outcomes of equivalent magnitude on all standardized measures except the GORT ORQ. On the GORT ORQ composite of fluency plus comprehension, superior outcomes and greater growth during intervention were revealed for children in the PHAB + RAVE-O condition. These latter results may reflect the additional contribution of semantic components to connected text reading.

What is more striking from the present analyses is the extent to which the two multiple-component programs demonstrated superior outcomes and continued growth 1 full year after the interventions ended. At the 1-year follow-up, children who had received either the PHAST or PHAB + RAVE-O programs continued to show a significant advantage relative to the PHAB + CSS participants on almost all tests of reading and spelling skill, including spelling and word efficiency measures (WRAT-3

Spelling and WRE), which had failed to show this advantage at immediate posttest. The superiority of the PHAST and PHAB + RAVE-O programs for these disabled readers is well illustrated here and replicated across multiple measures of reading and spelling achievement 1 year after the interventions ended.

PHAB + RAVE-O devoted daily time to direct decoding skills but spent equal time building up semantic, orthographic, and morphosyntactic knowledge. PHAST allocated equivalent time to decoding but supplemented it with explicit word identification strategies and training on other aspects of orthographic and morphological structure. The immediate and maintained success of both programs suggests that different pathways exist to successful reading remediation.

Semantic instruction in PHAB + RAVE-O contributed to vocabulary growth and improved semantic flexibility. Children in the PHAB + RAVE-O group demonstrated superior vocabulary outcomes, both on instructed words on the RAVE multiple definition task (Barzillai et al., 2010) and in providing multiple meanings to new vocabulary items on the standardized WORD-R. As testimony to the overall relationship between word identification and word knowledge, both multidimensional programs were superior to the PHAB + CSS program, which was better than the control program on trained words. Only the PHAB + RAVE-O intervention group demonstrated superiority on the standardized vocabulary measure, both at 70 hours and at 1-year follow-up.

Morphology. An often-neglected dimension of language concerns morphology and its contribution to word identification, vocabulary, syntax, and comprehension development (Berninger, Abbott, Billingsley, & Nagy, 2001; Carlisle & Rice, 2002; Henry, 2003; Moats, 2001, 2004). Both multidimensional programs incorporate considerable emphases on strategies for the quick recognition of morphemes and for understanding how they change the meaning of the word. The term Ender Benders was used as a mnemonic strategy in the PHAB + RAVE-O program to illustrate how different morphemes like *ed*, *er*, and *s* can change a noun to a verb (e.g., *jam* to *jammed*), an action to a person who performs that action (e.g., *move* to *mover*), and a singular word to a plural (e.g., *ram* to *rams*). The metacognitive term Ender Bender itself incorporates the principle of morphological transformation.

In PHAST, a somewhat different approach to morphology instruction is employed. One of the five PHAST strategies, Peeling Off, involves recognition and segmentation of morphemes in multisyllabic word identification. Children are taught the prefixes and suffixes of English, beginning with the most frequently occurring affixes. As affixes are introduced, prefixes are mounted as green leaves and suffixes as orange leaves on a "peeling off" tree.

Orthography. Another shared emphasis by the multidimensional programs is a focus on subsyllabic segments and common orthographic patterns. PHAB + RAVE-O emphasizes rapid recognition and practice of the most frequent orthographic patterns in English through a series of activities and computerized games called Speed Wizards (Wolf & Goodman, 1996) that allow for repeated practice and multiple exposures to these patterns.

Similarly, PHAST integrates work on different levels of subsyllabic segmentation, teaching the phonological Sounding Out strategy with its emphasis on the smallest subsyllabic units, and the Rhyming strategy with its focus on onset-rime segmentation. To learn the Rhyming strategy, children acquire over time 120 keywords representing the 120 most frequently occurring spelling patterns in English. These keywords are from the list developed for the original Benchmark School Word Identification/Vocabulary Development Program (Gaskins et al., 1986).

It can be speculated that this attention to morphology and orthography in the multidimensional programs, PHAST and PHAB + RAVE-O, facilitated the development not only of word recognition but also of spelling knowledge and resulted in superior spelling achievement for both programs at 1-year follow-up.

Fluent comprehension. A final question is whether the vocabulary, orthographic, syntactic, and morphological emphases of PHAB + RAVE-O and the orthographic, morphological, and metacognitive emphases of PHAST were associated with advantages in oral reading fluency and reading comprehension greater than that associated with the PHAB + CSS program. Consistent with recent work on multiple pathways to fluency (Katzir et al., 2008; Wolf & Katzir-Cohen, 2001), both multidimensional programs proved superior to the phonological control program on measures of oral reading fluency, text reading accuracy (GORT subscores), and passage comprehension (WRMT-R) at 70 hours and on GORT ORQ and Comprehension at 1-year follow-up.

Whether the added vocabulary and syntactic emphases of PHAB + RAVE-O resulted in greater comprehension gains than the metacognitive and strategy instruction focus of PHAST is not resolved by these data. The GORT Reading Quotient represents the best index of fluency and comprehension in the present battery. The PHAB + RAVE-O pro- gram demonstrated superior outcomes and greater linear growth on the ORQ at 70 hours, and a trend favoring PHAB + RAVE-O was found on the Comprehension subscore at posttest. These findings demonstrate the efficacy of PHAB + RAVE-O in facilitating fluent reading comprehension following only 70 hours of intervention.

These two treatment-specific findings are qualified by two other findings. Both multidimensional programs were associated with equivalent outcomes on WRMT-R Passage Comprehension at 70 hours and at 1-year testing and achieved equivalent long-term outcomes on the GORT Oral Reading Quotient at follow-up. The WRMT-R Passage Comprehension test employs a "cloze" procedure to measure comprehension, where the child must retrieve a specific one-word answer. Given the lexical retrieval issues identified in previous research on RD (German, 1992; Wolf & Goodglass, 1986; Wolf & Obregon, 1992), the cloze procedure may not be an optimal method for evaluating comprehension in readers with RD. It is certainly confounded with decoding skills. Appropriate measures of reading comprehension for struggling readers are scarce (Keenan, Betjemann, & Olson, 2008). It is not clear whether demonstrated gains in vocabulary for PHAB + RAVE-O children did not improve performance beyond PHAST on this test because of test demands on retrieval skills or whether it is simply that they did not translate into relatively greater comprehension gains than PHAST, because of the extra linguistic and metacognitive emphases of PHAST, which also supported improved comprehension.

Other interpretations may be considered. First, there are alternate pathways to successful comprehension, and both PHAST and PHAB + RAVE-O demonstrate two effective pathways to improved reading comprehension for young impaired readers. Results at 1-year follow-up are equally strong for both multidimensional programs on reading comprehension, and both programs maintain clear superiority over other groups on the ORQ and the GORT Comprehension subscore. PHAB + RAVE-O has a significant advantage over PHAST immediately following intervention, however, this is not maintained on the GORT Reading Quotient at follow-up testing. Two possible interpretations are that the progress made by the PHAST children allows them to catch up with the progress shown earlier by the PHAB + RAVE-O group, perhaps because growth by both groups on word attack and word identification skills resulted in more reading experience over the following year. Another possibility is compatible with one of the theoretical premises of the RAVE-O program: Fluent comprehension is dependent on evolving word knowledge, particularly semantic and morphosyntactic knowledge, as reading skills become more sophisticated in older grades. When there are no active emphases on these skills (as in the follow-up year), the general gains are maintained, but the advantage seen earlier from vocabulary and other linguistic emphases on word knowledge dissipates.

Word identification speed and reading rate. All three reading interventions were associated with significant improvement in word reading efficiency on the TOWRE, demonstrating superior outcomes at 70 hours and greater growth during intervention than for the control group. The two multiple- component interventions were superior at 1-year follow-up on both Word and Nonword Reading Efficiency measures to the phonological control condition and demonstrated greater continued growth. PHAB + RAVE-O children demonstrated an advantage over children in the PHAST program in the rate of linear growth over the follow-up period, although actual outcomes for PHAB +

RAVE-O and PHAST were equivalent. Finally, the PHAST children demonstrated significantly faster keyword identification immediately after their program ended but not at follow-up. The only measure of text reading rate was provided by the GORT: On the Reading Rate score, PHAB + RAVE-O and PHAST children demonstrated significant improvement in rate relative to the phonological control condition on 70-hour outcomes and linear growth over the course of the intervention. No effects were observed at 1-year follow-up.

While both multiple-component interventions were associated with improvements in specific dimensions of reading rate at 70 hours, and some at long-term follow-up, treatment- related improvements in word identification processes were easier to measure than growth in specific aspects of reading comprehension and reading fluency.

The importance of explicit strategy instruction. The PHAST and the PHAB + RAVE-O programs both include explicit strategy instruction as part of the intervention, an emphasis supported by previous research (Lovett, Lacerenza, Borden, et al., 2000; Swanson et al., 1999). Explicit strategy training and metacognitive monitoring are necessary to address and prevent generalization failures during remediation, and they provide an important component of effective remediation for RD in the acquisition of both decoding accuracy and reading comprehension skills (Lovett, Lacerenza, Borden, et al., 2000; Mason, 2004; Vaughn et al., 2000).

Young impaired readers in PHAST learned to use a Game Plan to self-direct their selection, implementation, and monitoring of the five PHAST strategies. Struggling readers acquire the prerequisite skills they need for strategy implementation and a self-talk dialogue structure that allows them to become competent independent readers. Subsequent development of the PHAST Comprehension Track in our current research classrooms (Lovett et al., 2005) supplements the word identification strategies with a set of complementary text comprehension strategies. The goal throughout is to equip the children with the skills and strategies they need to become fluent and enthusiastic readers.

In the PHAB + RAVE-O program, children learn an assortment of metacognitive word tricks to help them quickly recognize and segment syllable patterns, common affixes, and their associated meanings. The "Sam Spade" strategies target accuracy in lexical retrieval, and three specific comprehension strategies aid prediction, comprehension monitoring, and integration of independent thinking about the text.

Both multiple-component programs were successful in demonstrating generalized gains in reading skill that were evident in decoding and word recognition, text reading accuracy, reading rate, and reading comprehension. It might be argued that part of the superiority of both interventions relative to the phonological control condition is directly due to the inclusion of strategy training and metacognitive components in their instructional designs.

Cognitive-affective and motivational elements of effective intervention. There are many aspects of the multiple-component interventions to which their efficacy can be attributed. One of the most important may be that different explicit therapeutic elements are woven into the instructional content of lessons in both programs. Integral to the success of the PHAST and the PHAB + RAVE-O programs are methods to enhance self-esteem around the reading task and to foster engagement with language and print.

The PHAST program deliberately undertakes the retraining of unproductive attributions and misguided beliefs about effort and achievement, attempting to build perceptions of self-efficacy around the reading task and other learning challenges. Specific attributional retraining is woven into the strategy dialogue structure in every PHAST lesson for- mat. Children learn that success on a task is a matter of whether the appropriate strategy was selected and applied and whether they were flexible and persisted when first attempts were unsuccessful. Another therapeutic component of the PHAST program involves its use of low-frequency complex multisyllabic words as "challenge" words on which the children practice their strategies. Children who previously struggled with one-syllable words work through such "college words" as "unintelligible," in preparation for more sophisticated texts.

In a similar vein, the power of engagement with language is an implicitly therapeutic focus of the RAVE-O intervention, along with an emphasis on incremental success at each step of learning. Daily lessons include opportunities for the teacher and children to "play with" the multiple dimensions of words, while simultaneously giving them successes in reading them. Imaginative and whimsical activities are incorporated in the instruction, with a "novel mnemonic" provided for each type of metacognitive strategy that helps memory and retrieval. The teacher's own love and knowledge of language is actively used to engage the children in new attitudes toward language and reading. Children are encouraged to think for themselves while reading text and, in the process, to view themselves as successful learners.

Much remains unmeasured that is relevant to understanding individual and group differences in intervention response. Instructional group emerged in our results as an important and highly significant fixed effect in predicting outcomes and growth both during the intervention period and even during the 1 year following intervention. This cannot be dis- missed as a teacher effect, because participating teachers taught multiple programs within the design. Rather, the relationships and dynamic within the group and between the group and the teacher likely resulted in differences both in implementation variables, such as pacing of instruction, and in a wealth of contextual, motivational, and relational variables that affected the children's engagement, motivation, and attributions about the program and their own progress.

Recent work by Frijters at our Toronto site (Frijters et al., 2004; Frijters, De Palma, Barron, & Lovett, 2005) indicates that motivational differences among disabled readers mediate their response to intervention. Frijters's work confirms that motivation for reading is not a unitary construct and that different preintervention motivational profiles can be identified in children with RD. These profiles predict responsive- ness to remediation, indicating that motivation mediates remedial response. In addition, motivation appears to be amenable to modification in its interaction with intervention (Frijters et al., 2005; Frijters, Dodsworth, Lovett, Sevcik, & Morris, 2009).

There are significant limitations to this study that must be acknowledged. As noted earlier, the phonological control condition was not equated for amount of reading intervention time with the two multiple-component interventions. We have argued that the 70-hour phonological- only condition from our previous work provides this comparison historically, but the comparison is outside the present design. We are limited therefore in the conclusions we can reach based on results from the phonological-only comparison. We are also limited in our ability to measure changes in reading comprehension and reading fluency. Measures of these aspects of reading skill are not as well developed as those available for the assessment of word identification and decoding processes. Finally, although we report clear effects attributable to instructional group, we lack the ability to interpret these effects with our current battery, the program observations, and the lesson diaries completed each day.

Despite these limitations, this research demonstrates generalization of program benefits across a far broader population of disabled readers than ever assessed before. Results reveal that systematic, intense, linguistically informed interventions are associated with positive outcomes for young impaired readers of high or low IQ and from a range of ethnic backgrounds and environmental circumstances. Interventions that incorporate multiple components of language and that target a range of core deficits consistently produce superior effects to control programs that emphasize predominantly phonologically based reading instruction or alternate academic programming. These advantages are seen across the entire range of reading skills, including fluency and comprehension, historically the most difficult to facilitate.

Positive results following both PHAB + RAVE-O and PHAST highlight the significance of teaching all struggling readers about the structure of their language from phono- logical and orthographic structure within syllables, to variable pronunciations of vowels and vowel combinations, to semantic knowledge of words and morphemes. Successful remediation enables language learning across different oral and written language systems and enhances motivation and involvement. In the process, these forms of multidimensional intervention equip children both with the critical desire to learn and with a metalinguistic knowledge base that gives them a never-before-experienced "edge" over many, more able readers in their classrooms.

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Note

1. Not all children who met either a LA or DISC criteria were entered into the remediation study, because the study design called for a very explicit sampling strategy. It should be noted that because of some limited attrition (8.5%) during the intervention year (see Figure 1), there was an attempt to replace lost participants in specific sample cells during the following school year. Data from children who left the study during the remediation program are not included in any results presented here, although attrition analysis did not suggest attrition to be systematic in any obvious way. Eleven percent left the study during the year that followed the remediation; no attempt was made to replace these children in the study because they had received the full remediation program and evaluations related to it. Their data were lost to the follow-up analysis. Attrition analysis did not identify any systematic relationships with these students and other demographic or academic attributes. The stringency of the design resulted at times in situations where no children were available to meet the needs of a particular cell from a given school; overselection, therefore, occurred in some sampling cells to ensure consistent instructional group sizes throughout the study. Out of the 279 students (see Figure 1) who completed the full year of intervention (in either the math or reading groups), 23 (11%) students were not available for follow-up testing 1 year later. Out of the 68 students who initially received MATH + CSS, 9 (13%) were not available for the additional year of (reading) intervention and 7 more (10%) were not available for the follow-up testing 1 year later. Attrition analysis did not identify any systematic relationships with these students and other demographic or academic attributes.

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