Focusing attention on decoding for children with poor reading skills: A study of the word building intervention

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Focusing on decoding

Abstract

This series of studies examines the reading skills of children who have deficient decoding skills in the years following the first grade, and traces their progress across 20 sessions of a decoding-skills intervention called Word Building. Initially, the children demonstrated deficits in decoding, reading comprehension, and phonemic awareness skills. Further examination of decoding attempts revealed a pattern of accurate decoding of the first grapheme in a word, followed by relatively worse performance on subsequent vowels and consonants, suggesting that these children were not engaging in full alphabetic decoding. The intervention focused attention on each grapheme position within a word through a procedure of *progressive minimal pairing* of words that differed by one grapheme. Relative to a randomized control group, decoding attempts of children assigned to the intervention condition demonstrated significantly greater improvements in all grapheme positions, and also demonstrated significantly greater improvements in standardized measures of decoding, reading comprehension, and phonological awareness. Results are discussed in terms of the consequence of not fully engaging in alphabetic decoding during early reading experience, and the 'self teaching' role of alphabetic decoding for improving word identification, reading comprehension, and phonological awareness skills.

Key Words: Phonics, Phonological Awareness, Reading Comprehension, Reading Skills, Teaching Methods

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The value of direct instruction in phonics[1] has been supported in reviews of comparative classroom studies (Chall, 1967; Adams, 1990). The value of such approaches and their emphasis on alphabetic decoding of letters to sounds is particularly evident in intervention studies with children identified as poor readers or at risk for reading failure (Foorman et al, 1998; Lovett et al., 1988). Characteristically, the most dramatic benefits of explicit phonics approaches have been demonstrated in measures of word and pseudoword reading, skills that form the foundation of the reading process (Gough, 1991; Stanovich, 1991).

Nevertheless, questions continue to be raised about phonics instruction and intervention at several levels: What are the characteristics of at risk children who might benefit most from explicit phonics? Can intervention programs be adapted to focus specifically on well-specified cognitive deficits in decoding skill? Must decoding instruction be preceded by phonemic awareness training to produce benefits? Can reading comprehension benefit from an explicit phonics approach? At the most general level, what are the key cognitive principles, rather than the specific instructional programs, that underlie successful instruction in word decoding skill for poor readers? We address these questions across a series of studies that examined decoding, phonemic awareness, and reading comprehension skills of children who demonstrated difficulty in reading after one to three years of schooling.

The goal of our first study was to develop a cognitive profile of children who had been in regular reading classrooms but failed to acquire adequate decoding skills. We focused on developing fine-grained descriptions of their decoding ability, and on understanding the relation between their decoding difficulties and three other reading-related domains: phonemic awareness, word identification, and reading comprehension. By characterizing the abilities and limitations of these poor decoders, we hoped to understand better how particular features of explicit phonics activities might lead to benefits in each of these skills. Across a battery of cognitive measures, we sought to understand what abilities these children might have mastered already and what abilities might be particularly deficient.

Children who exhibit decoding difficulties beyond the first grade may demonstrate adequate command of letter sound correspondences for individual graphemes at the beginning of a word, but fail to apply that knowledge to other positions within a word (e.g., to the second letter of an initial consonant cluster, to a final consonant in a word), and may have particular difficulty with vowels. To the extent that this is true, such children could be said to have grasped a limited form of the alphabetic principle, yet their decoding abilities are not based on *combinatorial units* that play the same role at each position within a word form. In the first study, we address this notion by analyzing poor readers' decoding skills as a function of grapheme position within words.

In the second and third studies, we investigated the impact of a particular intervention designed to address difficulties in decoding graphemes in all positions within word forms. We used a highly structured tutorial intervention that is centered on a small set of instructional principles that might be particularly well suited to the strengths and weakness of children with poor decoding skills. The activities that form the basis of our intervention study were adapted from an instructional approach called *Word Building*, developed by Isabel Beck (Beck, 1989; Beck & Hamilton, 1996; 2000) and inspired by guidance from effective practice. In the adaptation for the present study, the materials were developed into a fully scripted series of steps that could be followed by novice tutors with minimal training. In addition, a system of periodic progress exams and progression rules were introduced to modify the difficulty of materials to individual student's changing abilities on a continuous basis.

A core aspect of Word Building, described in detail in Study 2, is the principle of focusing attention on constituent units within words. This principle holds that an important goal of effectively reading words involves representing each word as a combination of familiar letter sound correspondence units. Instruction that focuses attention on combinatorial units within words may play an important role in developing representations of printed words in a way that captures enough detail of all the letter sound units to produce a reasonable pronunciation. Such instruction seeks two specific outcomes: a) that learners build accurate representations of the words they encountered by representing all the grapheme-phoneme relations that are necessary to fully specifying words, and b) that learners develop a generalized facility at employing combinatorial units at the grapheme-phoneme level that can be used to productively generate pronunciations of unfamiliar words.

The idea that the quality of a child's word representations in reading can be improved by focusing attention on combinatorial units within printed words is consistent with theoretical proposals by Perfetti (1991) and Ehri (1991). These proposals emphasize the learner's acquisition of specific visual word forms through connections between orthography and phonology at the sub-lexical and lexical levels. For example, in the Restricted-Interactive Model (Perfetti, 1991), the key development in learning to read is the acquisition of word representations whose constituent letters and phonemes become increasingly specified in all positions of each word. In this model, the development of decoding ability concurrently assists in the acquisition of specific words and helps to develop a set of resources for the pronunciation and identification of unfamiliar words.

The notion that decoding ability plays a central role in building word recognition skill was further elaborated by Share and Stanovich (1995). Their *self-teaching* hypothesis holds that facility in manipulating sub lexical letter-sound units provides a child with a reliable means of decoding an adequate pronunciation of newly encountered printed words, as well as strengthening print addressable lexical representations of previously decoded words. Thus, as children begin to efficiently decode words in terms of combinatorial units, they begin to benefit from their reading experiences in two ways: They strengthen their word decoding abilities, and they build representations of words that are more accurate and more fully specified.

The Word Building activities described later provide a chain of words that differ by a single grapheme. A child forms the words in a lessons by stepping through a scripted set of transformations that change one word into another by changing a single grapheme at the beginning, middle, and end of the word. After each transformation, the child decodes the new word, which looks and sounds similar to the previously decoded word. This activity of consecutive minimal word contrasts is designed to help children attend to the subtle impact of a single grapheme change on the appearance and pronunciation of each word.

We examined the effectiveness of the instructional principles by tracking the impact of the intervention on the cognitive reading skills profile of children with inadequate decoding skills. First, we measured the impact of their decoding proficiency for each position within word forms. Then we used standardized measures of other reading skills: word attack, word identification, phonemic awareness, and reading comprehension. In this way, we were able to assess the impact that intervention-related improvements on decoding skill have on other reading-related abilities.

In the case of phonemic awareness, there are two perspectives relevant to understanding the relationship between phonemic awareness and decoding skill. One is that phonemic awareness is causally necessary as a prerequisite to learning to decode (Liberman & Shankweiler, 1979). The other is that phonemic awareness is causally reciprocal with learning to decode and serves as an ability that supports and is supported by progress in learning to decode (Perfetti, Beck, Bell & Hughes, 1987; Wagner, Torgeson, & Rashotte, 1994). There are distinctions in the instructional implications that can be drawn from each theoretical perspective. Under the prerequisite hypothesis, gains in decoding ability will be difficult to obtain without first addressing underlying core deficits in phonemic awareness skill. Under the reciprocal hypothesis, instructional activities focused on improving decoding should lead to gains in phonemic awareness. With an increasing emphasis on the importance of phonemic awareness for learning to read (Snow, Burns, & Griffin, 1988), it is important to examine the role of phonemic awareness improvement that might take place in the present intervention. This issue is examined in depth in Studies 2 and 3.

In the case of comprehension, a simplified theoretical position holds that reading is equal to decoding plus general language comprehension, a child who learns to decode should then be able to apply spoken language comprehension processes to written language. Thus, word reading in combination with general comprehension skill should largely determine reading comprehension success, as Hoover and Gough (1990) and others have argued. In support of this view, a recent analysis of the relationship between decoding abilities and reading comprehension abilities demonstrated that these skills are generally tightly correlated during early reading (Shankweiler et al., 1999).

Nevertheless, other factors can inhibit children from transferring gains they might make in decoding activities into gains in reading comprehension. For example, Foorman et al. (1998) has documented that Title 1 children assigned to explicit phonics classroom experiences demonstrated substantially stronger decoding skills at the end of the school year than did children who participated in three other instructional control conditions. Differences in reading comprehension abilities, however, were only marginally significant, suggesting that gains in decoding skill might not always translate directly into gains in reading comprehension. Research must begin to identify potential factors that help children directly transfer gains in decoding into gains in comprehension.

Inherent in many phonics approaches is the notion that children should not experience decoding as an exercise unrelated to actual reading, but should have the chance to immediately experience the payoff of increasing their decoding repertories by encountering new “decodable” words within connected text. Thus, integrating the content between decoding activities and text reading activities may be one way to promote transfer of decoding benefits into comprehension benefits. Furthermore, tutor-guided text reading activities may encourage transfer from decoding gains to comprehension gains by helping children orchestrate their efforts both to accurately decode the words and to comprehend message information. Because the integration of decoding and text reading is an inherent part of the Word Building intervention, we can assess whether they lead to improvements in reading comprehension measures.

Study 1

The goals of the first study were to: a) select a group of children who had demonstrated decoding deficits after one to three years of schooling, b) characterize their reading-related skills across an array of measures, and c) lay the foundation for an intervention study that attempts to improve decoding skills and track changes across a wide array of reading skills.

A screening test battery was constructed to select children with poor decoding skills who did not display deficits in oral vocabulary nor had psychological difficulties such as Attention Deficit Hyperactivity Disorder (ADHD). The screening test battery included measures of word identification and decoding skill, receptive oral vocabulary, and parent questionnaires. Results of these measures determined whether or not subjects were invited to participate further in the study. Participants selected for the study then received standardized assessments of phonemic awareness and reading comprehension, plus experimental measures that tested for decoding abilities in different positions within pseudowords.

Methods

Participants

Children between 7 and 10 years of age who had completed at least the first grade yet still demonstrated reading difficulties were recruited from elementary schools in a large metropolitan area. A flyer, distributed to parents via instructional support teachers, described an intervention study for children experiencing such reading difficulties as sounding out new words and reading grade-level material. Of the 68 children who participated in the initial assessment visit, 49 met the inclusion criteria (see following Selection Measures section). Of these, 38 children volunteered with parental consent to return for additional assessments and to enter a four-month intervention study (see Study 2). To allow clear comparisons between Study 1 and Study 2, all results reported below are restricted to the 24 children who completed both the additional assessment measures and the intervention (14 male, 10 female).

Selection measures

Decoding ability was assessed with the Woodcock Reading Mastery Test-Revised (WRMT-R; Woodcock, 1987) Word Attack sub-scale. This test presents children with increasingly complex novel pseudowords. Half the subjects received Form G, the other half Form H in order to counterbalance retesting the same children in Study 2. The primary inclusion criterion required children to perform below the 40th percentile on Word Attack. Receptive oral vocabulary was assessed with the Peabody Picture Vocabulary Test-Revised (PPVT-R; Dunn & Dunn, 1981). A second inclusion criterion required standard scores of greater than 85 on the PPVT-R. The third inclusion criterion required the absence of any indication of disorders in the clinical-range of severity that might independently account for decoding difficulties. Thus, parents completed the Child Behavior Checklist (CBCL; Achenbach & Edelbrock, 1983), the Conners Parent Rating Scale, and a questionnaire concerning professional diagnoses of psychological, visual, and auditory impairments.

Additional Measures of Reading-Related Skill

Word Identification. The Word Identification subscale of the WRMT-R (forms G and H) was also administered during the initial visit to characterize children's abilities to identify relatively high frequency words, many of which are not decodable at the level of grapheme-phoneme constituents. Because there was no maximum value set as an inclusion criterion, our selection procedures exhibited a bias toward selecting children with symptoms of phonological difficulties, as well as bias against the inclusion of children with surface dyslexia symptoms.

Reading comprehension. The WRMT-R Passage Comprehension Subscale, forms G and H (counterbalanced across subjects), requires children to read short texts ranging from single sentences to complex paragraphs, and respond to each by filling in a blank embedded in the text.

Phonemic Awareness. Blending Words, Blending Nonwords, and Elision sub-tests from the Comprehensive Test of Phonological Processing were administered (CTPP, Torgesen & Rashotte, 1997). In the Blending Words test, children listened to segments of words on a tape recorder and were asked to blend them together into a word pronunciation. The Blending Nonwords test followed similar procedures, but the segments combined to form pronounceable pseudowords. In the Elision test, the experimenter read a word, and then asked the child what real word would be made if a particular phoneme was removed. (e.g., Say BRAKE; now say BRAKE without saying /r/). The Initial Sound Matching test from the CTTP presents children with a spoken sample and a corresponding picture (e.g., sun), followed by three additional spoken words with corresponding pictures. The child's task is to choose the picture that starts with the same sound as the sample. The Final Sound Matching test is identical, except that the decision is made about the final consonant. Note that the Sound Matching tests were originally designed and standardized for use with children in kindergarten and first grade, thus only raw scores (percentage correct) are reported.

Decoding graphemes in three positions within a word form. Children were also asked to read an experimental test of 128 monosyllabic pseudowords. Pseudowords were constructed by sampling words from the Word Building intervention (see Study 2) and recombining onset and rime units to form novel pseudowords. Two analyses were conducted. The first analysis scored pronunciation accuracy separately for the onset, nucleus (vowel), and coda regions of each pseudoword. Finer-grained analyses investigated the influence of position on decoding consonants in the onset and coda regions by scoring accuracy for each individual consonant. For example, 96 of the onsets contained a single consonant (gip), and 32 contained clusters of two consonants (glom). Within separate analyses of onset and coda regions, accuracy was scored separately for single consonants (n = 96), consonants that appeared in the initial position of a cluster (n = 32), and consonants that appeared in the final position of a cluster (n = 32).

Results

Table 1 displays the results of the selection measures and demonstrates an overall pattern of deficits in decoding and word identification, despite relatively adequate oral vocabulary scores.

[Insert Table 1 about here]

Table 2 displays results of the experimental pseudoword test, coded for accuracy of particular positions of grapheme-phoneme content within the word form. As illustrated in the first section of Table 2, decoding attempts were relatively accurate within the onset region, worse within the coda region, and still, and still worse within the vowel region. An ANOVA analysis demonstrated a significant main effect of region [F (2, 44) = 62.84, p < .0001, and planned comparisons demonstrated that accuracy within the onset region was superior to the vowel region [t=125.49, p<.0001] and also superior to the coda regions [t = 35.81, p < .0001]. Furthermore, accuracy within the vowel region was significantly lower than accuracy within the coda region [t = 27.24, p < .0001].

[Insert Table 2 about here]

A post hoc analysis was conducted to determine whether the effect of region could be obtained on a subset of items that were selected to ensure that the same consonants appear in the same distribution between the onset and the coda regions. This post hoc analysis was conducted on a subset of 54 single-consonant onsets (out of 96) and 54 single-consonant codas (out of 96) matched for consonant content. Accuracy scores within this subset of materials revealed superior consonant decoding accuracy within onset relative to coda regions, as demonstrated by a significant main effect of region [$F = 54.06$, $p < .0001$].

Decoding accuracy within the onset region is further broken down in the second section of Table 2, revealing that decoding was relatively accurate for word-initial consonants, whether they occurred singularly or within the context of a consonant cluster. Accuracy for consonants in the second position of an onset cluster was relatively deficient. ANOVA analyses revealed a significant effect of Position [$F(2, 44) = 31.0$, $p < .0001$]. Planned comparisons revealed that accuracy for the second position within an onset consonant cluster was significantly less accurate than decoding accuracy for onset consonants that appeared either singularly [$t = 38.1$, $p < .0001$] or within the first position of an onset cluster [$t=53.6$, $p< .0001$].

To rule out the possibility that these effects were a result of more difficult consonants appearing in the second position of onset clusters, post hoc comparisons were conducted that restricted consideration to consonants that appeared equally often in the two positions being contrasted. No significant differences were revealed from a comparison between 24 consonants that appeared equally often as either a singular consonant onset or in the initial position of an onset cluster. A similar comparison showed that decoding accuracy was significantly lower for 14 consonants that appeared in the second position of an onset cluster than when those same 14 consonants occurred as a single consonant onset [$t = 25.3$, $p < .0001$].

The bottom section of Table 2 displays accuracy for consonants within different positions of the coda region. Unlike the pattern of position effects that appeared in the onset region, position effects within the coda region were characterized by superior performance for the final letter in a word. ANOVA analyses between the three classes of coda consonant positions (singular consonant codas, the first and the second position within consonant clusters) indicate a significant effect of position [$F(2, 44) = 15.4$, $p < .0001$]. Planned comparisons revealed that decoding accuracy for the first position within a coda consonant cluster was significantly less accurate than for either single consonants [$t = 20.2$, $p < .0001$] or consonants in the second position of an onset cluster [$t = 25.7$, $p < .0001$]. Furthermore, no significant differences appeared between single consonants and consonants in the second position of a cluster.

Again, post hoc comparisons were conducted on subsets of the materials to rule out the possibility that these effects were a result of more difficult consonants appearing in the first position of coda consonant clusters. A comparison based on 21 consonants that appeared equally often in the singular consonant codas and the first position within coda consonant clusters revealed significantly poorer accuracy for the first position within coda consonant clusters [$t = 4.4$, $p< .05$]. A second analysis based on 22 consonants that appeared equally often in single consonant codas and in the second position of clusters revealed a nonsignificant trend [$t = 2.9$, $p <.10$] favoring single consonant codas.[2]

Table 3 displays the results of the passage comprehension and phonological processing measures that were not used in the selection criteria for subjects. Measures of passage comprehension abilities demonstrated poor performance (below the 30th percentile, on average). Standard scores for phonological processing revealed that these children were relatively impaired on phonemic awareness measures.

[Table 3 about here]

To compare relative abilities across the Blending Words, Blending Nonwords, and Elision tests, ANOVA analyses were conducted on z-scores for these three tests. A significant effect of test [$F(2, 63) = 3.76$, $p < .05$] revealed that children were not equally deficient across all three tasks. Planned contrasts showed no significant differences between the two blending tasks, but revealed that Elision test performance was significantly more impaired than combined performance on the blending tests ($t = 6.751$, $p < 0.01$). This result suggests that although children selected for decoding difficulties may be somewhat impaired on blending skills, impairments are more pronounced for phonological measures that require the active manipulation of phoneme content within words.

The final two rows in Table 3 display mean accuracy performance on the Sound Matching test for initial consonants versus final single consonants for spoken words. Results demonstrate that, although accuracy on initial consonants was high, matching performance on final phonemes was relatively low, as revealed by a significant main effect of Position [$F(1, 20) = 37.19$, $p < .0001$]. This result suggests that word decoding difficulties might be related to more general difficulties in attending to particular positions within spoken and written words.

Discussion

The results of Study 1 reveal an overall reading skills profile that documents the children's deficits not only in decoding skill but also in word identification, phonemic awareness, and reading comprehension. The experimental pseudoword test provides some insights into the nature of the their decoding deficits. The children appear to have mastered some aspect of the alphabetic principle, as indicated by their relative skill at decoding the first letter of each pseudoword, but they also show consistent patterns of difficulty in decoding other letter positions within word forms. The worst performance was obtained for vowels, consistent with the fact that the vowel system carries the bulk of the variable mappings difficulties of English, as well as the bulk of reading errors for normal adult readers (Fowler, Liberman, & Shankweiler, 1977).

Although accuracy for decoding consonants was also deficient, the position analyses suggest that these deficiencies were dependent on where the consonants appeared within a word form. As such, the children can be said to have grasped a limited form of the *alphabetic principle* but have not yet begun to appreciate letter-sound correspondences as *combinatorial units* so that the same unit can play a similar role in each position of a word. In the terms of Ehri's (1995,1999) stage-based account of decoding development, these children could be said to have progressed beyond the "pre-alphabetic" stage and into the "partial alphabetic stage," but to have failed to break into the "full alphabetic stage" that allows decoding efforts to be applied to all the letter positions in a word. Alternatively, incremental theories that avoid postulating discrete stages (e.g., Share & Stanovich, 1995; Perfetti, 1991) might characterize these children as failing to make wide-scope generalizations of letter sound correspondences.

Tests of phonemic awareness also revealed patterns of deficiencies. The Sound Matching results demonstrated a pattern of position effects that were very similar to the decoding measures discussed earlier. The children have mastered the phonological skills required to identify and match single consonants that appear in the initial position of words. When the same skill was assessed for simple consonants at the ends of spoken words, the children experienced much greater difficulty. Standardized phonemic awareness measures suggest that, although these children are only moderately deficient in blending skills, they are more severely impaired on tasks that require manipulating phonemes within a word, as in the Elision task.

The findings of the phonemic awareness measures suggest that children might benefit from activities that target the manipulation of phonemes to transform one word into another. Word Building activities do this by transforming one word into another through the manipulation of a single letter. Such activities simultaneously draw attention to combinatorial units within both printed and spoken words and may promote gains in decoding and phonemic awareness in tandem. Whether interventions that target decoding skills through print-based activities can have a direct impact on phonemic awareness skills remains to be tested.

Study 2 examines the impact of the Word Building intervention on the deficits revealed in Study 1. Study 2 is a between-groups experiment involving the same 24 children described in Study 1.

Study 2

We hypothesized that Word Building will lead to improvements in decoding skills for the children in this sample, based on four assumptions about the cognitive skills of these children: 1) they fail to attend adequately to grapheme-phoneme units in positions beyond the initial grapheme; 2) they have limited decoding abilities that are easily disrupted by processing more than one or two graphemes at a time; 3) they have difficulties decoding vowels consistently; 4) they have limited phonological abilities that prevent them from easily parsing vowels, codas, and consonant clusters.

These four considerations suggest that the particular principles employed in Word Building were particularly well suited for these children. In addition to our hypothesis that the word building intervention should improve decoding skills, we also hypothesized that the principles inherent `in the intervention might act simultaneously to develop full alphabetic decoding, as well as improved phonemic awareness skills. We also hypothesized that focusing intervention on decoding skill might lead to benefits in reading comprehension, based on the notion that comprehension is directly dependent on efficient word recognition abilities (Perfetti, 1985).

Materials

Word Building materials used in this study were adapted from Beck and Hamilton (1996). The intervention consists of a set of 77 lessons divided into 23 units that progressively incorporated more difficult grapheme-phoneme units and word forms (e.g., from Consonant Vowel Consonant (CVC) to CCCVCC). The first 10 units focused on short vowels; the next 5 introduced long vowel sounds controlled by silent e; the next 4 units dealt with vowel digraphs (e.g., ee, ai, oa, ow, oy); and the final 4 units involved changes in vowel sounds in different phonetic environments (i.e., changes in vowel pronunciation when a vowel is followed by an r).

Within each lesson, children are given a small set of letter cards from which they build words as directed by the tutor. After the child forms a word and successfully reads it aloud, the tutor instructs the child to insert, delete, or exchange a single letter card which transforms the current word into the next word in the lesson sequence. The process, which is based on consecutive minimal word contrasts, continues as each word is in turn transformed into a new word. By decoding a word that contains a single new letter, while remaining otherwise identical to the previous word, the child's attention and decoding efforts are focused on the role that the new letter plays in the new word's pronunciation. Figure 1 displays an example of how a chain of single letter transformations successively focuses a child's attention on each letter position, including the medial vowel position.

[Figure 1 about here]

The sequences of letter changes were developed so that, when possible, attention is drawn to each position within a word form (i.e., to the initial consonant, final consonant, vowel, initial, or second consonant within an onset or coda cluster). Furthermore, the letter changes were designed, to the extent possible, to ensure that the same letters that appear in the initial position of words also appear in other positions..

Methods

Participants

The same 24 participants described in Study 1 voluntarily participated in Study 2 between July and October.[3] Intervention and Control groups were formed via an iterative random assignment procedure that assured the groups were well matched for age, sex, and the array of pretest measures. The group assignment procedure was conducted with the initial sample of 38 children who volunteered for the study. The two groups suffered substantial attrition over the four months of the study, largely due to parents' difficulty in transporting children to the study location, creating a potential source of group differences. Fortunately the two groups (12 in each) remained well matched for age and sex (7 males and 5 females in each group), and on the entire array of pretest measures. All group comparisons resulted in t-values < 1, with the exception of the Elision task, in which a non-significant trend suggested that the control group may have performed slightly better (Elision z-scores, $t=1.26$, $p<0.28$). The Intervention group participated in 20 intervention sessions over 4 months, whereas the Control group was assigned to a waiting-list to receive a similar intervention the following semester.

Post-test measures

The same measures reported in Study 1 were administered a second time when the intervention was over, except for the PPVT and parent questionnaires. Two participants in the Control group did not return to complete their post-test phonemic awareness test, and thus are not represented in the data reported below.

General Procedures

Participants in the Intervention group were scheduled to participate in 20 tutorial sessions lasting approximately 50 minutes each, as frequently as three sessions per week, plus four additional sessions for testing purposes. Participants completed the 24 visits within 14.2 weeks on average (range of 8.9 to 18.9, SD = 3.3). Each child was paired with an undergraduate tutor who participated in the study for credit or an hourly wage. Most tutor-student pairs remained constant during the intervention. All tutoring took place in a separate quiet room as parents or guardians remained in a nearby waiting area. The laboratory reading center was located on the campus of a large university in a large city in Northeastern U.S. Participants in the Control group were given educational materials from the America Reads Program, and their parents were encouraged to seek any reading support they wanted while their child was on the waiting list.

Intervention procedures

In the current adaptation of Word Building , the intervention was scripted into step-by-step instructions and decision-making algorithms that could be administered with minimal training by college undergraduates working as volunteer tutors. As noted earlier, at the beginning of a lesson, tutors presented each child with several letter cards to be used during that lesson and reviewed their associated sounds. Then the tutor instructed the child to "build" words as illustrated in Figure 1.

Throughout the Word Building activities, if children had trouble decoding a word, the tutors avoided pronouncing the word and instead helped scaffold the children's decoding attempts through a small set of activities. When children failed to make an attempt at pronouncing a word, the tutors encouraged them to attempt a pronunciation based on their knowledge of the letter sounds. When children struggled to combine letter sounds, tutors guided them through the process of progressively blending them together. When children misread a word as a similarly spelled word, the tutors wrote out both the target word and the erroneous word and encouraged the children to analyze the differences between the two words.

Each lesson concluded with reading sentences that contained a high proportion of words that had just been decoded and others that could be decoded given the material the child had covered thus far. Some non decodable words (i.e., words that could not be decoded based on the child's decoding repertoire) were included. For all decodable words, the tutor encouraged the child to decode the word and, as needed, provided help in the form of scaffolding activities noted earlier. If necessary, tutors pronounced non decodable words. Sentences usually took the form of silly questions (e.g., Can a sick kid kick a stick?). After the child successfully read a sentence, the tutor and child engaged in a discussion about the meaning of the sentence.

After completing a word building sequence, the tutor administered a brief "flashcard" assessment to determine whether the child could read at least 80% of the lesson words correctly. If the accuracy criterion was not met, more word building activities were carried out with those words.

Children progressed through the materials at their own pace, determined by lesson assessments and unit pretests and posttests and by the lesson flashcard assessments. At the beginning of each unit, children were given a pretest of words sampled from the unit lessons. If decoding accuracy was 90% or greater, the child was permitted to skip that unit and progress to the next unit pretest. If accuracy was less than 90% on a unit pretest, the child was given the lessons of that unit. On completing the unit lessons, the child took a unit posttest. The same 90% accuracy criterion was used to determine if the child could progress to the next unit pretest or needed more time on the current unit. These promotion and retention algorithms functioned continuously to adapt the difficulty level of materials to the child's ability.

Results

Each set of measures was subjected to a repeated measures ANOVA contrasting Group (Intervention vs. Control) as a between-subjects factor and Time Span (July pretest vs. October posttest) as a within-subjects factor. Effects that are specifically related to the intervention are expressed in Group x Time Span interactions.

Intervention Effects on decoding skill: Experimental pseudowords

We assessed the degree to which children made improvements in decoding accuracy for different positions within a word form by examining accuracy changes in the experimental pseudoword reading test. Figure 2 demonstrates changes in decoding accuracy in the onset, nucleus (vowel), and coda regions over the course of the intervention time span.

[Figure 2 about here]

Participants in the Intervention group showed larger decoding improvements than participants in the Control group, in all three regions of word forms, leading to a significant Group x Time effect [F (1, 22) = 17.1, $p < .0005$]. These results demonstrated that the intervention was successful at improving decoding abilities in the onset, vowel, and coda regions of the word form. A significant Region x Group x Time interaction [F (2, 44) = 6.0, $p < .005$] indicated that the Intervention group improved more rapidly for vowel and coda regions than for onset regions. Given that the Intervention group post-test accuracy for onset regions was near 100%, this interaction likely reflects a ceiling effect in mastering onset pronunciations. Figure 3 demonstrates changes in decoding performance in three consonant positions (i.e., singular, initial position in a cluster, second position within a cluster) that occur in the onset and coda regions.

[Figure 3 about here]

Results in the onset region show that difficulties in decoding the second position in an onset cluster persisted in the Waiting-list control group, whereas the Intervention group demonstrated dramatic gains in this position. The observation is supported by a significant Position x Time x Group interaction [F (2, 44) = 8.1, $p < .001$)]. Results in the coda region indicate that the difficulties in decoding consonants persisted in the Waiting-list control group, including less accurate decoding of the first consonant of a coda consonant cluster. The Intervention group, however, demonstrated improvements in all three positions, leading to a significant Time x Group interaction [F (1, 22) = 8.7, $p < .01$].

Taken together, the various analyses of position effects on decoding accuracy converge to indicate that deficient decoding abilities for grapheme positions beyond the initial grapheme tended to persist over time in the absence of direct intervention, and that the intervention led to improvements in the application of decoding skills within each position of a word form.

Intervention Effects on Standardized Measures of Reading Skills

In addition to the Group x Time Span repeated measures ANOVA analyses described earlier, the standardization information revealed by the WRMT-R subscales provided a means of quantifying the number of children in each group who demonstrated significant improvements over the four month intervention period, by allowing raw scores to be converted into grade equivalence scores. We developed an a priori learning criterion that enabled us to determine whether each child advanced beyond what would be expected of a typical child over a similar time span. Because the intervention spanned a period of less than four months, children who demonstrated improvements exceeding one third of a grade level were classified as passing the learning criterion. Non-parametric (Chi-square) analyses were used to compare the proportion of children in each group who passed the learning criterion. The Chi-square analyses are presented as a complement to the ANOVA analyses because they place less emphasis on the magnitude achieved by a minority of children and greater emphasis on the proportion of children who achieved a desirable outcome.

Word Attack (Decoding)

Changes in decoding skills were first assessed by repeated measures ANOVA analyses of the Woodcock Reading Mastery Test-Revised (WRMT-R) Word Attack Subscale. Table 4 tabulates mean performance. ANOVA results are summarized in Table 5. As indicated on the tables, the Intervention group demonstrated significantly larger improvement in Word Attack scores relative to the control group.

[Tables 4 and 5 about here]

Figure 4 illustrates the pretest and postest data for individual children, graphically illustrating that participation in the intervention led to gains for all participants, ranging from nominal improvements to several grade levels, whereas the control group demonstrated fewer improvements over the same time span.

[Figure 4 about here]

Correlation analyses revealed no significant relationship either between pretest scores and the magnitude of gains in either group or across the subjects as a whole, suggesting that the intervention-based gains were equivalent across the range of skills that children displayed before the intervention began

The learning criterion analysis (already described) demonstrated that 11 of the 12 children in the Intervention group produced gains that surpassed the one third grade level learning criterion. During that same time only 4 of the 12 children in the Control group passed this criterion. Chi-square comparison demonstrated that the proportion of children in the Intervention group who surpassed the criterion was significantly greater than in the Control Group ($p < .01$).

Word Identification

As indicated in Table 6, both groups of children on average produced less than 0.2 grade levels of improvement in word identification. Results of ANOVA analyses summarized in Table 7 demonstrate that these small improvements led to only a marginally significant Time Span main effect (for grade equivalence measures only). Furthermore, the ANOVA results provide no evidence to support the notion that the intervention produced direct benefits for the word identification measure.

[Tables 6 and 7 about here]

Figure 5 presents pretest and postest scores for individual children on the Word Identification test. The graph demonstrates that very few children in the Control and Intervention groups surpassed the one third grade level learning criterion. Only 1 of 12 children in the Control Group and 2 of 12 children in the Intervention group demonstrated improvements exceeding the learning criterion. A Chi-square analysis revealed no significant group differences in the proportion of children passing the learning criterion.

[Figure 5 about here]

Results of the Word Identification test stand in stark contrast to the results of both the experimental Pseudoword test and the Word Attack subscale of the WRMT-R. One explanation for this discrepancy is that the Word Identification test contains a high proportion of irregular or inconsistent words that cannot necessarily be read more accurately by enhancing grapheme-phoneme decoding skills. Of the 126 test words from forms G and H of the Word Identification test that fell within the range of improvements for the children in this study, approximately 60% of these items were non-decodable using the grapheme-phoneme elements trained in the 77 lessons of the intervention.[4] This suggests that the items on the Word Identification test are not necessarily sensitive to gains in decoding words with regular pronunciations.

Passage Comprehension

As summarized in Table 8, the Intervention group demonstrated an average gain of 0.8 grade levels of improvement on the Passage Comprehension subscale of the WRMT-R, whereas the Control group demonstrated an average gain of only 0.2 grade levels. ANOVA results summarized in Table 9 show a significant interaction between Group and Time for raw scores, suggesting that children randomly assigned to the Intervention group experienced significantly greater improvements in Passage Comprehension than did the subjects who were randomly assigned to the Control group condition. When results were translated into Grade Equivalent scores, this significant effect became a nonsignificant trend in the same direction.

[Tables 8 and 9 about here]

An examination of individual subject data plotted in Figure 6 demonstrates that Control group overall gains can be largely attributed to the improvements of two subjects, whereas gains for the Intervention group were more broadly distributed across the group. Application of the learning criterion revealed that 9 of 12 children surpassed the learning criterion of one third grade level of improvement during the intervention. A Chi-square comparison between the Control and Intervention groups demonstrated a significant effect of group assignment on the number of children passing the criterion ($p < .01$). Correlation analyses demonstrated no significant relationship between the magnitude of gains and the magnitude of pretest scores in either of the groups, suggesting that children who started off with the highest (or lowest) pretest scores were not necessarily producing the most (or least) gains. A Chi-square comparison between the Control and Intervention groups showed a significant effect of group assignment on the number of children passing the criterion ($p<.01$).

[Figure 6 about here]

The overall pattern emerging from our analyses of the Passage Comprehension subtest indicates that participation in the intervention led to marginally significant increases in performance under the ANOVA analysis, and to robustly significant results under the Chi-square analysis. The large gains produced by 2 of the 12 children in the Control group contributed to the lack of sensitivity of the ANOVA results. In such cases, nonparametric tests, which do not rest on assumptions of homoscedacity, are more appropriate. Nevertheless, the Control group demonstrated that a minority of individuals can produce dramatic gains without the benefits of this particular intervention. In contrast, the gains demonstrated in the Intervention group appear to be broadly distributed across most members of the group.

Phonemic awareness Measures

Table 10 summarizes the results of the three phonemic awareness standardized subtests from the CTTP: Blending Words, Blending Nonwords, and Elision. An examination of the mean Raw and Standard scores reveals that the Intervention group gained roughly 0.75 z-scores across all three measures, whereas gains of the Control group were minimal in all but the Blending Words subtest. Results from each subtest were analyzed separately, as summarized in the next three paragraphs.

[Table 10 about here]

Blending Words

As shown in the first section of Table 10, both the Intervention and the Control groups demonstrated improvements on the Blending Words Subtest. Standard scores were submitted to repeated measures ANOVA analysis, revealing a significant main effect of Time [$F\ (1, 20) = 13.2, p < .001$]. Although the Intervention group gains were slightly larger than the Control group gains, the Group x Time interaction did not approach significance [$F\ (1, 20)\ p < 1$]; thus, these data do not directly support an association between the gains observed in Blending Words and participation in the intervention. Figure 7 illustrates pretest and postest standard scores for each individual in the Intervention and the Control groups.

[Figure 7 about here]

Blending Nonwords

Results of the Blending Nonwords test are tabulated in the second section of Table 10. Standard scores were submitted to repeated measures ANOVA analysis to determine the impact of the intervention on Blending Nonwords performance. Improvements for the Intervention group were significantly larger than improvements for the Control group, as evidenced by a significant Group x Time interaction [F (1, 20) = 4.417, $p < .0485$], which in turn supported a marginally significant main effect of Time [F (1, 20) = 3.801, $p < .065$]. Individual subject plots presented in Figure 8 demonstrate that the benefits attributable to the intervention are broadly distributed across the individuals in the Intervention group.

[Figure 8 about here]

Elision

The Elision test requires children to manipulate phoneme information to transform one word into another. As summarized in the third section of Table 10, participation in the Intervention group led to substantial gains in Elision test performance. This observation is substantiated by repeated measures ANOVA analyses of standard scores, which demonstrated a significant Group x Time interaction [F (1, 20) = 5.0, $p < .037$].

[Figure 9 about here]

As illustrated in Figure 9, the individual subject data demonstrate gains in Elision standard scores that are broadly distributed among most subjects in the Intervention group and fail to show a systematic correlation between magnitude of gains and starting pretest scores.

Discussion

Study 2 generally demonstrates that the Word Building intervention improved many of the skill deficits children demonstrated in the cognitive profile of Study 1. Most notably, children who participated in the intervention mostly overcame their limitations in decoding graphemes in all positions of the experimental pseudoword test. These benefits were also demonstrated by an improvement of 1.2 grade levels in standardized measures of decoding, suggesting that focusing attention on combinatorial units within words had a substantial impact on decoding ability.

Results of the three phonological processing measures together generally indicate that although children in the Control group demonstrated significant improvements for Blending Words during the intervention, gains for the Control group were restricted to blending familiar words. When blending was examined in a context that increased phonological demands by using novel pseudowords, the Control group's gains were significantly inferior to the gains of the Intervention group. Furthermore, the Control group's failure to demonstrate significant improvements on the Elision task suggests that the deficits demonstrated in Study 1 are rather persistent, and that whatever accounted for their enhanced performance at blending words did not lead to improvements in more demanding phonemic awareness tasks. Taken as a whole, results of the phonemic awareness measures suggest that Word Building procedures can not only lead to substantial gains in decoding but, at the same, time to improved phonemic awareness skills. The phonemic awareness skills most affected appear to require phonemic analysis, in accord with the causally reciprocal model of the relation between reading and phonological awareness (Perfetti, Beck, Bell, & Hughes, 1987).

Gains for reading comprehension in the Intervention group suggest that Word Building was successful at helping children to enlist their improved decoding skills in the service of comprehending text. Given the nature of the Passage Comprehension subtest, which requires children to read text and fill in missing words, at least a portion of the gains observed likely reflect more accurate decoding of the words in each passage. Additionally, a portion of the comprehension gains may have resulted from the tutor-directed sentence reading activities in which tutors repeatedly asked children to elaborate on the meaning of each sentence.

One exception to the Intervention group's improvements in phonemic awareness, decoding, and comprehension lie in the results of the Word Identification measure, which includes a high proportion of words with inconsistent spelling-to-sound correspondences and a large number of polysyllabic items. During the four months of Study 2, neither the Intervention group nor the Control group demonstrated significant improvement on this measure. This pattern may be the result of intervention's nearly exclusive focus on monosyllabic words containing consistent spelling-to-sound patterns. This finding points to limitations of the intervention which are explored in Study 3.

The strength of the conclusions of Study 2 might be limited by the small sample size remaining at the end of the four month study. With such a small sample in each group, the results of the 12 children who were randomly assigned to the Intervention group may not be representative of gains expected from the overall population of children defined by the selection measures. Furthermore, the small sample size in Study 2 also raises the possibility that participants in the Control group were inherently less likely to improve over time than were participants in the Intervention group. Thus, Study 3 was designed as a replication to include children who had been controls in Study 2.

Study 3

The purpose of the third study was to assess whether the gains observed for the Intervention group in Study 2 (Cohort 1) could be replicated with the Waiting list Control group (Cohort 2) participating in a similar intervention. Study 3 employed the same general procedures applied to the Intervention group in Study 2 but also introduced several modifications designed to enhance transfer of grapheme-phoneme decoding from lesson activities to naturalistic text reading, thereby potentially enhancing word identification skills.

Methods

Participants

Initially, the 12 children who participated in the Waiting List Control group of Study 2 were invited to participate in an improved version of the intervention. Eight participants from the Study 2 Control group accepted and completed the intervention protocol of Study 3. The parents of three participants did not to enroll their children in the intervention, primarily due to difficulties meeting transportation demands. These three children were replaced by three new participants who met the inclusion criteria outlined in Study 1 and were recruited to bring the total to 12 participants.

Intervention Procedure

From January to April, intervention sessions took place after school hours. The intervention was the same as that of Study 2, except for three modifications that were introduced to enhance the effectiveness of the intervention. First, the curriculum was substantially shortened, from 77 to 51 lessons, by deleting lessons containing highly redundant content with adjacent lessons. This change was introduced to allow participants to cover more grapheme-phoneme content at the expense of receiving less instruction on particular content. Second, six new lessons were added to the end of the materials to target multisyllabic words. However, only 4 of the 12 participants progressed rapidly enough to participate in these final six lessons. Third, lesson activities described in Study 2 were supplemented by two additional activities: short books and homework sentences. Specifically, after completing each activity in a lesson, children read aloud a short book under the tutor's supervision. Books selected from the Collections for Young Scholars Minibook Series (Open Court Publishing Company, 1995) were paired with lessons based on the overlap between grapheme-phoneme content. Additionally, as children completed each session they were given a single page containing sentences such as those described in Study 2 and asked to read them to their parents at home.

Pretest and postest measures

The same reading skill measures reported in Studies 1 and 2 were administered prior to the January intervention and again on completion of the intervention in April or early May of the same year. The same phonemic awareness measures were also applied, but only 8 of the 12 children contributed complete pretest and posttest data to these measures. Due to an error, two children in Intervention Cohort 2 did not receive pretesting on the phonemic awareness measures. Additionally, post-testing was compromised for two additional children: one failed to return for the final post-test session, and another child's data was excluded on the basis of a tutor report of untypical oppositional behavior during the final testing session.

Results

Given that the primary goal of Study 3 was to replicate the intervention gains demonstrated in Study 2, our analyses focus on whether a new group of 12 participants (Cohort 2) would produce similar gains. To this end, we conducted repeated measures ANOVA analyses including the factors of Time Span (before and after intervention) and Cohort (Cohort 1, Cohort 2). Although improvements that are similar across both intervention cohorts will contribute to main effects of Time, differences between the two cohorts will manifest as Time x Cohort interactions.

Decoding Experimental Pseudowords

As illustrated in Figure 10, the second cohort's performance on the experimental pseudoword reading test demonstrated improvements during the intervention that closely replicate the magnitude and pattern of change demonstrated in by the first cohort.

[Figure 10 about here]

The first panel in Figure 10 summarizes results separately for onset, vowel, and coda regions. ANOVA comparisons show that the Intervention group demonstrated changes in the relative accuracy pattern across the three regions, as demonstrated by a significant Region x Time interaction [F (2, 44) = 22.6, $p < .0001$]. Thus the intervention reliably improved children's decoding efforts in medial and final positions within word forms. The central panel in Figure 10 summarizes decoding performance before and after intervention for consonants that appear in three different classes of consonants in the onset. As was the case for the first intervention cohort, the second cohort demonstrated the greatest gains for the second position in an onset cluster, supporting a significant interaction between Onset Phoneme Type and Time Span [F (2, 44) = 24.8, $p < .0001$)].

The third panel in Figure 10 illustrates decoding accuracy for three classes of coda consonants, showing a replication of the pattern of gains initially demonstrated by the first intervention cohort. ANOVA analyses demonstrated a robust effect of Time Span [F (1, 22) = 47.4, $p < .0001$], whereas Cohort had no effect. A significant Time Span x Position interaction [F = (2, 44) = 5.9, $p < .005$], which also demonstrated no interaction with the Cohort factor, was driven by the gains being more rapid for the initial position in coda consonant clusters than for the other classes of coda consonants. The only cohort effect to approach significance did not involve Time Span as a factor. A significant interaction between Coda Consonant Position and Cohort [F (2, 44) = 4.6, p < .02] was present. Although both intervention cohorts demonstrated a systematic tendency to perform less accurately on the first (vs. second) phoneme within coda blends, the two cohorts differed (perhaps inexplicably) on their performance for solitary coda phonemes relative to coda blend phonemes.

Overall, results across all three analyses of the experimental pseudowords reveals that the second intervention cohort demonstrated gains in decoding ability that were statistically equivalent to the gains of the first intervention cohort in Study 2.

Standardized measures of reading skill

As summarized in Table 11, the participants in Cohort 2 made clear gains across all three standardized measures of reading skills. Table 12 presents the results of the ANOVA analyses that examined Time Span and Cohort effects for intervention Cohorts 1 and 2. Overall, significant Time Span effects are present for all three measures, indicating that, taken as a whole, the intervention subjects made significant progress in decoding, word identification, and reading comprehension. No Cohort effects appeared for measures of Word Attack or Passage Comprehension, indicating that the gains of the second cohort were at least statistically equivalent to the gains of the first. In contrast, gains for Cohort 2 in Word Identification were far greater than for the first cohort, leading to a significant Time Span x Cohort interaction.

[Tables 11 and 12 about here]

Figure 11 illustrates changes in each child's grade equivalence score for Word Attack, Word Identification, and Passage Comprehension measures of the WRMT-R. For each measure, the proportion of children who surpassed the one third grade level learning criterion were calculated and that proportion was compared with the first and second intervention cohorts in a series of Chi-square analyses. Word Attack subtest results showed that 11 of the 12 children in the second cohort surpassed the learning criterion, demonstrating a clear replication of the intervention results with no significant differences between the two intervention cohorts. Similarly, Passage Comprehension results measures revealed that 9 of the 12 children in Cohort 2 surpassed the learning criterion.

[Figure 11 about here]

Chi-square analyses indicated no significant differences between the proportion of children in each cohort who surpassed the learning criterion, suggesting that the intervention reliably led to broad, consistent improvements in reading comprehension. The Word Identification subtest grade equivalence scores indicated that 7 of the 12 children in Cohort 2 surpassed the learning criterion, a significantly greater proportion of children than in the first intervention cohort (Chi square <.01).

Phonemic awareness

As summarized in Table 13, the results of the phonemic awareness assessments for Cohort 2 reveal improvements across all three measures that roughly parallel the improvements of the first intervention cohort. Table 14 presents the results of ANOVA analyses.

[Tables 13 and 14 about here]

Results of the phonemic awareness measures show that, as a combined group, the children who participated in either intervention demonstrated significant improvement in all three measures of phonemic awareness measures, as indicated by the significant main effects of Time across all three measures. In addition, there were no significant Time x Cohort interactions, suggesting that the gains in phonemic awareness demonstrated by the first intervention cohort were replicated in the second.

[Figure 12 about here]

Individual subject data for the three pseudoword tests are presented in Figure 12 for illustration purposes. It should be noted that the phonemic awareness analyses are less sensitive to potential Cohort effects than the other analyses reported earlier, because fewer subjects provided complete pretest and posttest data for the phonemic awareness measures.

Discussion

In most respects, the results of Study 3 replicated the results obtained for the Intervention group in Study 2. The results of the experimental pseudoword test and the standardized decoding measures demonstrated improvement during the study that were statistically equal to, and nominally larger than, the decoding gains demonstrated by the first Intervention cohort. Similarly, reading comprehension gains were statistically equivalent for the first and second intervention cohorts. The overall pattern of phonemic awareness results was also similar across the two intervention cohorts. The strength of this phonemic awareness replication, however, was somewhat compromised by the small number of subjects who participated in this test.

One substantial difference between the two intervention cohorts was in the extent to which participants in the first and second cohort improved their performance on the Word Identification test. Word Identification gains in Study 3 far surpassed the gains of either group in Study 2. The differences in performance on this measure are potentially linked to modifications made in the intervention procedures for Study 3 (i.e., faster progression through the lessons, book reading, sentence homework). Given that our waiting list control design introduced a time lag between the first and second intervention cohorts, it is not possible to separate differences associated with changes in intervention techniques from differences associated with time-of-year effects.

Overall, the findings of Study 3 support many of the conclusions from Study 2 concerning the benefits of the intervention on a wide array of reading-related skills. Furthermore, the results of Study 3 suggest that most children in the Control group of Study 2 benefited from the intervention to the same extent as the children in the first Intervention group. Therefore the results of Study 2 are not likely to reflect latent differences between the Control and Intervention groups.

General Discussion

These studies provide evidence for the effectiveness of a particular approach to the teaching of decoding, Word Building. Gains were observed in decoding, phonemic awareness, and passage comprehension. Comparisons with a randomly assigned waiting list control group demonstrated that the benefits were the direct result of participation in the intervention. Replication of the intervention results with the waiting list control group established the reliability of the central results on which we base our conclusions.

Beyond testing the effectiveness of an intervention, however, our studies have aimed to contribute to understanding the nature of decoding difficulty. What goes wrong for children who fail to engage in full alphabetic decoding and how does this inhibit overall reading achievement? Why does an intervention that focuses a child's attention on decoding grapheme-phoneme units in all positions within words have a substantial impact on many reading-related skills? What instructional principles mediate effective intervention for poor readers?

In addressing these questions, we draw upon a theoretical framework of normal reading development that is shared by several theorists (i.e., Perfetti, 1985, Share & Stanovich, 1995; Ehri, 1995, 1999). The framework views alphabetic decoding as a central skill in reading development, primarily because of the critical role that decoding plays in the process of self teaching. The self teaching framework holds that as children engage in the process of attending to all the elements in a word, they are able to use reading to teach themselves unfamiliar printed words. It also helps them to build and refine representations of words that occur often. In this framework, alphabetic decoding skill is continually engaged during the reading experience of the normally developing reader, thus making decoding skill and reading experience mutually essential for acquiring a high level of reading achievement. Thus alphabetic decoding ability serve as *boot strapping* (Share, 1995) mechanisms that allow reading skill to progress from early to expert stages over several years of reading experience.

This framework of normal reading development is potentially useful for understanding reading impairments. Fine-grained analyses of decoding skills provide some potentially important observations that help explain why the children in this study did not develop reading skill at a normal rate. Study 1 demonstrated that, when these children encounter unfamiliar word forms, they engaged in strategies that Ehri classifies as reflecting a partially alphabetic decoding stage. Although the children might actively focus attention on decoding the first letter of a word, they do not actively apply decoding strategies to each letter in a word. They likely use this minimal decoding information during reading as one constraint in their word recognition processes. In this way, the children might fail to benefit from the self-reinforcing aspect that comes from continually applying alphabetic decoding skills across all letters in a word. Furthermore, by failing to engage in full alphabetic decoding, the children fail to benefit fully from the self-teaching mechanism that full alphabetic decoding provides to normally developing readers. This explanation is consistent with the pattern of results demonstrated by the Control group over the 4 months of observation in Study 2. The effects of letter position on their word decoding accuracy remained highly stable during the observation period, as did their overall decoding ability.

One implication of the framework is that intervention procedures that encourage and scaffold the process of full alphabetic decoding should help children benefit from their reading experiences in ways that both help to further develop their decoding skills and help them to engage in more efficient self-teaching. The children in the first and second intervention cohorts produced dramatic improvements in overall decoding ability and demonstrated that these improvements accrued in every letter position within a word form.

What instructional principles account for Word Building helping children with poor reading skills to make advances in their decoding abilities? We suggest that manipulating a single grapheme at a time in the consecutive minimal contrast procedure may help to scaffold the process of decoding graphemes, regardless of where in a word they are positioned applying single grapheme change technique to a different position in each trial begins to address the children’s fundamental stumbling block: the inability to decode graphemes in medial and final positions. The basic principle of progressive minimal contrast is combined with materials that gradually increase in difficulty (e.g., the complexity of vowels is slowly and systematically introduced across the entire intervention) and with adaptive techniques that continually adjust the difficulty of the material to match the child's increasing abilities.

Given the nature of the intervention and the focus on scaffolding decoding abilities to eventually encourage full alphabetic decoding, it is perhaps not surprising that large decoding improvements were observed. The benefits of participating in the intervention, however, were not restricted to decoding abilities. One skill area in which the intervention led to significant gains without explicit training was phonemic awareness.

The fact that an intervention that focuses on alphabetic decoding has an impact on phonological awareness measures might seem at odds with the literature that points to phonological awareness as a causal precursor to reading skill (i.e., Liberman & Liberman, 1990; Liberman, Shankweiler, & Liberman, 1989). Research on phonological awareness training provides evidence for a causal link; students who receive phonological awareness training prior to reading instruction show higher early reading achievement (Cunningham, 1990; Lundberg, 1994). Such research supports the use of teaching practices that engage children in analyses of spoken words (Adams, 1990; Snow, Burns & Griffin, 1998). Once reading experience begins, however, the process of actively decoding an alphabetic orthography may begin to influence phonological awareness (Morais, Cary, Algeria, & Bertelson, 1979; Perfetti, Beck, Bell, & Hughes, 1987). One mechanism for this influence is the increasing pressure that decoding places on the phonological system to represent phoneme units *within* words.

In the Reciprocal model of the relationship between phonological awareness and decoding, the degree to which children engage in alphabetic decoding may be especially important in forcing phonological awareness abilities to progress beyond syllable and onset-rime units to phoneme units. This may be why alphabetic decoding plays a critical role in the development of more analytic forms of phonological awareness, such as the Elision task (Perfetti, Beck, Bell, & Hughes, 1987). Thus, the reciprocal hypothesis of the development of decoding and phonological skills provides a potentially useful explanation of how benefits in decoding ability might lead to gains in phonological awareness skills. When children are encouraged to engage in full alphabetic decoding, they place increasing pressure on their own phonological abilities to represent phonemes in each position of a word.

This general account for decoding-based gains in phonological awareness can be supplemented by a more specific possibility raised by our studies. As already emphasized, a key component of the Word Building intervention is that it directs attention to phonemes not merely in connection with graphemes but also in connection with position-specific graphemes. Because an entire word is visible and only one letter has been changed from previously visible words, phoneme manipulation is given strong support. This should be especially helpful for phonemes internal to the syllable. Simultaneously seeing a letter and hearing the phoneme that is responsible for a new word should support a fuller phonological representation connected to a word's spelling. This may draw the child's attention to the task of analyzing spoken words as a collection of segmentable, combinatorial phoneme units.

The practical issue that is relevant here involves carrying out phonological awareness training as an activity by itself or integrating it with reading instruction. Successful intervention results have been shown for phonological awareness alone (Bentin & Leshem, 1993; Hurford et al, 1994) and for interventions that combine phonological awareness with printed letters (Ball & Blachman, 1991; Torgesen, Morgan, & Davis, 1992). Whether the integrated approach (phonological awareness in the context of print) produces better reading outcomes than phonological awareness only in the context of speech is difficult to decide based on the available research. Activities centered exclusively on spoken words may be suited for developing early forms of phonological awareness that typically precede full alphabetic decoding. However children who have not been introduced to the relationship between speech and print normally fail analytic phonological awareness tasks (but not blending), and this is precisely the level of phonological awareness most likely to be supported by explicit decoding instruction. Thus, when targeting students who have begun formal reading instruction, combining print and speech in activities that focus attention on individual grapheme-phoneme units may have an advantage.

What principles inherent in the intervention led to an increase in comprehension scores? Reading comprehension measures provide another domain in which the Intervention group demonstrated gains surpassing both the control group and the one third grade-level criterion. The reading comprehension gains here contrast with similar intervention studies demonstrating clear gains in decoding skills but marginally significant gains in reading comprehension (i.e., Foorman, Francis, Fletcher, et. al, 1998). In fact, we cannot be certain about the source of comprehension gains in the present study. Despite strong theoretical and empirical links between decoding and comprehension (e.g., Perfetti, 1985), producing gains in comprehension by training students only on decoding is clearly not easy. We suspect that a key ingredient for transfer to comprehension is the opportunity to practice the acquired decoding skills in texts. Such practice can both solidify decoding gains and, if most of the words in a text are easily decodable, allow resources to go to other aspects of comprehension. Although our comprehension task was restricted to sentences, we believe that the students' engagement with the sentences was an opportunity for relevant practice. Because words in the Silly Question activity had been used in Word Building, the students could spend less mental resources on decoding words and focus more readily on the task of constructing meaning.

Although this explains a successful link between word decoding and sentence comprehension within the training sessions, it alone does not explain transfer to a standardized comprehension test. For this step, something else is needed. One conjecture is that the successful linkage between word building and sentence comprehension encouraged children to transfer their developing decoding skills to text. This process could lift comprehension skill both directly and indirectly through the motivational gain that can come from new found success. Clearly, whether this conjecture is correct or not, an important question for research is identifying the critical components of decoding instruction that can allow a simultaneous lifting of comprehension.

To summarize, the self-teaching framework provides an account that can help explain the pattern of results demonstrated across the intervention studies. In this framework, the act of engaging in full alphabetic decoding during reading experience plays a central role in the development of effective and efficient word recognition skills. Efficient word decoding skills enhance reading comprehension and develop some forms of phonological awareness. Children who fail to engage in full alphabetic decoding should experience slower growth across each of the reading skills described.

This account fits well with the pattern of deficits displayed by the children in this study, as well as the magnitude of gains obtained from the intervention. Most of the gains were in measures that directly assessed decoding ability, with the greatest gains occurring for grapheme units within medial and final positions of word forms. The second largest gains appeared in the Elision task, which is closely related to alphabetic decoding. The third largest gains appeared in the passage comprehension measures, which are perhaps only indirectly influenced by decoding ability via the efficiency of recognizing words in a text.

In conclusion, we have demonstrated that the Word Building intervention is particularly well suited to the reading deficits of students beyond the first grade who demonstrated poor decoding skills. Given that the instructional principles inherent in Word Building are built on insights from the normal development of literacy, Beck and her colleagues have used these techniques in first-grade classrooms to teach beginning reading, resulting in positive appraisals by first grade teachers. We propose that applying these techniques early in the reading process will both encourage full alphabetic decoding from the start of reading and potentially prevent the difficulties demonstrated by the children in this study.

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Notes

[1] The term "phonics" has had a long history of use in reading instruction, but it has also been the subject of much ambiguity and misunderstanding. It implies an emphasis either on phonology (the sound structure of language) or on phonemes (the inventory of sounds in a language), and on acquiring connections between these and letters. "Phonic" approaches to instruction can variably incorporate activities ranging from phonemic awareness training with spoken words, extensive drills in letter-sound correspondences, presentation of words in "rhyme families," explicit instruction of 'rules' that capture regularities in letter-sound combinations, implicit structuring of materials, systematic presentation of orthographic patterns which are introduced either implicitly or explicitly, to "opportunistic" approaches that point out letter-sound correspondences during text reading.

[2] Direct comparisons between first and second position within an onset cluster were not conducted, due to low number of consonants that appeared equally often in these positions (n=4).

[3] During the intervention time-span of this study, many of these children were recruited for other experiments not directly related to the issues of this paper. These experiments included fMRI measures, naming speed measures, and auditory processing of tones and spoken words, and will be reported elsewhere.

[4] This estimate is likely to be rather conservative, given that most children did not complete or test out of all 77 lessons.

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Table 1
Means (and standard deviations) for the selection measures (n=24)

Variable	Mean	(Std. Dev.)
Age (in months)	100.5	(11.6)
WRMT-R Word Attack (raw)	6.6	(4.6)
WRMT-R Word Attack % Rank	20.3	(10.1)
WRMT-R Word ID (raw)	33.5	(12.4)
WRMT-R Word ID % Rank	27.8	(17.7)
PPVT-R (raw)	119.0	(17.4)
PPVT-R (standard score)	105.0	(10.9)

Table 2
Mean percentage accuracy (and standard deviations) of decoding attempts on an experimental set of 128 pseudowords calculated separately for targeted regions and positions within each pseudoword

Variable	Mean	(Std. Dev.)
Regions within Word-form		
Onset	70.1	(15.2)
Vowel	40.0	(18.6)
Coda	54.1	(20.2)
Individual Consonants within Onset		
Singular	79.1	(10.9)
Initial Position in Cluster	84.3	(14.0)
Second Position in Cluster	51.2	(32.3)
Individual Consonants within Coda		
Singular	58.4	(19.2)
Initial Position in Cluster	43.7	(28.7)
Second Position in Cluster	60.3	(21.6)

Table 3
Means (and standard deviations) for the additional Cognitive Profile Measures

Variable	Mean	Std. Dev.
Passage Comprehension raw	16.7	(8.4)
Passage Comprehension %	28.9	(19.1)
CTTP Word Blending raw	12.0	(3.31)
CTTP Word Blending z-score	-0.86	(0.59)
CTTP Nonword Blending raw	9.7	(3.5)
CTTP Nonword Blending z-score	-0.55	(0.75)
CTTP Elision raw	11.91	(4.5)
CTTP Elision z-score	-1.25	(0.75)
Initial Sound Matching percentage	83.5	(21.5)
Final Sound Matching percentage	53.6	(29.8)

Table 4
Raw Scores and Grade Equivalence Means (and Standard Deviations) for Woodcock Reading Mastery Test-Revised Word Attack Subscale Pretests and Posttests

Measure						
	Raw Score			Grade Equivalence		
Group	Pre	Post	*Gain*	Pre	Post	*Gain*
Control	6.4 (5.1)	7.3 (6.9)	*0.9*	1.5 (0.9)	1.7 (1.0)	*0.2*
Intervention	6.8 (4.3)	14.8 (5.4)	*8.0*	1.6 (0.4)	2.8 (0.8)	*1.2*

Table 5
ANOVA Summary for Time Span (Pretest vs. Post-Test Results of the WRMT-R Word Attack subscale) by Group (Intervention vs. Control)

	Measure			
	Raw Scores		Grade Equivalence	
Source of Variance	F (1, 22)	p	F (1,22)	p
Time Span	24.8	.0001	16.8	.0005
Group 3.6	.069	4.3	.049	
Time Span x Group	15.7	.0007	7.8	.01

Table 6
Raw Scores and Grade Equivalence Means (and Standard Deviations) for Woodcock Reading Mastery Test-Revised Word Identification Subscale Pretests and Posttests

	Measure					
	Raw Score			Grade Equivalence		
Group	Pre	Post	*Gain*	Pre	Post	*Gain*
Control	31.4 (14.7)	31.6 (14.5)	*0.2*	1.9 (0.5)	2.0 (0.4)	*0.1*
Intervention	35.5 (9.9)	38.8 (10.2)	*3.3*	2.1 (0.3)	2.3 (0.5)	*0.2*

Table 7

ANOVA summary for pretest and posttest results of the WRMT-R Word Identification test

	Measure			
	Raw Scores		Grade Equivalence	
Source of Variance	F (1, 22)	p	F (1,22)	p
Time Span	1.0	.32	4.5	.04
Group 1.4	.26	1.3	.26	
Time Span x Group	0.83	.37	0.6	.45

Table 8
Raw Scores and Grade Equivalence Means (and Standard Deviations) for the WRMT-R Passage Comprehension Subscale

Measure						
	Raw Score			Grade Equivalence		
Group	Pre	Post	*Gain*	Pre	Post	*Gain*
Control	15.5 (7.5)	17.6 (9.8)	*2.1*	1.7 (0.7)	2.0 (1.2)	*0.2*
Intervention	18.0 (9.5)	25.0 (7.8)	7.0	2.0 (1.0)	2.8(1.2)	*0.8*

Table 9
ANOVA summary for pretest and posttest results of WRMT-R Passage Comprehension test

	Measure			
	Raw Scores		Grade Equivalence	
Source of Variance	F (1,22)	p	F (1,22)	p.
Time Span	19.2	.0002	15.6	.0005
Group 2.1	.15	1.9	.18	
Time Span x Group	5.3	.03	3.1	.09

Table 10
Pretest and Posttest Means (and Standard Deviations) for Raw and Standard Scores of the Three Standardized Sub-scales of Phonological Processing (CTPP)

Task	Measure					
	Raw Score			Standard Score		
Group	Pre	Post	*Gain*	Pre	Post	*Gain*
Word Blending						
Control	11.5 (3.8)	14.3 (4.6)	*2.8*	-0.97 (0.62)	-0.44 (0.77)	*0.53*
Intervention	12.5 (2.8)	16.6 (4.9)	*4.1*	-0.75 (0.55)	-0.01 (0.94)	*0.75*
Nonword Blending						
Control	10.3 (2.6)	10.0 (4.2)	*-0.3*	-0.42 (0.52)	-0.45 (0.83)	*-0.03*
Intervention	9.2 (4.4)	12.5 (3.2)	*3.3*	-0.67 (0.98)	0.08 (0.71)	*0.75*
Elision						
Control	12.5 (5.2)	13.4 (4.3)	*0.9*	-1.07 (0.79)	-0.93 (0.85)	*0.13*
Intervention	11.3 (4.0)	14.6 (4.1)	*3.3*	-1.43 (0.71)	-0.69 (0.66)	*0.73*

Table 11
Raw Scores and Grade Equivalence Means (and Standard Deviations) for Woodcock Reading Mastery Test-Revised

	Measure					
	Raw Score			Grade Equivalence		
Test	Pre	Post	*Gain*	Pre	Post	*Gain*
Word Attack	9.1 (7.8)	18.4 (9.2)	*9.3*	1.9 (1.1)	3.5 (1.6)	*1.6*
Word Identification	37.0 (15.9)	48.5 (13.6)	*10.5*	2.2 (0.5)	2.8 (0.9)	0.6
Passage Comprehension	20.8 (9.8)	26.9 (7.2)	*6.1*	2.3 (1.2)	3.0 (1.3)	0.7

Table 12
Summary of three repeated measures ANOVA analyses contrasting performance of Cohort (Intervention Cohort 1, Intervention Cohort 2) by Time (before intervention, after intervention) for Word Attack, Word ID, and Passage Comprehension

		Measure			
		Raw Scores		Grade Equivalence	
Test	Source	F (1,22)	p	F (1,22)	p
Word Attack					
	Cohort	1.2	.29	3.2	.21
	Time	97.0	.0001	71.0	.0001
	Time x Cohort	0.57	.45	1.9	.17
Word Identification					
	Cohort	1.2	.28	2.0	.17
	Time	55.5	.0001	17.0	.0005
	Time x Cohort	17.4	.0004	5.2	.03
Passage Comprehension					
	Cohort	0.4	.49	0.2	.59
	Time	49.2	.0001	34.5	.0001
	Time x Cohort	0.2	.63	0.1	.94

Table 13
Means (and standard deviations) for the three standardized tests of phonological awareness (CTPP) for Intervention Cohort 2

	Measure					
	Raw Score			Standard Score		
Group	Pre	Post	*Gain*	Pre	Post	*Gain*
Word Blending	16.1 (4.8)	19.0 (3.7)	*2.9*	-0.16 (0.87)	0.37 (0.66)	*0.53*
Nonword Blending	12.4 (4.1)	14.0 (4.6)	*1.6*	-0.03 (0.91)	0.33 (0.99)	*0.36*
Elision	14.0 (5.7)	15.9 (5.6)	*1.9*	-1.02 (1.04)	-0.61 (1.03)	*0.41*

Table 14
Summary of three repeated measures ANOVA analyses contrasting performance of Cohort (Intervention Cohort 1, Intervention Cohort 2) by Time (before intervention, after intervention) for Word Blending, Nonword Blending and Elision tests.

		Measure			
		Raw Scores		Grade Equivalence	
Test	Source	F (1,18)	p	F (1,18)	p
Word Blending					
	Cohort	3.6	0.07	3.1	0.10
	Time	13.6	0.0016	10.7	0.0039
	Cohort x Time	0.40	0.54	0.3	0.60
Nonword Blending					
	Cohort	2.3	0.15	1.7	0.20
	Time	6.0	0.0252	5.9	0.0261
	Cohort x Time	0.70	0.41	0.7	0.40
Elision					
	Cohort	0.5	0.47	0.6	0.46
	Time	20.9	0.0002	20.1	0.0003
	Cohort x Time	1.8	0.20	1.0	0.33

Figure Captions

Figure 1. Illustration of the progression of word transformations in the word decoding activity of the Word Building intervention. After creating an initial word from letter cards, children are given instructions to change a particular letter card (e.g., Take away **t** and put **p** in its place) and then to read the newly formed word. The new grapheme card in each trial is highlighted in gray to illustrate how each word transformation focuses a child's attention on different positions in the word form by holding constant the other letters from the previous word.

Figure 2. Mean accuracy (with standard error bars) for the Pseudoword Reading Task in Study 2 before and after the intervention, as a function of region within each pseudoword (Onset, Vowel, Coda).

Figure 3. Mean accuracy (with standard error bars) for performance within the onset region of the pseudoword task in Study 2 before and after the intervention as a function of phoneme position (Solitary, First in Blend, Second in Blend).

Figure 4. Individual Word Attack grade equivalence scores for Study 2 before and after the intervention. Scores of individuals within each group are arranged from right to left in rank order of pretest performance.

Figure 5. Individual Word Identification grade equivalence scores for Study 2 before and after the intervention. Scores of individuals within each group are arranged from right to left in rank order of pretest performance.

Figure 6. Individual Passage Comprehension grade equivalence scores for Study 2 before and after the intervention. Individuals in each group are arranged from left to right in rank order of pretest performance.

Figure 7. Individual Word Blending standard scores for Study 2 before and after the intervention. Individuals within each group are arranged from left to right in rank order of pretest scores.

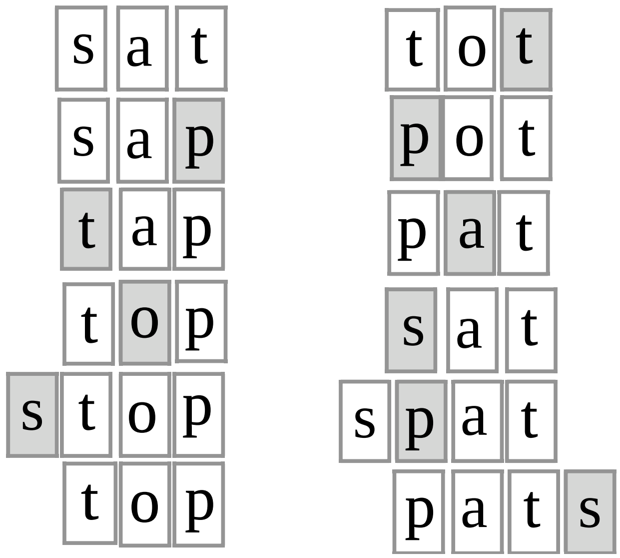
Figure 8. Individual Nonword Blending standard scores for Study 2 before and after the intervention. Individuals within each group are arranged left to right in rank order of pretest scores.

Figure 9. Individual Elision standard scores for Study 2 before and after the intervention. Individuals within each group are arranged from left to right in rank order of pretest scores.

Figure 10. Mean accuracy (with standard error bars) for the Pseudoword Reading Task for Cohort 2 (Study 3) before and after the intervention. The left panel analyzes all pronunciations in three regions (Onset, Vowel, Coda). The middle panel divides pronunciation of onset consonants into three classes (Singular, 1st in Cluster, 2nd in cluster). The right panel divides pronunciation of coda consonants into the same three classes.

Figure 11. Intervention Cohort 2 individual grade equivalence scores for Word Attack, Word Identification, and Passage Comprehension before and after the intervention. Scores of individuals are arranged from right to left in rank order of pretest performance.

Figure 12. Individual Word Blending, Nonword Blending, and Elision scores for Study 3 before and after the intervention. Individuals within each group are arranged from left to right in rank order of pretest scores.


s a t
s a p
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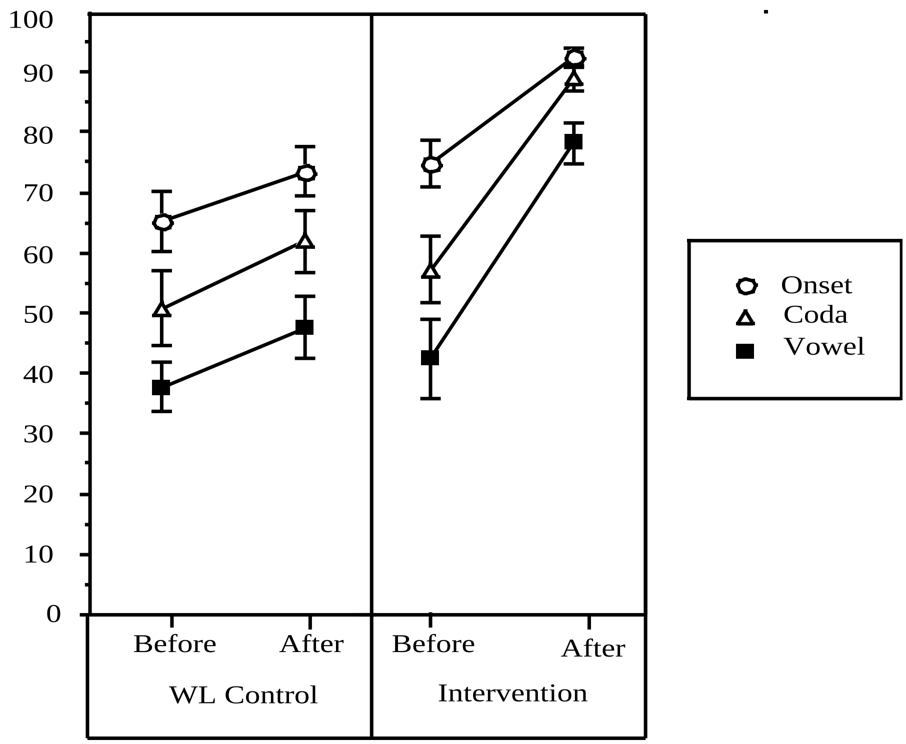
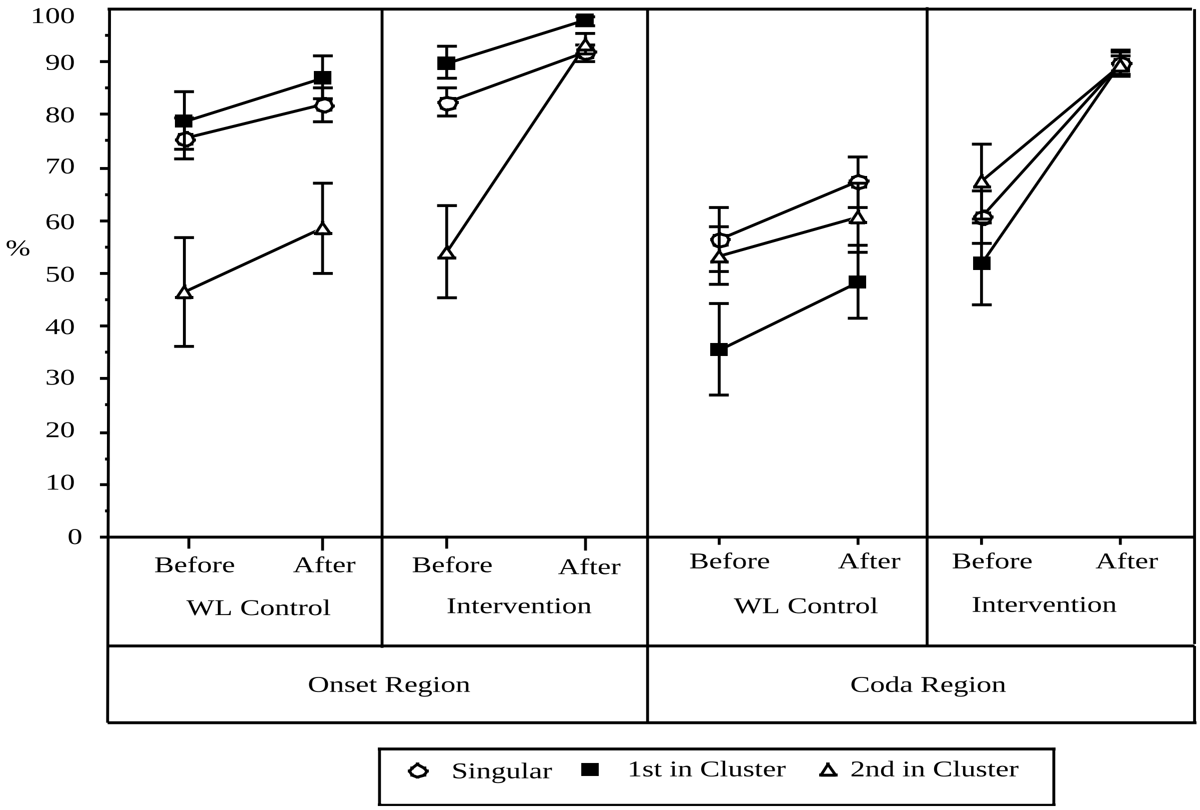
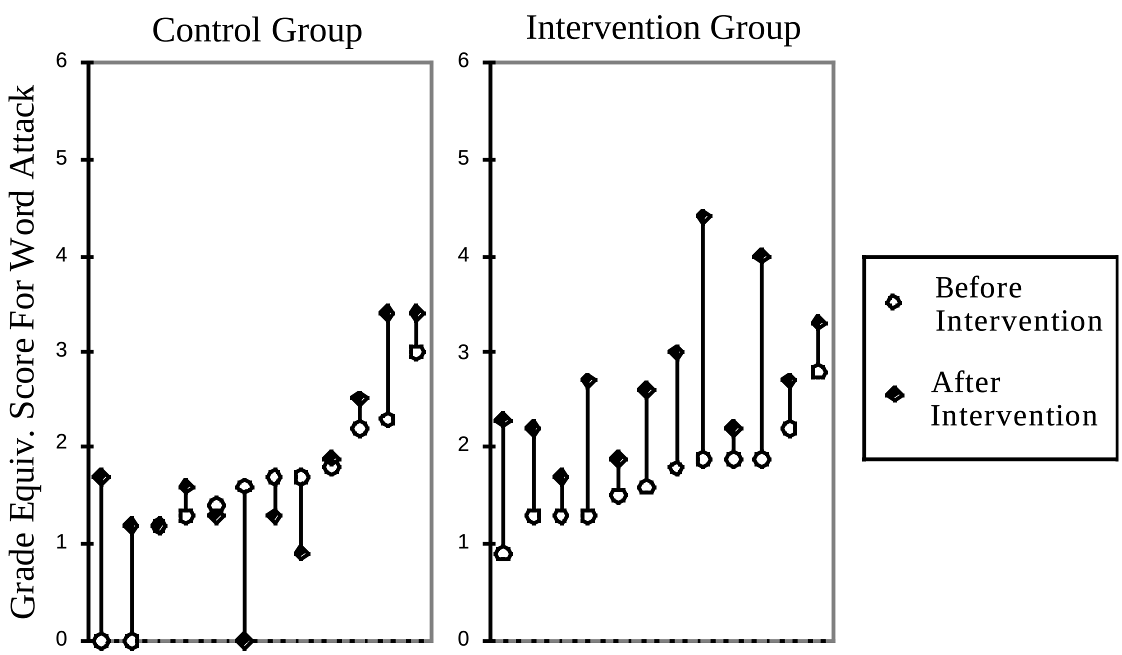
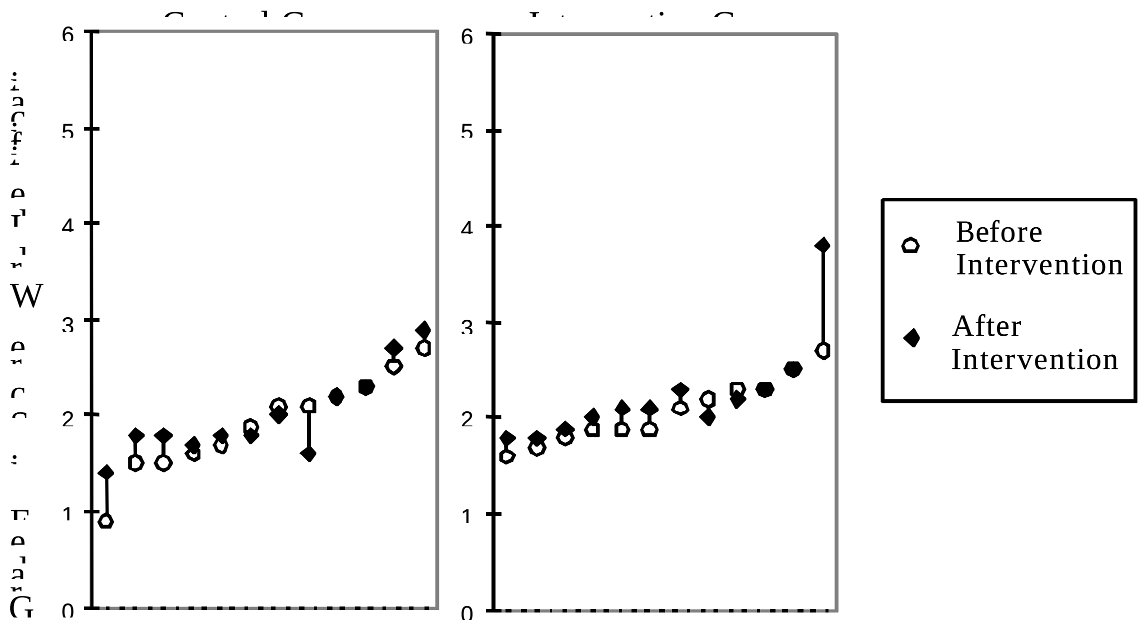
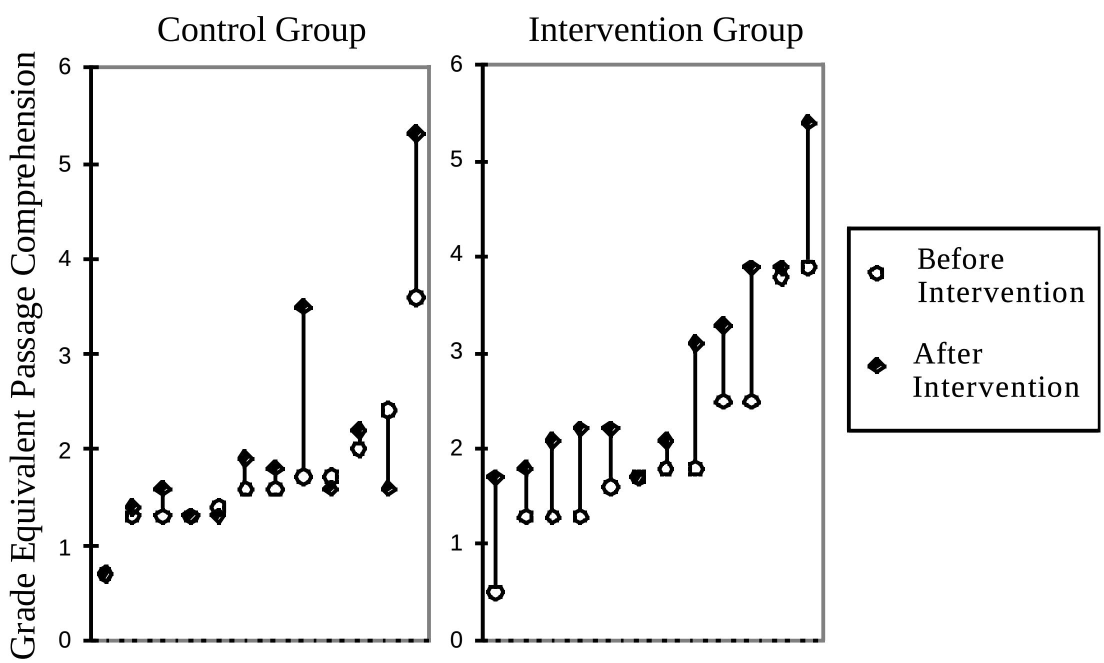

100
90
80
70
60
50
40
30
20
10
0
Before
After
Before
After
WL Control
Intervention
Onset
Coda
Vowel

.

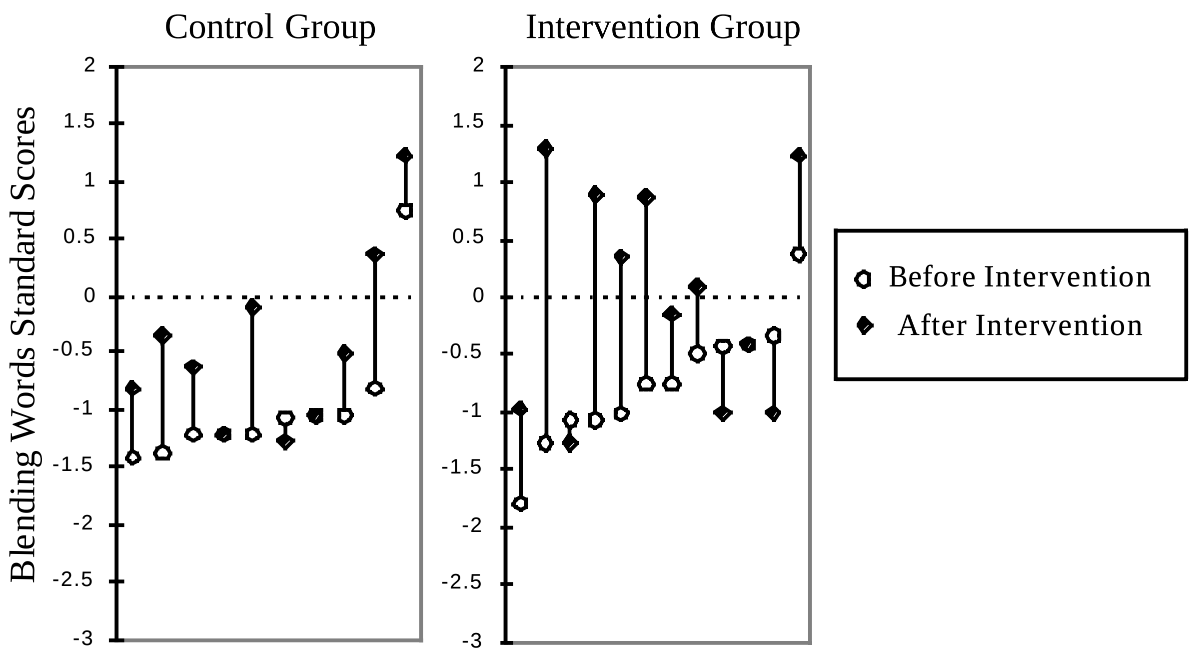

100
90
80
70
60
50
40
30
20
10
0
%
Before
After
WL Control
Before
After
Intervention
Before
After
WL Control
Before
After
Intervention
Onset Region
Coda Region
Singular
1st in Cluster
2nd in Cluster

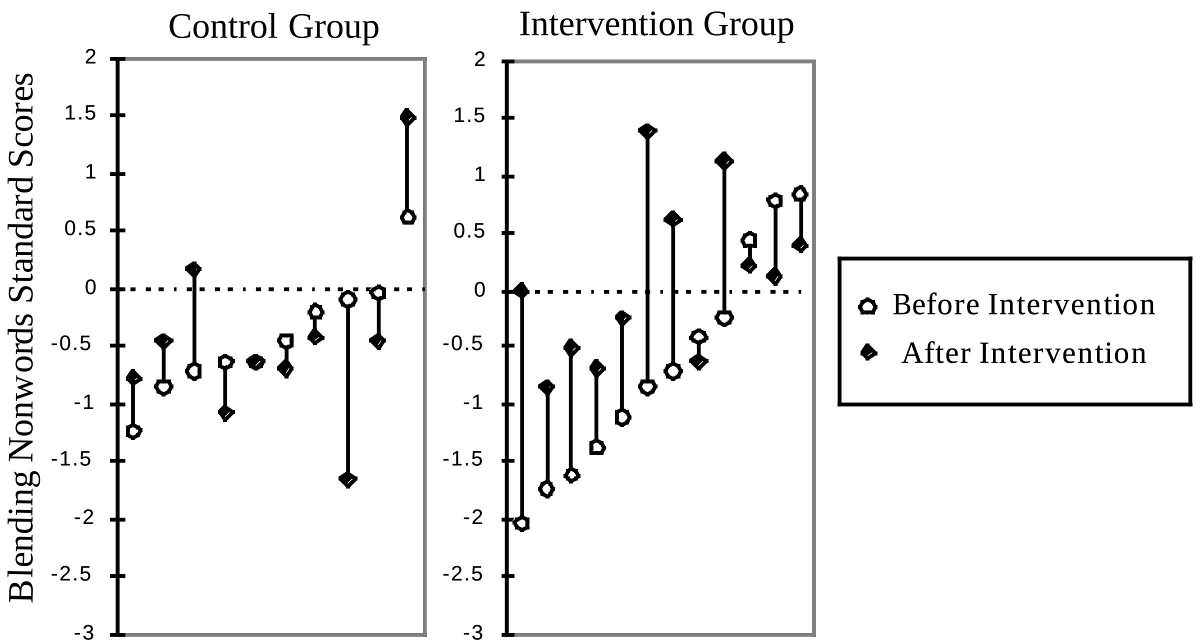

Control Group
Intervention Group
Grade Equiv. Score For Word Attack
0
1
2
3
4
5
6
Before Intervention
After Intervention

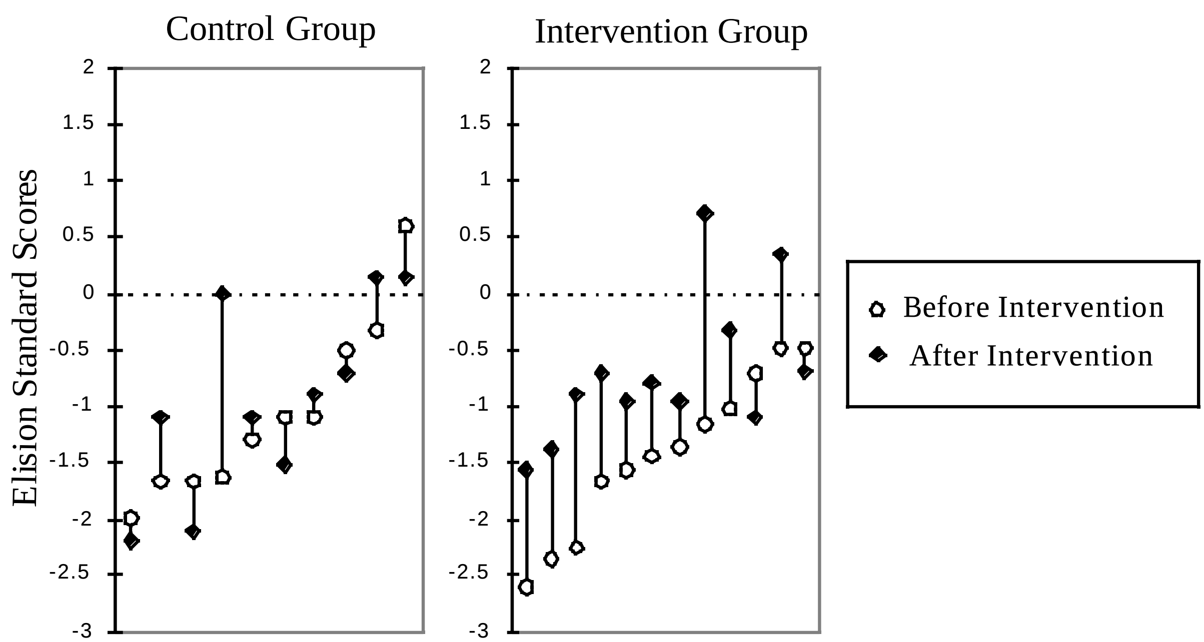

6
5
4
3
2
1
0
Before Intervention
After Intervention


Control Group
Intervention Group
Grade Equivalent Passage Comprehension
0
1
2
3
4
5
6
Before Intervention
After Intervention

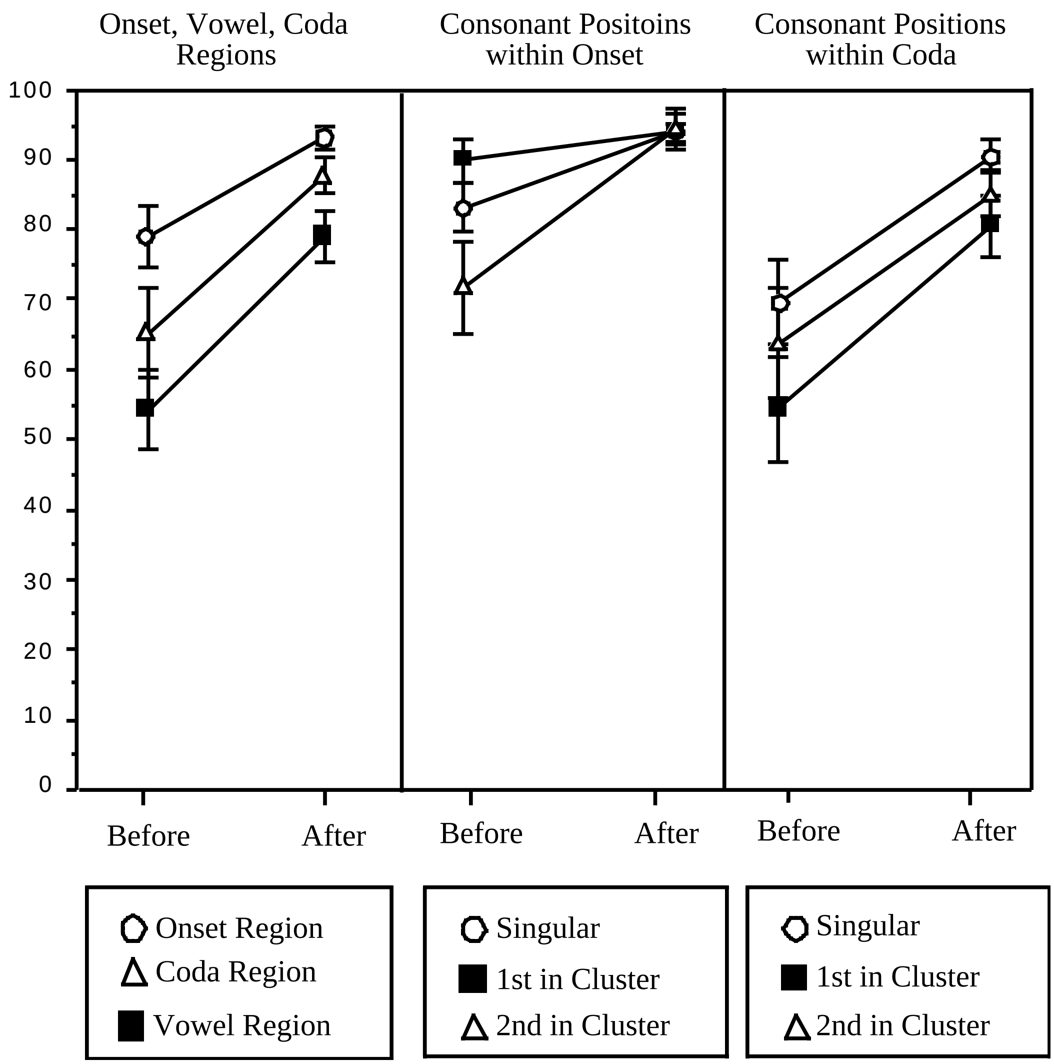
.


Control Group
Intervention Group
Blending Words Standard Scores
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
Before Intervention
After Intervention

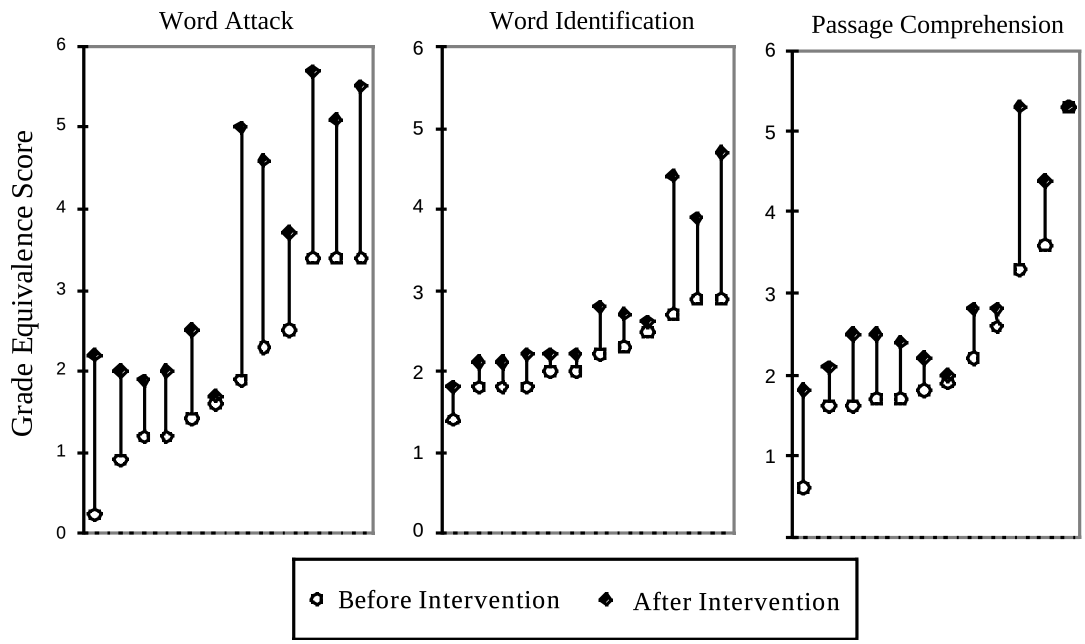

Control Group
Intervention Group
Blending Nonwords Standard Scores
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
Before Intervention
After Intervention

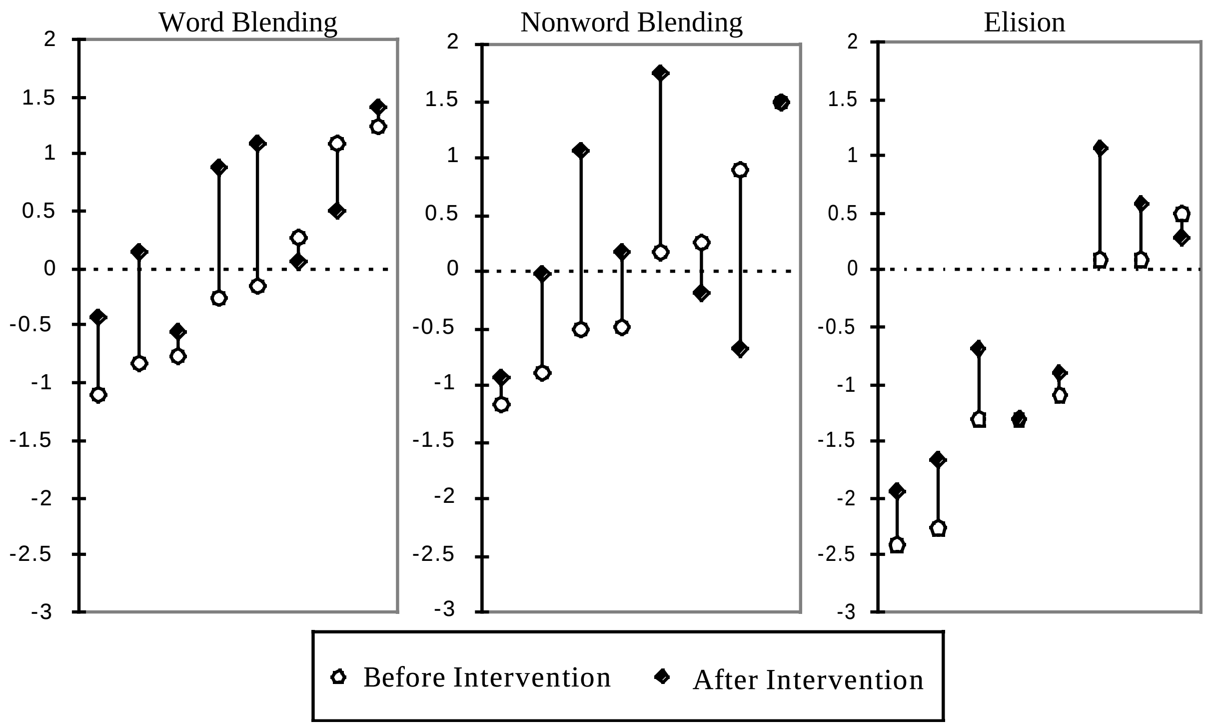


Control Group
Intervention Group
Elision Standard Scores
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
Before Intervention
After Intervention



Onset, Vowel, Coda Regions
Consonant Positoins within Onset
Consonant Positions within Coda
100
90
80
70
60
50
40
30
20
10
0
Before
After
Before
After
Before
After
Onset Region
Coda Region
Vowel Region
Singular
1st in Cluster
2nd in Cluster
Singular
1st in Cluster
2nd in Cluster


Word Attack
Word Identification
Passage Comprehension
Grade Equivalence Score
0
1
2
3
4
5
6
Before Intervention
After Intervention


Word Blending
Nonword Blending
Elision
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
Before Intervention
After Intervention