Recent Discoveries from Research on Remedial Interventions for Children with Dyslexia

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The search for effective remedial methods for children with dyslexia has a long and productive history (Clark and Uhry, 1995). However, it is only quite recently that objective information has been available in sufficient quantities to provide reliable answers to even basic questions about remedial interventions for older children with serious reading disabilities. The primary goal of this chapter is to describe and justify a few of the most important conclusions from recent research on remedial interventions for children with dyslexia. Along the way, we will also discover a number of critical areas in which there is currently a glaring lack of useful information.

Defining the target of intervention

One the most obvious and yet difficult lessons to keep in mind about reading and learning disabilities is that they are heterogeneous. The fact that the broad category of “learning disabilities” encompasses a variety of different kinds of learning difficulty is widely acknowledged in definitions (Hammill, 1990), and this should be reflected in the way research is conducted in this area. Because the term “learning disabilities” is used to refer to a collection of different types of learning problems, it is not feasible to build a coherent theory or science of “learning disabilities” per se (Stanovich, 1993; Torgesen, 1993). Rather, researchers in this area must carefully specify the subtype of learning disability they are focusing on, whether it be a disability in reading, in mathematics, or in social/behavioral learning.

Although the field of reading disabilities is, by definition, narrower than the field of learning disabilities, the same need to specify the target population as clearly as possible seems critical in order to build a coherent scientific knowledge base about children who have different kinds of problems learning to read. For example, in the comprehensive summary of research on reading and reading instruction published by the National Research Council in the United States

(Snow, Burns, and Griffin, 1998), three broad reasons for reading difficulties were identified: 1) problems in understanding and using the alphabetic principle to acquire fluent and accurate word reading skills; 2) failure to acquire the verbal knowledge and strategies that are specifically needed for comprehension of written material; and, 3) absence or loss of initial motivation to read, or failure to develop a mature appreciation of the rewards of reading. Although a simple trichotomy such as this undoubtedly oversimplifies the range of difficulties children have in learning to read, it does illustrate the need to specify the type of reading difficulty on which one's research is focused. Intervention research focusing on children whose primary difficulty is accurate and fluent word identification will certainly produce different conclusions about the essential elements of instruction than research on children who can read words accurately, but have difficulty constructing the meaning of text (see Nation, this volume, for a summary of research on such children).

The research reported in this chapter focused on children who met the recent definition of dyslexia proposed by the International Dyslexia Association: "Dyslexia is one of several distinct learning disabilities. It is a specific language-based disorder of constitutional origin characterized by difficulties in single word decoding…" (Lyon, 1995, p.7). The reference to "language based disorder" in this definition is supported by a range of converging findings indicating that the word reading difficulties of children with this type of reading disability are caused primarily by weaknesses in the ability to process the phonological features of words (Liberman, Shankweiler, & Liberman, 1989, Torgesen, 1999; Vellutino & Fletcher, this volume). The phonological processing disabilities of these children make it difficult for them to acquire skill in using the alphabetic principle to identify novel words in text (Share and Stanovich, 1995), and this, in turn, places severe constraints on the word learning process necessary for becoming a fluent reader (Ehri, 2002).

When children with dyslexia have been in school three or four years and have not had sufficiently strong preventive instruction, they will show two obvious difficulties when asked to read text at their grade level. First, they will not be able to recognize as high a proportion of the words in the text as fluently as average readers. There will be many words they stumble on, guess at, or attempt to "sound out." The second problem is that their attempts to identify words they do not immediately recognize will produce many errors. They will not be efficient in using grapho-phonemic clues in combination with context to identify unknown words. Because these children often have broad verbal abilities that are substantially higher than their word reading abilities, it is the word reading difficulties of these children that are thought to present the most immediate barrier to good reading comprehension.

The intervention research reported in this chapter focuses primarily on children with phonologically-based reading disabilities that manifest themselves in problems learning to identify words in text with fluency and accuracy. Of course, many of these children also suffer from a lack of motivation for reading, particularly after they have failed in learning to read for three or four years. Some may also have subtle oral language or verbal knowledge problems that play a role in limiting their comprehension (Snowling, 2000). Additionally, the biological or constitutional basis of these children's reading difficulties was not directly examined for any of the intervention samples to be discussed. Thus, it is clearly possible that the samples contained a mix of children whose difficulties were primarily constitutional in origin and those who may have entered school delayed in phonological development because of limitations in their pre-school language experience. Conceptually, however, this chapter is focused on remedial research for children who struggle in reading because they have special difficulties mastering the process of identifying words in print.

An early case study and other discouraging examples

One of the most famous and well-documented case studies describing the development of reading skill in a student with phonologically-based reading disabilities is the case of JM, reported initially by Snowling and her colleagues (Snowling, Stackhouse, and Rack, 1986). JM was almost prototypical in the extent to which his characteristics matched those specified in current definitions of dyslexia. He had strong general learning abilities (Full Scale IQ = 123), coupled with inordinate difficulties mastering the alphabetic principle and showed evidence of phonological processing disabilities (very low performance on verbal short-term memory tasks). At some point during his 8^{th} year, JM began attending a special school for dyslexic children, which provided specialized, intensive teaching. Although the exact details of the instruction he received are not provided in the follow-up report (Snowling and Hulme, 1989), it is clear that they did involve structured reading activities and a multi-sensory approach to spelling. During his four years in this special school placement, JM progressed in reading by only half the average rate, and even less in spelling. His weakness with alphabetic reading skills improved very little: when he was 12, he was able to decode novel words at only the level of a 7 year old. The conclusion one might arrive at by studying JM's development is that the ultimate prognoses for intervention efforts with older dyslexic children is bleak, and particularly so for the skills required to decode unknown words. That JM's educational progress is not unique among children with phonologically-based reading disabilities is attested by the expression we frequently hear in schools, "if a child hasn't acquired phonics skills by the third grade (8 years old), they are not going to learn it, and we should try something else."

This conclusion is reinforced in an excellent and widely cited study (Lovett, Bordon, Lacerenza, Benson, & Brackstone, 1994) that examined the relative effectiveness of several carefully contrasted interventions for older children with phonologically-based reading disabilities. This study produced useful information about critical elements of instruction for children with reading disabilities, and it showed that their core disabilities could be improved somewhat through direct instruction. However, at the conclusion of the study (in which the children were taught in pairs for 35 one-hour sessions) their reading skills still fell in the severely disabled range. The children in the two strongest interventions began the study with an average standard score on a measure of word reading ability of 64.0 (which is below the 1st percentile), and at the conclusion of the study, their score was 69.5 (which is still below the 2nd percentile), with pre- and post-test scores on a measure of reading comprehension being 66.4 and 70.8. In other words, after 35 hours of relatively intensive instruction (one teacher:2 students), the children in this study still would be classified as having a very serious reading disability. Although one might argue that continued application of the successful instructional techniques from this study would eventually bring the student's reading skills into the average range, in the absence of direct evidence there is no way to know if this assumption is correct.

There is also evidence from a variety of sources that typical public school interventions for children with reading disabilities can most accurately be characterized as *stabilizing* their degree of reading failure rather than *remediating*, or normalizing, their reading skills (Kavale, 1988; Schumaker, Deshler, & Ellis, 1986). For example, in a carefully monitored longitudinal study, McKinney and his colleagues (McKinney, 1990) found that special education placements for children with reading disabilities produced no gains in word level reading skills relative to normal readers during a three year period in elementary school. The children with reading disabilities began their instruction in special education with an average standard score of 92, and after three years of this instruction, their standard score for word level skills was 90. The children actually experienced a significant relative decline in their standing on a test of reading comprehension, falling from an average score of 94 to a standard score of 88 three years later.

Standard scores are an excellent metric for determining the “success” or “ failure” of interventions for children with reading disabilities, because they describe the child’s relative position within the distribution of reading skills in a large standardization sample. For most of the measures referred to in this chapter, standard scores will have a mean of 100 and a standard deviation of 15. Thus, an increase in standard score indicates that a student has “closed the gap” with average readers. By the same token, if standard scores decrease, it means the child has fallen even further behind relative to his/her same-age peers.

A recent study with a different outcome for children with severe reading disabilities

When we began our intervention research in 1996, we were aware of previous findings about the difficulties of dramatically altering the reading skills of older children with severe phonologically-based reading disabilities. We designed our initial study (Torgesen, Alexander, Wagner, Rashotte, Voeller, Conway, & Rose, 2001a) to provide extremely intensive instruction using two different phonologically-based remedial strategies, and our goal was to discover the extent to which the reading difficulties of these children could be remediated if we intervened as powerfully as our resources would allow. We provided 67.5 hours of one-to-one instruction delivered in two 50 minute sessions each a day for about eight weeks. 60 children, who had been receiving special education services for an average of 16 months at the time they were identified for participation in the study, were randomly assigned to the two intervention conditions.

Although both of the instructional programs in this study provided explicit instruction in phonemic awareness and phonemically based decoding strategies, they differed dramatically in the amount of time spent in three major instructional domains. For example, children in one condition, which was based on an earlier version of the *Lindamood Phoneme Sequencing Program for Reading, Spelling, and Speech* (Lindamood & Lindamood, 1998), spent 85% of their time learning and practicing articulatory/phonemic awareness and phonemic decoding and encoding skills in single word activities (activities that did not involve reading meaningful text), 10% of their time learning to fluently recognize high-frequency words, and only 5% of their time reading meaningful text. Children in the other instructional condition, labeled *Embedded Phonics*, spent 20% of their time on phonemic awareness and phonemic decoding activities involving single words, 30% of their time learning highfrequency “sight words”, and 50% of their time reading meaningful text with teacher support.

The reading skills and language/cognitive characteristics of the children at the start of this study are shown in Table 1. It is clear from the data presented in this table that children in both conditions, on average, met the definitional criteria for children with severe phonologically-based reading disabilities. Children in both groups were severely impaired in their ability to use phonemic strategies to decode unknown words (Word attack scores below the 1st percentile), and they also had very limited abilities to identify words, as shown by their scores on the Word Identification test. Both groups were also relatively impaired in phonemic awareness, verbal short-term memory, and rapid automatic naming abilities, which are all characteristics of children with phonemically based reading difficulties (Snowling, 2000; Torgesen, 1999). On average, the students in this sample were probably not as impaired in verbal short-term memory as JM, although this can only be estimated since JM did not take a standardized test in this area.

Figure 1 provides the best overall summary of results from this study. It charts the growth of children in both instructional conditions on a broad measure of reading skill that combined scores for word reading accuracy and reading comprehension into a single standard score (on this test, a score of 100 is average). The figure shows changes in standard scores on this measure of broad reading ability during over the 16 month period the children were attending special education classes, during the 8 week intervention period, and during a two year follow-up period in which about half the children were no longer receiving special education classes at their schools.

Three aspects of this figure deserve particular mention. First, it is apparent that the instruction these children received in their special education classes was sufficient to maintain the level of their reading deficiency (they did not fall further behind, but neither did they close the gap with same-age peers). Second, the intensive intervention period produced a dramatic increment in their rate of reading growth for reading accuracy and comprehension. Third, as a whole, the children continued to make gains relative to average children during the two-year follow-up period. During the period of instruction in special education, the children's broad reading abilities remained at about the 7th percentile, and at the two year follow-up point, they were at about the 30th percentile.

Although the data reported in Figure 1 provide a useful summary of the impact of the intervention on the children's reading skills, it is equally important to understand the effects of the interventions on more differentiated components of reading skill. Figure 2 illustrates the immediate and long-term growth in phonemic decoding skills as measures by the Word Attack subtest of the *Woodcock Reading Mastery Test-Revised* (Woodcock, 1987)(top panel), text reading accuracy as measured by the *Gray Oral Reading Test-3rd Edition* (Wiederholt & Bryan, 1992), text reading fluency from the Gray, and Passage Comprehension from the Woodcock. If a standard score of 90 is taken as the bottom boundary of the "average range" of reading ability, then it is apparent that, with the exception of reading fluency, children in both groups ended the follow-up period either solidly in the average range or at the low end of the average range in reading ability. The only statistically reliable difference between the groups in reading achievement occurred for phonemic decoding ability at the immediate post-test. Overall, the impact of both reading interventions was remarkably similar. The strongest impact of both interventions was on the children's ability to apply phonemic decoding strategies to unknown words.

In order to produce a group of children that might be more comparable to JM in terms of the degree of their impairment in verbal short-term memory, the 60 children who participated in the interventions were divided into low (n=8) , middle (n= 45), and high (n=7) groups in terms of their performance on the digit span test from an experimental version of the *Comprehensive Test of Phonological Processes* (Wagner, Torgesen, & Rashotte, 1999). The standard scores on the digit span test for children in the low group ranged from 70 to 85, with a mean of 78.3. The Word Attack subtest from the *Woodcock Reading Mastery Test-Revised* is a measure of generalized phonemic decoding skills because it requires children to "sound out" nonwords that follow regular English spelling patterns, and none of the nonwords on this test were taught in either of the interventions. The children with the weakest verbal short-term memory improved from a standard score of 70.2 on the pre-test to a score of 93.5 on the post test. Corresponding improvements for the other two groups were: middle – 67.4 to 91.6, high – 74.1 to 95.6. These data indicate that even the children with the most severe impairments in verbal short-term memory made gains in generalized phonemic decoding skills that were similar to the group as a whole.

Before leaving this study, it is important to note two other findings. First, as would be expected, the interventions were not equally successful with all children. About a fourth of the children lost most of the standard score gains they experienced from the intervention during the two year follow-up period. Although almost all of the children responded well during the intervention period, only slightly more than half were able to sustain or improve their gains once the intensive intervention period was over. The student variables that most reliably predicted growth trajectories during the follow-up period were teacher ratings of attentional behaviors, receptive language skills, and socio-economic status.

Second, it is important to point out that the lack of change in the standard score for reading fluency for the entire sample does not mean that the children in this study did not become more fluent readers in an absolute sense. In fact, as long as the difficulty level of passages remained constant, they became substantially more fluent. For example, at the pre-test, the most difficult passage the children read on the *Gray Oral Reading Test* was read at 38 words per minute with 10 errors. At the two-year follow-up point, a passage of equivalent difficulty was read at 101 words per minute with 2 errors. The same pattern was observed on the next most difficult passage which was read at pre-test at 42 words per minute with 6 errors, while at posttest an equivalent passage was read at 104 words per minute with one error. Thus, the children did show marked improvement in the fluency with which they could read relatively simple passages; it was only when they were compared to their peers on passages closer to their grade level that they continued to show a striking lack of fluency while reading text.

Reading gains in other studies of intensive interventions

In an effort to determine whether the rates of growth in phonemic decoding skills and other reading skills obtained in our initial study are comparable to other recent reports of interventions with older children, we examined results from 13 intervention samples using a common growth metric. This metric is calculated by dividing the amount of gain in standard score units by the number of hours of instruction that are provided, so rate of growth is expressed as the number of standard score points gained per hour of instruction. Of course, this metric depends on the common use across studies of standardized measures that have the same standard deviation, but there are a number of studies that have used measures similar enough to allow rough comparisons. Table 2 reports these growth rates for phonemic decoding (Ph. Dec.), word reading accuracy (Acc.), and passage comprehension (Comp.), along with other characteristics of the samples and the interventions they received. Not all scores are represented for each study, because standardized measures were not provided in all three areas of reading skill for all samples.

All of the studies reported in Table 2 provided interventions to children with severe to moderate word-level reading difficulties. In almost all the studies, the students began the interventions with scores in either phonemic decoding or word reading accuracy below the 5th percentile. In three of the samples (Rashotte, MacPhee, & Torgesen, 2001 and the small group (1:4) intervention samples in Torgesen, Rashotte, Alexander, Alexander, & MacPhee, 2003a), the students began with phonemic decoding skills around the 10th percentile. The intervention methods used in 5 of the studies (Torgesen, et al., 2001a; Wise, Ring, & Olson, 1999; Alexander, Anderson, Heilman, Voeller, & Torgesen, 1991; Truch, 1994; the 1:1 study in Torgesen, et. al., 2003a) were variants of the Lindamood method (Lindamood & Lindamood, 1998), and all of the methods provided explicit instruction in phonemic awareness and phonemic decoding skills. The studies reported by Lovett, Lacarenza, Bordon, Frijters, Steinbach, & DePalma (2000) and by Torgesen, et al. (2001a) contained two approximately equally effective interventions, and results for both interventions are reported separately.

Several aspects of the data reported in Table 2 are worthy of specific discussion. First, there is remarkable consistency in the rates of growth for phonemic decoding skills, word reading accuracy, and passage comprehension skills reported across the studies. The consistency in rate of gain across these studies suggests that the high rates of growth obtained in the study described earlier in this section (Torgesen, et al., 2001a) should be generalizable to other settings, with other teachers implementing the interventions. The similarities in growth rate between the LIPS (*The Lindamood Phoneme Sequencing Program for Reading, Spelling, and Speech*) and EP (*Embedded Phonics*) conditions in the Torgesen, et al., (2001a) study, along with the consistencies across other studies that did not use the Lindamood method, suggests that, given the right level of intensity and teacher skill, it may be possible to obtain these rates of growth using a variety of approaches to direct instruction in reading. One might even suggest that these rates could serve as benchmarks for “reasonable progress” in reading for students receiving remedial instruction in both public and private settings. As such, they are clearly much higher than is typically achieved in most current special education settings.

Another point to note from Table 2 is that growth rates for phonemic decoding skills are consistently higher than they are for word reading accuracy and passage comprehension. Not only the substantial growth rate, but also the essential “normalization” of phonemic decoding skills reported in a number of these studies indicates that even children with severe difficulties in the phonological domain can acquire productive and generative phonemic decoding skills if they are taught with intensity and skill.

Finally, it is important to understand a number of factors that probably influenced differences across studies in both the rate of growth and outcome status. These factors range from obvious things such as the particular measure of word reading accuracy that was used, to more subtle things such as the hours of intervention that were provided. For example, in our studies, we find that estimates of word reading accuracy are consistently higher when a measure of text reading accuracy (such as the Gray Oral Reading Test) is used rather than a measure of single word reading accuracy (such as the Woodcock Reading Mastery Test). The particular test used to assess word reading accuracy affects the estimate of final status more than it does the estimate of growth rate. For example, in the Torgesen, et al., (2001a) intervention study, post-test standard scores for word reading accuracy as measured by the Woodcock were 82.4 and 80.5 for the LIPS and EP programs, respectively. In contrast, post-test scores for word reading accuracy from the Gray were 89.4 and 87.5, respectively. The higher scores for the Gray undoubtedly reflect the student's ability to use passage level context as an aid to more accurate identification of words (Stanovich & Stanovich, 1995).

Another factor that is likely to influence the estimate of growth rate obtained within any single study is the number of hours of intervention that were provided. Truch (2003) has recently documented that rate of gain may decelerate quite rapidly for intensive interventions after the first 12 hours of the intervention. In his study, 80 hours of intensive instruction using the Phono-Graphix method (McGuinness, McGuinness, & McGuinness, 1999) were provided to 202 students ranging in age from 6 years old to over 17 years old. For students ranging in age from 10-16, the average gains per hour of instruction for single word reading accuracy was .74

standard score points per hour of instruction for the first 12 hours of instruction. For the next twelve hours, the rate was .11, and for the final 56 hours, it was .10 standard score points per hour. Although this study did not calculate standard scores for their phonemic decoding measure, the findings were similar, but expressed in terms of grade level units per hour of instruction. For phonemic decoding, the growth rate for the first 12 hours of instruction was .25 grade level units per hour of instruction, for the next 12 hours it was .07, and for the final 56 hours, it was .04. This deceleration in growth rate across time within intensive interventions is probably part of the explanation for the particularly low growth rates observed in the 133 hour intervention study reported by Torgesen, et al., (2003a). However, another factor may have also been operating in this study to moderate the growth rates that were observed.

This study was conducted in the same school district, and within many of the same schools, as a previously reported (Torgesen, et al., 2001a) study of intensive interventions. In spite of the fact that children in the second study received twice as much instruction as those in the first study, they actually improved less in text reading accuracy and comprehension than the first group. Since both the first and second groups had received very similar interventions and had been selected by the same criteria, the most likely explanation for this unexpected finding is that the latter group had more severe reading disabilities than the first one. Our primary evidence for this assertion is that the special education classes from which the children were selected had improved substantially during the three years that intervened between the selections of the two samples. It was actually more difficult to find students who read poorly enough to meet our selection criteria when we selected the second sample than it was when we identified children for the first study. Teachers who had worked in both studies also noticed immediately that the second group was “much more difficult to teach” than children in the first sample.

This finding introduces an important moderating variable that must be kept in mind when looking at the results of intervention studies. The actual reading impairment a child shows at any point is always the result of an interaction between the child's degree of disability and the strength of instruction that has been provided. Children with a mild reading disability who are provided only weak instruction (in the regular classroom or in a special education setting) will show larger reading impairments when tested than will children with the same degree of reading disability who have had stronger instruction. By the same token, children who remain severely reading impaired within a strong instructional environment are likely to have a more serious reading disability than those who have remained impaired after receiving only weak instruction. Thus, if researchers select their intervention samples from among children who have already received a good dose of appropriate and reasonably intensive instruction, the children in those samples will be more difficult to teach than children who are selected by the same reading criteria from a weaker instructional environment. This moderating factor raises the clear possibility that, if schools are successful in organizing instruction to provide powerful support for the initial acquisition of reading skills in young children (Foorman & Torgesen, 2001; Torgesen, 2002), growth rates for students in special education may not show the improvement one might expect, even with better models of intervention.

What about the remaining problems in fluency?

One of the consistent findings in our remedial research for children who begin the intervention with moderate or serious impairments in word reading ability is that the interventions have not been sufficient to close the gap in reading fluency. Although the gap in phonemic decoding, reading accuracy, and comprehension can be substantially or completely closed by current interventions, the gap in fluency has remained much less tractable to intervention for moderately and seriously impaired children.

When teachers or other researchers see these results, they think immediately that there must be something wrong with our interventions. Perhaps the interventions we have used emphasize "phonics" too much, perhaps they focus on accuracy too much, or perhaps they do not provide enough practice in reading fluency itself. We do not entirely discount these possibilities, but we also have considerable evidence that the problem may lie in the nature of reading fluency itself, rather than in the interventions. First, in one study with severely impaired readers (Torgesen, et al., 2001a), one of the instructional interventions invested 50% of instructional time in reading connected text, while the other invested only 5%. There was no difference in fluency outcomes.

Second, we have reported a series of interventions with students who had mild (10th percentile) or moderate (30th percentile) impairments in word level reading skills, and which focused considerable instructional time in text reading activities with an emphasis on both modeling and practicing fluent reading (Torgesen, et al., 2003a). Again, the students who began the intervention with moderate level (10th percentile) word reading difficulties showed only small improvement in their age – based percentile ranking for fluency, although they increased substantially in other dimensions of reading skill. Third, and probably most important, we have not obtained the same differences in outcomes between reading fluency and reading accuracy in our prevention studies as has occurred in the remedial studies. Figure 3 shows the standard scores (a score of 100 is average) for reading accuracy and fluency outcomes for four samples of 9-12 year old children with severe (below 2nd percentile) to moderate (10th percentile) word level reading difficulties. Each sample is identified by their reading accuracy percentile at the beginning of the intervention. For reference, outcomes for these samples were also reported in Table 2. The leftmost data is from Torgesen, et al., (2001a), next is from the severely impaired sample in Torgesen, et al., (2003a), next is from the moderately impaired sample that received 51 hours of intervention from Torgesen, et al., (2003a), and next is the moderately impaired sample that received 100 hours of intervention.

Outcomes for text reading fluency and accuracy from two prevention studies are presented on the right side of Figure 3.   The most obvious difference between the outcomes from the prevention and remediation studies is that the gap between reading fluency and reading accuracy is not nearly as large for the prevention as for the remediation studies. The first prevention study (Prev 1) (Torgesen, et al., 1999) provided 2 ½ years of instruction to children in 20 minute sessions four days a week from the second semester of kindergarten through second grade. The children were identified as the 10% most at risk for reading failure because of low scores in phonemic awareness and letter knowledge in the first semester of kindergarten. The data in Table 1 show the performance of children in the most effective instructional condition at the end of fourth grade (which was based on the LIPS program), two years after the intervention was concluded. The children's scores for both reading accuracy and fluency are solidly in the average range.

In the second study (Prev 2) (Torgesen, Wagner, Rashotte, & Herron, 2003b), we provided preventive instruction during first grade to children identified at the beginning of first grade as the 20% most at risk for reading failure. The children were taught in small groups using a combination of teacher led and computer assisted instruction in 50 minute sessions, four days a week from October through May. The data in Figure 3 show the performance of the children from the most effective condition at the end of second grade, one year after the intervention concluded. Again, both reading accuracy and fluency scores are solidly within the average range, and the gap between these scores is very small.

We have proposed elsewhere (Torgesen, Rashotte, & Alexander, 2001b) several possible explanations for the difficulty we have experienced in helping older children to "close the gap" in reading fluency after they have struggled in learning to read for several years. The most important factor appears to involve difficulties in making up for the huge deficits in reading practice the older children have accumulated by the time they reach late elementary school. These differences in reading practice emerge during the earliest stages of reading instruction (Allington, 1984; Beimiller, 1977-1978) and they become more pronounced as the children advance across the grades in elementary school. For example, Cunningham and Stanovich (1998) reported evidence suggesting enormous differences in the amount of reading done by 5th grade good and poor readers outside of school. A child at the 90th percentile of reading ability may read as many words in two days as a child at the 10th percentile reads in an entire year outside the school setting. Reading practice varies directly with the severity of a child's reading disability, so that children with severe reading disabilities receive only a very small fraction of the total reading practice obtained by children with normal reading skills.

One of the major results of this lack of reading practice is a severe limitation in the number of words the children with reading disabilities can recognize automatically, or at a single glance (Ehri, 2002; Share & Stanovich, 1995), which is sometimes referred to by teachers as the child's "sight word vocabulary." This limitation of "sight word" vocabulary is a principle characteristic of most children with reading disabilities after the initial phase in learning to read (Rashotte, et al., 2001, Torgesen, et al., 2001a; Wise, et al., 1999). The limitation arises because children must read specific words accurately a number of times before they can become part off their sight vocabulary (Rietsma, 1983). As Ehri (2002) points out, "sight words include any word that readers have practiced reading sufficiently often to be read from memory." (p. 10).

We have shown elsewhere (Torgesen, Rashotte, & Alexander, 2001b) that inefficiency in identifying single words is the most important factor in accounting for individual differences in text reading fluency in samples of children with reading disabilities. When these findings are combined with the fact that the number of less frequent words (words children are less likely to have encountered before in text) increases rapidly after about third grade level (Adams, 1990), it is easy to see why it is so difficult for children who have failed in reading for the first three or four years of school to close the gap in reading fluency with their normally achieving peers. If successively higher grade level passages include increasing numbers of less frequent words, and normal readers are continually expanding their sight vocabularies through their own reading behavior, it should be very difficult for children, once significantly behind in the growth of their sight word vocabulary, to close the gap in reading fluency. Such "catching up" would seem to require an extensive period of time in which the reading practice of the previously disabled children was actually *greater* than that of their peers. Even if word reading accuracy is dramatically increased through the more efficient use of analytic word reading processes, reliance on analytic processes will not produce the kind of fluent reading that results when most of the words in a passage can be recognized "by sight."

Additional areas of knowledge from intervention research with older children

This chapter has focused rather narrowly on reporting knowledge about the extent to which the reading skills of older children with phonologically-based reading disabilities can be "normalized" by current interventions. However, a complete science of intervention should include at least two other types of knowledge.   Perhaps most fundamental to a science of intervention is knowledge about the specific instructional methods that are most effective for children with various kinds of disabilities. Findings from research on reading and reading growth (Ehri, 2002; Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg.,2001) as well as from intervention studies (Foorman, Francis, Fletcher, Schatschneider, & Mehta, 1998; Hatcher, Hulme, & Snowling, 2004; Torgesen, et al., 1999) suggest that phonemically based interventions are essential for children with phonologically-based reading difficulties.   The data from Table 2 indicate that there are a number of equally effective ways to provide this instruction, although the comparisons available from Table 2 do not involve random assignment to methods within the same population of children, so they must be interpreted with caution.   It is also true that others (Lovett, et al., 2000) have documented significant differences in effectiveness for methods that contain phonemically explicit instruction but vary in the range of word identification strategies that are taught. Hatcher, et al., (2004) have also provided some recent evidence that, for children with more severe disabilities, it may be particularly important to provide explicit instruction at the level of the individual phoneme rather than, for example, at the level of onset/rime units.   It is clearly necessary for future research to continue to refine our knowledge about the elements of instruction that can most powerfully accelerate the reading development of older children with phonologically-based reading disabilities.

Research is also needed to determine whether there are interventions that may be particularly successful in addressing the reading fluency problems of children once their reading accuracy problems are remediated. There is a substantial body of evidence in support of the use of repeated reading as an intervention for children with fluency problems (Meyer & Felton, 1999), but there is no evidence currently available that this technique can produce "normalization" of fluency in children who have struggled in learning to read for several years. Wolf and her colleagues (Wolf, Miller, & Donnelly, 2000) are currently investigating interventions specifically targeted on fluency issues that extend considerably beyond the use of repeated reading, but as yet there are no reports of findings available from these studies.

A second area of inquiry that is part of an emerging science of intervention concerns questions about changes in the localization and timing of brain functions that occur because of effective interventions. The central question addressed in this type of research is whether the localization and timing of brain processes that support reading are "normalized" in reading disabled individuals after effective interventions (Papinicolaou, et al., 2003). Initial findings suggest that powerful interventions with older and younger children do produce a relative "normalization" of localization and timing of brain functions that support phonological processes in reading, but this area of research is still in its infancy, so conclusions remain very tentative at this point.

A final and significant remaining gap in our knowledge

In the United States, there is a strong national movement toward school-based accountability for the reading achievement of all children. The provisions of the *No Child Left Behind Act* of 2002 requires states to set reading standards by third grade that determine whether or not a child has attained adequate reading skills. Within each state, the effectiveness of both preventive and remedial programs in reading will ultimately be evaluated by examining the percentage of children who fail to meet standards for adequate reading ability by the end of third grade. Typically, the tests that states use to assess reading outcomes are group administered reading comprehension tests. The best of these tests include lengthy passages, and require both multiple choice and written answers to questions.

The new accountability standards require students in special education to be tested by the same measures that are used to evaluate reading outcomes in all children. Thus, the effectiveness of remedial instruction for students such as those reported on in this chapter will ultimately be evaluated in terms of their ability to respond adequately on these complex measures of reading comprehension. To date, none of the recent studies of intensive interventions for older students with phonologically-based reading disabilities has included information about the success of students on these “high stakes”, state administered reading achievement tests. Measures typically used in intervention research are administered 1:1, and may provide performance supports that are not available in group settings.

Given the remaining problems in reading fluency that remain after effective remediation, it seems doubtful that many of the students from current intervention research would be successful when faced with the challenge of responding to questions from lengthy passages in a group setting. Although these tests do not typically have a stringent time limit, they also do not provide unlimited time to respond, and thus reading fluency problems may create special difficulties for older children whose reading accuracy problems have been substantially remediated by effective interventions. It is thus a matter of some urgency to examine the conditions that need to be in place to raise the reading skills of children with reading disabilities into the acceptable range on the kinds of group administered reading comprehension tests that are becoming the ‘benchmark” for acceptable reading performance in public schools in the United States and many other countries.

Concluding comments

As documented in this chapter, we now have considerable evidence available concerning the effectiveness of intensive and explicit reading interventions for children who have struggled in learning to read. We know, for example, that it is possible to teach almost all children to accurately apply the alphabetic principle in decoding novel words, even if they have struggled to acquire this skill during the first 3-4 years of schooling. We also know that the text reading accuracy and reading comprehension of children with relatively severe reading disabilities can be accelerated dramatically by carefully administered interventions that are more intensive than instruction typically provided in special education settings.   We have yet to discover interventions that can "normalize" the reading fluency of students who have missed out on 2-4 years of reading practice because of very poor reading skills during the early elementary school years. However, this problem may ultimately arise from the nature of reading fluency itself and the fact that fluency continues to accelerate rapidly in "average" readers during the late elementary, middle, and high school years, rather than being an inherent problem with the instructional methods currently available.

The most important questions that one is left with after considering the results of the effective interventions described in this chapter (other than those already described) concern the extent to which it may be possible to make these high quality interventions available to all children who need them. What conditions of funding, procedure, training, and support are necessary to insure that all children receive the kinds of reading instruction they require to become proficient? As we learn more and more about "what works" for these children, our attention may more confidently begin to focus on the practical applications of our new knowledge. Even at first glance, it is clear that a wider range of expertise and methods may need to be applied to solving the problems of application than has thus far been required to produce the knowledge reported in this chapter.

References

Adams, M. J. (1990). Beginning to read. Cambridge, MA: MIT Press.

Alexander, A., Anderson, H., Heilman, P.C., Voeller, K.S., and Torgesen, J.K. 1991. Phonological awareness training and remediation of analytic decoding deficits in a group of severe dyslexics. *Annals of Dyslexia 41*: 193-206.

Allington, R. L. (1984). Content coverage and contextual reading in reading groups. *Journal of Reading Behavior, 16*, 85-96.

Beimiller, A. (1977-1978). Relationships between oral reading rates for letters, words, and simple text in the development of reading achievement. *Reading Research Quarterly*, *13*, 223-253.

Clark, D.B., and Uhry, J.K. (1995). Dyslexia: Theory and Practice of Remedial Instruction, 2nd Edition. Baltimore, MD: York Press.

Cunningham, A.E. & Stanovich, K.E. (1998). What reading does for the mind. *American Educator*, *22,* 8-15.

Ehri, L. (2002). Phases of acquisition in learning to read words and implications for teaching. In R. Stainthorp and P. Tomlinson (Eds.) *Learning and teaching reading.* (pp. 7-28) London: British Journal of Educational Psychology Monograph Series II.

Foorman, B. & Torgesen, J.K. (2001), Critical elements of classroom and small-group instruction to promote reading success in all children. *Learning Disabilities Research and Practice, 16,* 203-121.

Foorman, B.R., Francis, D.J., Fletcher, J.M., Schatschneider, C., & Mehta, P. (1998). The role of instruction in learning to read: Preventing reading failure in at-risk children. *Journal of Educational Psychology, 90*, 37-55.

Hammill, D.D. (l990). On defining learning disabilities: An emerging consensus. *Journal of Learning Disabilities, 23*, 74-84.

Hatcher, P., Hulme, C. and Ellis, A.W. (1994) Ameliorating early reading failure by integrating the teaching of reading and phonological skills: The phonological linkage hypothesis. *Child Development, 65*, 41-57.

Hatcher, P.J., Hulme, C. & Snowling, M.J. (2004) Explicit phoneme training combined with phonic reading instruction helps young children at risk of reading failure. *Journal of Child Psychology & Psychiatr, 45, 338-358.*

Kavale, K.A., (1988). The long-term consequences of learning disabilities. In M.C. Wang, H.J. Walburg, & M.C. Reynolds (Eds.), *The handbook of special education: Research and practice* (pp. 303-344). New York: Pergamon.

Liberman, I.Y., Shankweiler, D., & Liberman, A.M. (1989). The alphabetic principle and learning to read. In Shankweiler, D. & Liberman, I.Y. (Eds.), *Phonology and reading disability: Solving the reading puzzle*(pp.1-33). Ann Arbor, MI: U. of Michigan Press.

Lindamood, P. & Lindamood, P. (l998). *The Lindamood Phoneme Sequencing Program for Reading, Spelling, and Speech,* Austin, TX: PRO-ED, Inc.

Lovett, M.W., Borden, S. L., Lacerenza, L., Benson, N. J., & Brackstone, D. (1994). Treating the core deficits of developmental dyslexia: Evidence of transfer of learning after phonologically-and strategy-based reading training programs. *Journal of Educational Psychology, 30*, 805-822.

Lovett, M.W., Lacerenza, L., Borden, S.L., Frijters, J.C., Seteinbach, K.A., & DePalma, M. (2000). Components of effective remediation for developmental reading disabilities: combining phonological and strategy-based instruction to improve outcomes. *Journal of Educational Psychology, 92*, 263-283.

Lyon, G.R. (1995). Towards a definition of dyslexia. *Annals of Dyslexia, 45*, 3-27.

McGuinness,C., McGuinness, D., & McGuinness, G. (1996). Phono-Graphix: A new method for remediating reading difficulties. *Annals of Dyslexia, 46*, 73-96.

McKinney, J.D. (1990). Longitudinal research on the behavioral characteristics of children with learning disabilities. In J.Torgesen (Ed.), *Cognitive and behavioral characteristics of children with learning disabilities*. (pp.). Austin, TX.: PRO-ED.

Meyer, M. S., & Felton, R. H. (1999). Repeated reading to enhance fluency: Old approaches and new directions. *Annals of Dyslexia, 49*, 283-306.

Papanicolaou, A.C., Simos, P.G., Fletcher, J.M., Francis, D.J., Foorman, B., Castillo, E.M., & Sarkari, S. (2003). Early development and plasticity of neuro-physiological processes involved in reading. In B. Foorman (Ed.) Preventing and Remediating Reading Difficulties: Bringing Science to Scale. (pp. 3-22). Baltimore, MD; York Press.

Rashotte, C.A., MacPhee, K., & Torgesen, J.K. (2001). The effectiveness of a group reading instruction program with poor readers in multiple grades. *Learning Disability Quarterly.24*, 119-134.

Rayner, K., Foorman, B.R., Perfetti, C.A., Pesetsky, D., & Seidenberg, M.S. (2001). How psychological science informs the teaching of reading. *Psychological Science in the Public Interest, 2:* 31-73.

Reitsma, P. (1983). Printed word learning in beginning readers. *Journal of Experimental Child Psychology*. *75*, 321-339.

Schumaker,J.B., Deshler,D.D., & Ellis,E.S. (1986). Intervention issues related to the education of learning disabled adolescents. In J.K. Torgesen & B.Y.L. Wong(Eds.), *Psychological and Educational Perspectives on Learning Disabilitie*s (pp. 329-365). New York: Academic Press.

Share, D. L., & Stanovich, K. E. (1995). Cognitive processes in early reading development: A model of acquisition and individual differences. *Issues in Education: Contributions from Educational Psychology, 1*, 1-57.

Snow, C.E., Burns, M.S. & Griffin, P. (1998). *Preventing reading difficulties in young children*. Washington, DC: National Academy Press.

Snowling, M. and Hulme, C. (l989). A longitudinal case study of developmental phonological dyslexia. *Cognitive Neuropsychology, 6*, 379-401.

Snowling, M. J. (2000). *Dyslexia, 2nd Ed*. Oxford: Blackwell Publishers

Snowling, M.J., Stackhouse, J. & Rack, J. (1986). Phonological dyslexia and dysgraphia: A developmental analysis. *Cognitive Neuropsychology, 3*, 309-39.

Stanovich, K.E. & Stanovich, P. J., (1995). How research might inform the debate about early reading acquisition. *Journal of Research in Reading, 18*, 87-105.

Stanovich, K.E. (1993). The construct validity of discrepancy definitions of reading disability. In G.R. Lyon, D.B. Gray, J.F. Kavanagh, & N.A. Krasnegor (Eds.), *Better understanding learning disabilities* (pp. 273-308). Baltimore: Paul H. Brooks.

Torgesen, J.K. (1993). Variations on theory in learning disabilities. In R. Lyon, D. Gray, N Krasnegor, and J. Kavenagh (Eds.) *Better Understanding Learning Disabilities:*

Perspectives on classification, identification, and assessment and their Implications for Education and Policy. (pp. 153-170). Baltimore: Brookes Publishing.

Torgesen, J.K. (1999). Phonologically based reading disabilities: Toward a coherent theory of one kind of learning disability. In R.J. Sternberg & L. Spear-Swerling (Eds.), *Perspectives on Learning Disabilities*. (pp. 231-262). New Haven: Westview Press.

Torgesen, J.K. (2002). The prevention of reading difficulties. *Journal of School Psychology, 40,* 7-26.

Torgesen, J.K., Alexander, A. W., Wagner, R.K., Rashotte, C.A., Voeller, K., Conway, T. & Rose, E. (2001a). Intensive remedial instruction for children with severe reading disabilities: Immediate and long-term outcomes from two instructional approaches. *Journal of Learning Disabilities, 34, 33-58.*

Torgesen, J.K., Rashotte, C.A., Alexander, A. (2001b). Principles of fluency instruction in reading: Relationships with established empirical outcomes. In M. Wolf (Ed.)*, Dyslexia, Fluency, and the Brain.* Parkton, MD: York Press.

Torgesen, J.K., Rashotte, C.A., Alexander, A., Alexander, J., & MacPhee, K. (2003a). Progress towards understanding the instructional conditions necessary for remediating reading difficulties in older children. In B. Foorman (Ed.)*. Preventing and Remediating Reading Difficulties: Bringing Science to Scale.(*pp. 275-298). Parkton, MD: York Press.

Torgesen, J.K., Wagner, R.K., Rashotte, C.A., and Herron, J. (2003b). Summary of Outcomes from First grade Study with *Read, Write, and Type* and *Auditory Discrimination In Depth* instruction and software with at-risk children. Technical Report #3, Florida Center for Reading Research, Tallahassee, FL.

Torgesen, J.K., Wagner, R. K., Rashotte, C.A., Rose, E., Lindamood, P., Conway, T. , & Garvin, C. (1999). Preventing reading failure in young children with phonological processing disabilities: Group and individual responses to instruction. *Journal of Educational Psycholog, 91, 579-593.*

Truch, S. (1994). Stimulating basic reading processes using *Auditory Discrimination in Depth*, *Annals of Dyslexia*, *44*, 60-80.

Truch, S. (2003). *Comparing remedial outcomes using LIPS and Phono-Graphix: An in-depth look from a clinical perspective*. Unpublished manuscript. The Reading Foundation, Calgary, Alberta, Canada.

Wagner, R. K., Torgesen, J.K., & Rashotte, C.A. (1999). *Comprehensive Test of Phonological Processes*. Austin, TX: PRO-ED Publishing, Inc.

Wiederholt, J.L. & Bryant, B.R. (l992). *Gray Oral Reading Tests--III.* Austin, TX: PRO-ED.

Wise, B.W., Ring, J. , & Olson, R.K. (1999). Training phonological awareness with and without explicit attention to articulation. *Journal of Experimental Child Psychology, 72*, 271-304.

Wolf, M., Miller, L., & Donnelly, K. (2000). Retrieval, Automaticiy, Vocabulary Elaboration, Orthography (RAVE-O): A comprehensive, fluency-based reading intervention program. *Journal of Learning Disabilities 33*:322-24.

Woodcock, R.W. (l987). *Woodcock Reading Mastery Tests-Revised*. Circle Pines, Minn.: American Guidance Service.

Table 1
Subject Characteristics

	Instructional Condition	
Variable	Lindamood	Embedded Phonics
N	30	30
Age (in months)	117.6 (10.5)	117.6 (12.6)
Full Scale IQ	96.2 (9.9)	95.6 (10.3)
Verbal IQ	92.2 (8.5)	93.0 (12.3)
Phonemic Decoding-Word Attack[1]	67.8 (12.3)	69.4 (8.5)
Word Identification[1]	67.8 (8.6)	66.5 (9.1)
Phoneme Awareness (LAC)[2]	54.7 (15.6)	47.6 (14.3)
Phonemic Awareness (Elision)[3]	88.8 (13.10)	84.2 (11.2)
Verbal Short-Term Memory[4]	88.8 (14.6)	88.3 (13.5)
RAN Digits[5]	86.9 (10.7)	84.2 (9.l3)
Spelling[6]	75.6 (4.6)	74.4 (4.9)
Sex Ratio	22M/8F	21M/9F

[1]Subtests from the *Woodcock Reading Mastery Test-Revised*-standard scores with mean of 100 and Standard Deviation of 15
[2]*Lindamood Auditory Conceptualization Test*—raw scores
[3]Elision subtest from the *Comprehensive Test of Phonological Processes* – standard score (X = 100, SD=15)
[4]Digit memory from the *Comprehensive Test of Phonological Processes* - standard score (X = 100, SD=15)
[5]Rapid automatic naming of Digits from the *Comprehensive Test of Phonological Processes* - standard score (X = 100, SD=15)
[6]Spelling subtest from *Kaufman Tests of Educational Achievement* - standard score (X = 100, SD=15)

Table 2: Gains in standard score points per hour of instruction for three measures of reading skill

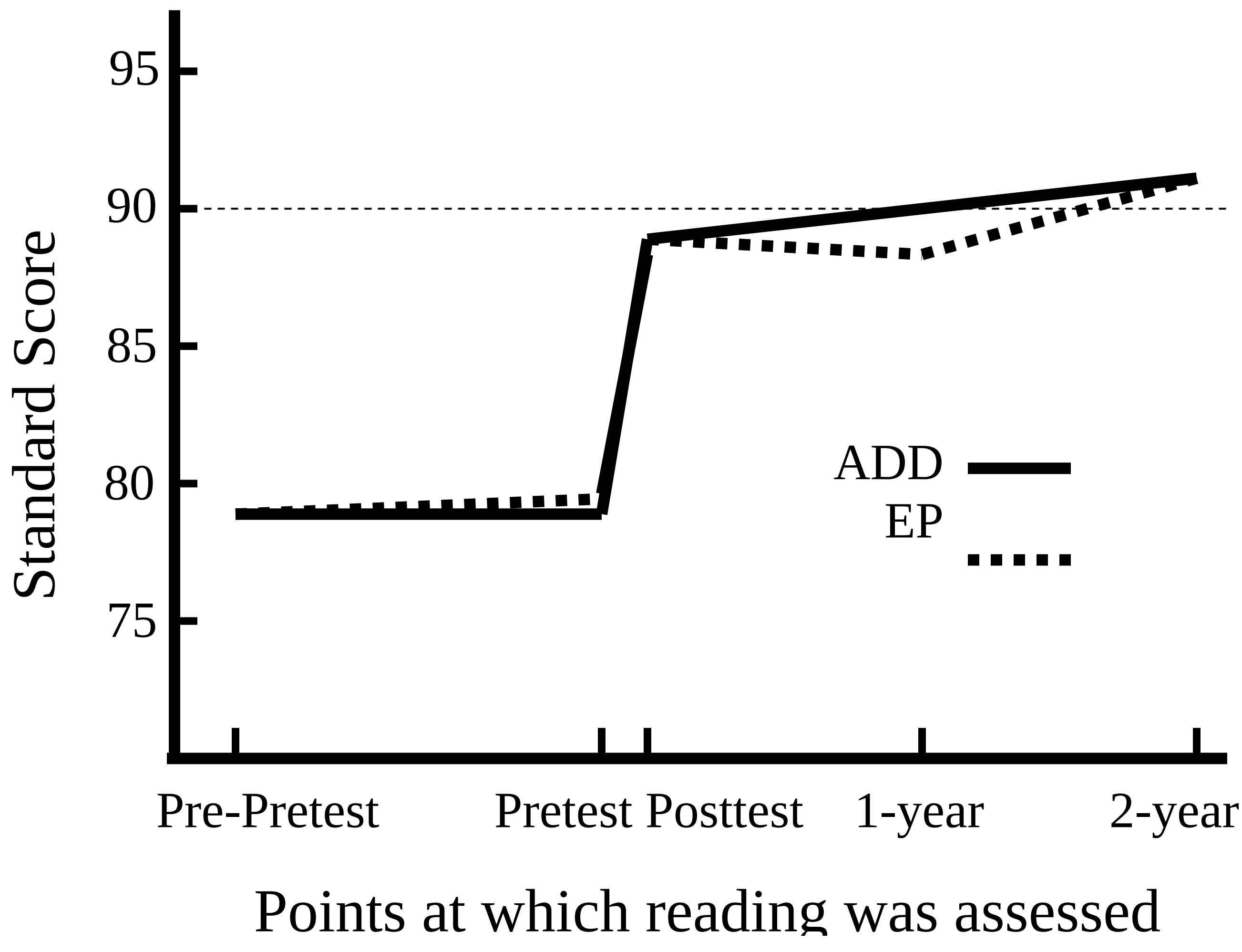
Authors of Study	Name of Intervention	Ave. Age of Subjects	Group Size	Hours of Intervention	Pre-test SS Ph. Dec.	Pre-test SS Acc.	Post-test SS Ph. Dec.	Post-test SS Acc.	SS Gains per Hour of Instruct. Ph. Dec.	SS Gains per Hour of Instruct. Acc.	SS Gains per Hour of Instruct. Comp.
Torgesen, et al., (2001a)	LIPS	9yr,10mo.	1:1	67.5	68.5	68.9	96.4	82.4	.41	.20	.12
Torgesen, et al., (2001a)	EP	9yr, 10mo.	1:1	67.5	70.1	66.4	90.3	80.5	.30	.21	.15
Wise, et al., (1999)		8yr, 9mo.	1:4,1:1	40	81.8	73.6	93.7	83.4	.30	.24	.14
Lovett, et al., (1994	PHAB/DI	9yr, 7mo	1:2	35	--	64.0	--	69.5	--	.16	.14
Alexander, et al., (1991)	ADD	10yr, 8mo	1:1	65	77.7	75.1	98.4	87.6	.32	.19	--
Truch (1994)	ADD	12yr, 10mo	1:1	80	--	76.0	--	93.0	--	.21	--
Rashotte, et al., (2001)	Spell Read	9yr, 8mo	1:4	35	82.6	87.4	98.9	98.1	.47	.31	.32
Torgesen, et al., (2003a)	Spell Read	12 yr.	1:4	100	88	77	111.0	96.0	.23	.19	.19
Torgesen, et al., (2003a)	Spell Read	12 yr.	1:4	51	87	82	102.0	90.0	.29	.16	.24
Lovett, et al., (2000)	PHAB/WIST	9yr, 8mo	1:3	70	67.0	62	84.0	75.0	.24	.18	.16
Lovett, et al., (2000)	WIST/PHAB	9yr, 8mo	1:3	70	59.0	56.0	80.0	70.0	.30	.20	.18
Truch (2003)	Phono-Graphix	12yr, 10 mo	1:1	80	--	83.5	--	98.8	--	.19	--
Torgesen, et al., (2003a)	LIPS+Fluency + Vis/Verb	9yr,10mo	1:1,1:2	133	72.0	76.0	96.0	85.0	.18	.07	.07
Hatcher, et al., 1994	Sound Linkage	7 yr, 6 mo.	1:1	20	--	76.8	--	83.0	--	.31	.39

Figure Captions

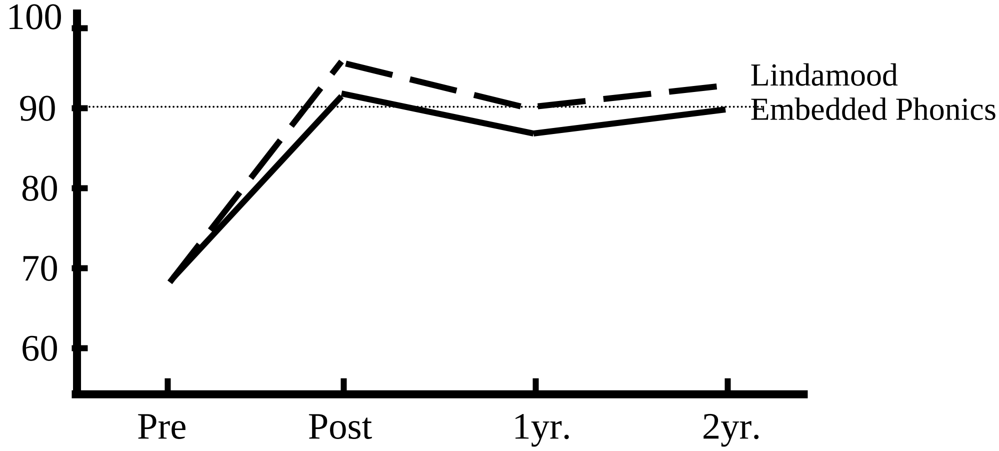
Figure 1: Standard Scores on the Broad Reading Cluster before, during, and following 67.5 hours of intensive intervention (From Torgesen, et al. (2001a). Intensive remedial instruction for children with severe reading disabilities: Immediate and long-term outcomes from two instructional approaches. *Journal of Learning Disabilities, 34, 33-58.* ADD = Auditory Discrimination in Depth, EP= Embedded Phonics

Figure 2: Growth in standard scores on measures of phonemic decoding, reading accuracy, reading rate, and reading comprehension for children receiving 67.5 hours of intensive intervention

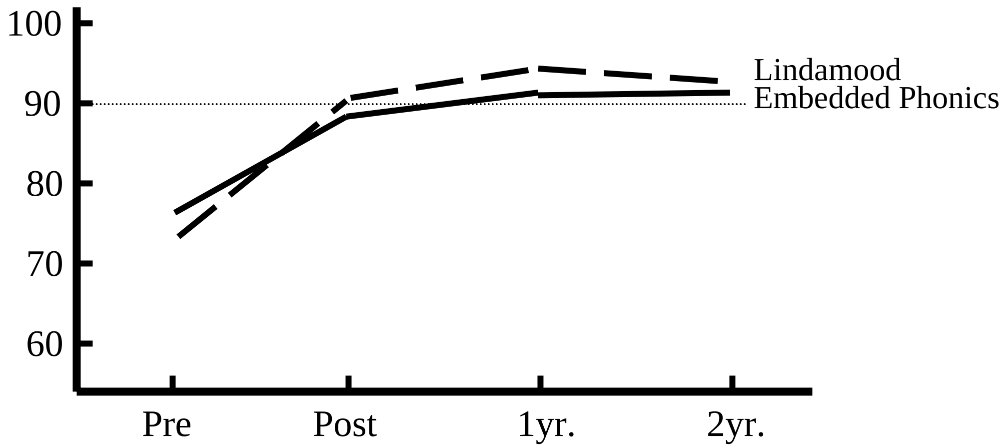
Figure 3: Outcomes for reading accuracy and reading rate from remedial and preventive studies of children with phonologically-based reading disabilities


95
90
85
80
75
Standard Score
ADD
EP
Pre-Pretest
Pretest
Posttest
1-year
2-year
Points at which reading was assessed

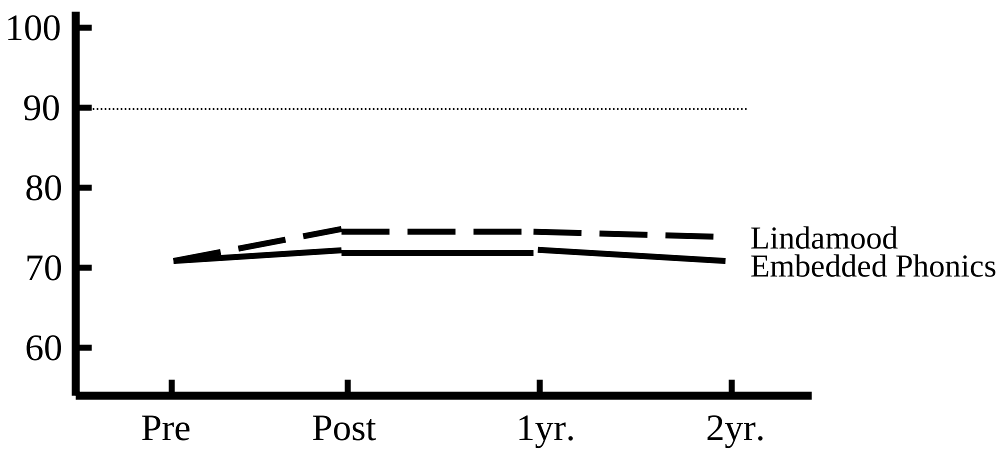
Word Attack



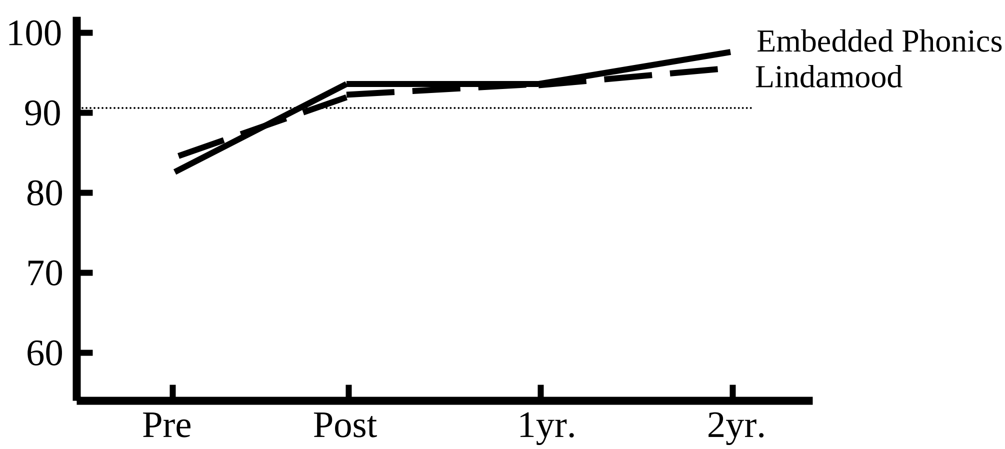
Text Reading Accuracy

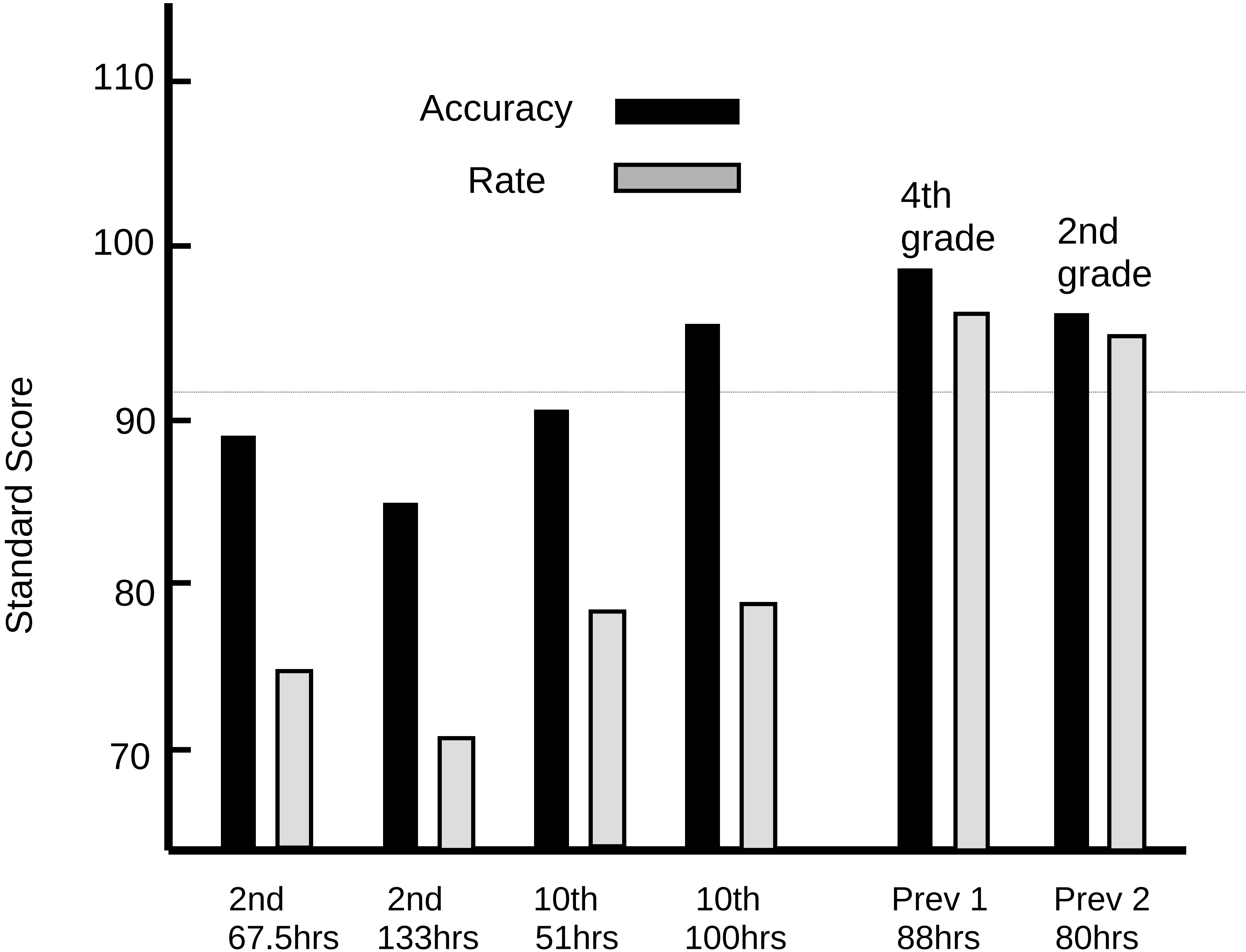


Text Reading Fluency



Passage Comprehension




Standard Score
110
100
90
80
70
Accuracy
Rate
4th grade
2nd grade
2nd 67.5hrs
2nd 133hrs
10th 51hrs
10th 100hrs
Prev 1 88hrs
Prev 2 80hrs