THE ROLE OF PHONEMIC AWARENESS AND NAMING SPEED IN PREDICTING RESPONSE TO BRIEF TRAINING OF READING SKILLS

by

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ABSTRACT

The purpose of this research was to examine whether phonemic awareness and rapid naming skills are independent predictors of response to brief training of reading skills. In Study One, the role of these two skills in predicting response to training was studied in a sample of children with poor phonemic awareness. Results indicated that children learned to read the training words as a function of training, and when initial word recognition scores were controlled, they also showed increased ability to read other words and pseudowords in the same families as the training words. Furthermore, in addition to being poorer readers on standardized test measures, slow naming children had more difficulty learning sound analysis skills than children with faster naming skills. Slow namers were also less likely than fast namers to identify words and nonwords sharing rime patterns with words they knew, suggesting less use of orthographic pattern information. These results suggest that among children with the core weakness thought to be associated with reading disabilities, those with fast naming skills had additional resources contributing to word identification.

Study Two extended these findings by examining the factors related to reading outcome within a sample of poor readers. The primary aim of the study was to investigate whether phonemic awareness and naming speed are independent predictors of training outcome both immediately after training and after a one- or two-day delay. Study Two also investigated three possible mechanisms for improvement following training: (a) increased phonemic awareness, (b) increased knowledge of whole word orthographic patterns in the training words, and (c) increased sensitivity to rime patterns within the trained words. Forty poor readers participated in a thirty-minute training program aimed at increasing their ability

to identify 12 training words. Although children learned to read the training words and showed transfer of knowledge to other words in the same families, training outcome was not predicted by phonemic awareness or rapid naming skills. Instead, initial scores on a standardized test of word identification were the best predictors of growth in a number of different reading outcome measures. In terms of the mechanisms of improvement of reading skill, children showed improved phonemic sensitivity and whole word orthographic knowledge following training, but these improvements could not be predicted by initial phonemic awareness or naming speed skills. Additionally, final scores on these two mechanism tasks were unrelated to final reading performance.

The results of these two studies are interpreted as providing support for the double deficit hypothesis at a descriptive level. The role of the two skills in predicting treatment outcome is less clear. It is speculated that the particular populations studied as well as the nature of the training used have implications for the results obtained.

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INTRODUCTION

One major development in the literature on reading acquisition is the consensus that phonological processing skills are important in learning to read (for reviews see Adams, 1990; Wagner & Torgesen, 1987). Phonological processing refers to the use of sound-based information in processing oral or written language (Wagner & Torgesen, 1987). According to the phonological deficit account of reading disability, children fail to acquire age-appropriate reading skills because of a specific deficit in phonological processing. This deficit results in difficulties learning letter-sound correspondences, which then result in poor word recognition skills, and in turn, hinder the fluency and comprehension of reading. Support for this account comes from studies which have shown that impaired performance (relative to age and reading level-match controls) on pseudoword decoding tasks is the most common indicator of reading disability (for a review see Rack, Snowling & Olson, 1992). Accurate decoding on such tasks requires the application of grapheme-phoneme correspondence rules, and thus, the tasks are relatively pure measures of phonological processing skill.

Children with general phonological processing difficulties often struggle with a specific aspect of this type of processing, namely phonemic awareness. Children with poor phonemic awareness are not sensitive to individual phonemes in spoken words. These children are thought to process words holistically, making it more difficult for them to apply decoding skills when they encounter novel words. A number of treatment studies have shown that training of phonemic awareness in children at risk of reading failure improves later reading skills, particularly when training also includes grapheme-phoneme correspondence rules. (e.g., Bryant & Bradley, 1985; Byrne & Fielding-Barnsley, 1995; Hatcher, Hulme & Ellis, 1994).

Although it is clear that most poor readers have weak phonemic awareness, a second deficit possessed by many poor readers is often overlooked. Poor readers are frequently slow to name simple visual symbols, such as colours, objects, numbers, or letters. In the rapid automatized naming (RAN) paradigm, children are asked to name a series of symbols presented in random order several times, as rapidly as possible. Denckla and Rudel (1976), in the seminal work in this area, showed that reading disabled children differed from children with other forms of learning disability and normal controls on speed of naming visual stimuli (such as colours, objects, digits or letters). Other studies have shown reading impaired children to be slower to name symbols than average peers (Bowers, Steffy & Tate, 1988; Bowers & Swanson, 1991), children with attention deficit disorder (Felton & Wood, 1989), and reading-level controls (Wolf, 1991). Deficits in naming speed are present in reading-impaired populations through adulthood (Felton, Naylor & Wood, 1990), and naming speed is a longitudinal predictor of reading ability (Bowers, 1995; Manis, Seidenberg & Doi, 1999; Meyer, Wood, Hart & Felton, 1998; Torgesen, Wagner, Rashotte, Burgess & Hecht, 1997b). Performance on rapid naming tasks is independent of general verbal ability (Bowers et al., 1988).

Unlike phonemic awareness, the direct teaching of rapid naming skills, particularly naming of non-alphabetic symbols such as digits or colours, is not expected to translate into better reading skills. Moreover, children do not actually name each letter in a word when reading; therefore, the relation between naming speed and reading is not thought to be simple or direct. A better understanding of the processes underlying naming speed is necessary in order to develop interventions that target difficulties experienced by slow naming children. While many studies have shown that naming speed is related to reading, the route by which the ability to name symbols quickly affects reading is less clear.

Two main ways to interpret the correlation between reading and rapid naming ability have been proposed. Some researchers have considered symbol naming speed to be a measure of phonological processing skill. For example, Wagner and Torgesen (1987) describe naming speed as a measure of phonological retrieval from memory. According to this account, naming tasks require the retrieval of pronunciations of symbols from long-term memory, just as reading requires the retrieval of the pronunciations of letters, word segments and whole words from a long-term store. Thus, rapid naming tasks are measures of the efficiency of a phonological process. Recent support for this hypothesis comes from studies which have shown that naming speed measures share variance with measures of phonological processing (e.g., Wagner, Torgesen, Laughon, Simmons & Rashotte, 1993; Torgesen et al., 1997b). According to this model, interventions which teach target phonological skills should benefit all children, regardless of whether they have weak naming speed skills or not. However, as pointed out by Torgesen, Wagner and Rashotte (1994), some children continue to struggle to read despite intensive intervention aimed at the phonological domain. Understanding these "treatment resistors" remains a goal of researchers in this area.

While symbol naming speed shares some variance with measures of phonological processing skill, it also contributes variance which is independent of such measures. Studies have shown that naming speed and phonemic awareness form separate factors accounting for various aspects of reading (Swanson & Alexander, 1997; Torgesen et al., 1997b; Wagner et al., 1993). Other studies have shown that phonemic awareness and naming speed each correlate most highly with different aspects of reading. More specifically, after controlling for phonological variables, naming speed has been shown to predict variance in word recognition and reading speed, but its relation to pseudoword decoding and reading comprehension is less strong (Bowers, 1995, Bowers & Swanson, 1991; Cornwall, 1992; Manis et al., 1999).

Double Deficit Hypothesis of Reading Difficulties

The relative independence of rapid naming skills from phonemic awareness led Bowers and Wolf (1993) to propose a "double deficit" hypothesis of reading difficulties. According to this model, rapid naming requires cognitive processes such as visual encoding and lexical access, and these processes must occur rapidly and precisely in time (Bowers & Wolf, 1993). Deficits in naming speed are associated with deficits in the timing of the various reading subprocesses. Specifically, this theory proposes that when visual symbol identification occurs slowly, links between letters in a word are not made as easily. Thus, knowledge of common letter patterns is impaired, and the child has difficulty reading fluently. If naming speed represents a process related to how quickly children learn orthographic patterns, then children with poor naming speed may need more exposure to print, or more practice with particular letter patterns in order to make their recognition of these patterns automatic.

Theories of reading can be divided into two main classes, both of which incorporate the importance of phonological and orthographic information in learning to read. Dual route theories (e.g., Coltheart, 1978) suggest that word recognition occurs through one of two routes: 1) a sublexical or phonological route in which sounds are mapped on to the letters and words are identified using grapheme-phoneme conversion rules; and 2) a lexical or orthographic route in which the pronunciation of the word is accessed directly through the orthographic representation of that word. According to these theories, two main patterns of reading impairment should occur: 1) phonological dyslexia, in which the sublexical route is impaired, and the reader has difficulty decoding nonwords, but exception word reading is intact; and 2) surface dyslexia, in which the lexical route is impaired, and the reader is unable to read exception words, while decoding is relatively intact. In contrast to dual route theories, connectionist theories of reading (e.g. Seidenberg & McClelland, 1989) include both phonological and orthographic information in a single route. According to such models, the reader forms associations between orthographic and phonological representations through repeated exposure. Context and meaning are also built into these models as other means of assisting word recognition. Difficulties with word recognition may occur through weak connections between the various sources of information. Thus, these models are more easily able to account for "mixed" types of dyslexia, in which readers have difficulty with both nonword decoding and sight word recognition.

The double deficit model was not meant to be a test of the relative merits of one type of theory of reading over the other. Rather, the model was designed to highlight the fact that poor readers may have impairments in other areas besides phonological processing. Thus, the model is consistent with dual route and connectionist theories of reading, as both theories incorporate the importance of phonological decoding and orthographic knowledge for skilled reading. Relative weakness in one or the other skill area will show itself in word identification because word identification is affected by both variables. Applying this line of thinking to the double deficit hypothesis, children with poor naming speed may be reliant on phonological decoding because their presumably weak orthographic skills result in difficulty reading words "by sight". Similarly, children with poor phonological skills for whom naming speed is fast may be able to compensate for weak decoding skills by using orthographic processes to help decode words in word families. Children with both deficits are thought to be particularly impaired in reading, because neither method of word identification is adequately available to them. The double deficit model predicts that phonologically based treatments will maximally benefit children with only phonological deficits: children with naming speed deficits need treatments which are based in orthographic processes, with children with both deficits needing a combination of the two types of treatment.

Support for Double Deficit Theory of Reading Difficulties

Support for the double deficit theory of reading difficulties comes from a variety of sources. Studies by Bowers and Wolf (Bowers, 1995; Bowers, Sunseth & Golden, 1999; Wolf & Bowers, in press) have shown partial independence for measures of phonemic awareness and naming speed. The partial independence of these measures allowed for the identification of four subgroups of children: those with no deficits (ND), those with a single deficit in phonemic awareness (PD), those with a single deficit in naming speed (NSD), and those with double deficits in both phonemic awareness and naming speed (DD). If phonological skills are necessary and sufficient for reading development, then children with equally poor phonological skills should be equally poor readers, regardless of their status on the naming speed measure. However, the results of these studies showed children with a deficit in only one area to be less impaired in reading than those with double deficits. Consistent with predictions made by the double deficit hypothesis, these results suggest that children with a single deficit may be able to use skills tapped by the other measure, thus accounting for their higher reading scores in comparison to children with both deficits.

A number of studies have shown specific relationships between naming speed and measures of orthographic processing skills, providing further support for the double deficit hypothesis. Performance on orthographic choice tasks (in which children are required to distinguish the correct spelling of a word from its sound-alike foil) is related to naming speed, even after controlling for phonological skill (Manis et al., 1999; Torgesen et al., 1997b). Similar results have been reported for other measures of orthographic processing such including word likeness tasks and spelling recognition tasks (Bowers et al., 1999; Manis et al., 1999; Manis and Doi, in press)

If naming speed and reading are related through their joint relations with orthographic processing skill, then children with weak phonemic awareness but fast naming speed may be more likely to use orthographic information when reading. This increased reliance on orthography, which also occurs as part of normal reading development (Adams, 1990; Ehri, 1992), may explain why single deficit children are typically better readers than those with double deficits. Interestingly, Torgesen, Wagner & Rashotte (1997a) recently showed that growth in phonological skills through training did not lead to corresponding increases in orthographic skills or reading comprehension. Thus, it may be weak orthographic skills that cause some children to remain poor readers even after extensive intervention.

Implications for Remediation

As noted earlier and explained in more depth by Wolf (1997) and Wolf and Bowers (in press), the double deficit hypothesis has implications for remediation. If phonemic awareness and naming speed relate to different reading subskills, then one would expect that treatment programs targeting either orthographic or phonological skills would be maximally beneficial to different subgroups of children. In other words, children with only phonological deficits would be well-served by interventions targeting phonological skills. Children with naming deficits (either alone or in combination with phonological deficits) would benefit less, because the intervention does not address their associated deficits in automatic retrieval and orthographic processing. Indeed, while studies of the effectiveness of training of phonological skills have shown long-term improvements in children's reading accuracy, one study has shown that these effects do not include increased automaticity of reading (Byrne & Fielding-Barnsley, 1995). Children with deficits in both phonemic awareness and naming speed would be expected to need the most training, in order to overcome their deficits in both areas. Such an account would help to understand why some children are "treatment resistors" (Torgesen et al., 1994) and do not improve, despite intensive intervention aimed at phonological processing skills.

Evidence for the relation between slow naming speed and poor response to treatment comes from a number of training studies that have used phonemic awareness and naming speed as predictors of treatment outcome. Badian (1993) reported that in a sample of six- to eight-year-olds referred for special help in reading, poor readers with strong phonemic awareness achieved the best reading outcome over a two-year period. Children whose reading deteriorated compared to age expectations over the two-year period were characterized by slow naming skills. Another training study (Levy & Bourrassa, 1998) showed that children with slow naming skills took longer to learn a set of words, even when initial reading skill differences were controlled statistically. The difference between the slow-naming and fast-naming groups was largest when trained using a whole word strategy and smaller with segmentation training. A study by Ring, Wise & Olson (1998) further delineated the situations in which naming speed is related to treatment outcome. This study showed that following training, naming speed predicted accuracy of timed, but not untimed word recognition. Thus, the effects of naming speed on treatment outcome may be particularly strong in situations that place heavy demands upon rapid recognition of words.

Finally, the most direct support for the hypothesis that the groups of children identified by the double deficit hypothesis differ in response to training comes from a reanalysis of previously published data (Lovett, Borden, DeLuca, Lacerenza, Benson & Brackstone, 1994) according to the double deficit model (Lovett & Steinbach, in press). This study showed that children with only a phonological deficit made the greatest gains on nonword decoding tasks. Thus, it appears that having a naming speed deficit (whether alone or in combination with a phonological deficit) may make it more difficult for children to learn phonological decoding skills, the very skills targeted by most intervention programs. It is important to note that despite the advantage of the phonological deficit group on gains in nonword reading, all groups, including the double deficit group, showed transfer to uninstructed words, demonstrating the overall effectiveness of the interventions. In addition, participants in this study were extremely poor readers. It remains to be determined whether these results would hold in a sample with less severe reading difficulties.

Aims of Present Research

Previous research indicates that naming speed is an important correlate of later reading skills (Bowers, 1995, Meyer et al., 1998; Manis et al., 1999; Torgesen et al., 1997b) and of improvement in reading skills following intensive training of reading skills in severely impaired readers (Levy & Bourrassa, 1998; Lovett & Steinbach, in press). The present research aims to extend these findings by addressing the question of whether naming speed predicts individual differences in treatment outcome in less impaired readers from a regular classroom setting. The present studies were designed to examine this question using a brief training format. While brief training was expected to lead to only very short-term benefits, it is thought that these benefits might be related to the effects of more intensive training. Treatment outcome was measured using a variety of measures, including reading of the training words, reading of other words and nonwords in the same families as the training words, and phonemic awareness.

Based on intervention research involving poor readers in the middle elementary grades (Levy & Lysynchuk, 1997; Roth & Beck, 1987) training emphasized dividing words into onset and rime segments, as well as simple phonics and orthographic rules. Children were also given practice in rapidly identifying the correct spelling of the training words. The heterogeneous nature of the training was based on previous research showing that training of phonemic awareness in conjunction with decoding skills is more effective than training either skill in isolation (Bryant & Bradley, 1985; Hatcher et al., 1994).

The double deficit model predicts that slow naming children have weaker orthographic knowledge than fast namers. Thus, it was hypothesized that slow namers would be less likely to use knowledge of common letter patterns to help them transfer knowledge learned in training to other words and pseudowords sharing the same rime pattern as the training words. Whether or not double deficit children show less transfer than children with only one deficit has not been well established. Lovett & Steinbach (in press) showed that while all deficit subgroups showed transfer to untrained words and nonwords after training, double deficit children performed more poorly than children in either single deficit group on one transfer measure. This task consisted of words that shared letter patterns with the training words. On the more distant transfer measures, two of which included words unrelated to the training words, all three deficit groups showed equivalent gains. Thus, the disadvantage of double deficit children on transfer tasks may depend on the orthographic similarity of the training and transfer words, as these children seem to struggle to recognize trained letter patterns when they appear in other words.

Are the results of studies examining transfer after direct and intensive training of reading skills similar to results of studies investigating application of existing knowledge to other targets? Bowers (1996) examined whether phonemic analysis and naming speed were independent predictors of application of word recognition skills to other words and pseudowords sharing a rime among children from regular Grade 2 and Grade 3 classrooms. It was hypothesized that because application of rime knowledge requires phonemic analysis skill as well as orthographic knowledge of the letter pattern in the rime itself, deficits in either phonemic awareness or naming speed would be associated with poor performance. Contrary to prediction, however, results indicated that phonemic analysis was the only skill associated with use of rime knowledge. In this full class sample, processes tapped by naming speed were not predictive of use of rime knowledge. It remains to be determined, however, whether higher use of orthographic information will characterize children with weak phonological skills but faster naming speed in contrast to those with double deficits.

STUDY 1

Introduction

Study One was designed to test the predictions of the double deficit hypothesis of reading in a sample of children with poor phonological skills. This population was chosen because many existing interventions specifically target phonological skills. It was of interest whether those children with a deficit in naming speed would indeed benefit less from training than children with a single deficit in phonemic awareness. In other words, the question of whether slow naming speed creates further barriers to reading acquisition over and above phonological deficits was of particular interest in this study.

In contrast to studies that select participants who have been referred for special services and represent the most severely impaired children in the school system, the current sample was selected from regular classrooms in the public school system. Children were screened on measures of phonemic awareness and naming speed and selected for the study if they scored below the 30^{th} percentile for the sample on the phonemic awareness measure. It was expected that most participants would be poor readers, but the sample clearly represents less severely impaired readers than the dyslexics studied by Lovett and Steinbach (in press).

The specific questions addressed in Study One are as follows. These questions fall directly out of predictions of the double deficit hypothesis of reading.

1) Do children with a single deficit in phonemic awareness differ from children with double deficits in phonemic awareness and naming speed in terms of performance on standardized reading measures?
2) Within a sample of children with weak phonological skills, do those children with an added deficit in naming speed benefit less from training?

3) Are children in the double deficit group less likely to use orthographic knowledge to help them read words sharing a rime pattern with known words?

Method

Participants

Two hundred and one children (101 males, 100 females) in twelve regular Grade 3 classes in two local publicly-funded school boards participated in the screening phase of the study. These children were all the children in Grade 3 in five schools whose parents gave permission for participation in the study and who themselves consented to participate.

Participant Selection

On the basis of screening, 53 children (31 males and 22 females) were selected for participation in the main phase of the study. The selection criterion was performance at or below the 30th percentile for the sample on the Auditory Analysis Test, in the absence of major speech or hearing defects. These children corresponded to those children having a raw score of 14 or below on the short form of the AAT. While two children spoke a language other than English at home, all were fluent in English. One child was excluded from the study because of repeated absences at the time of testing, another was excluded because she was unable to complete the second session of testing. Thus, the final sample consisted of 51 children, all of whom had weak phonemic analysis skills.

Forty-nine of the 51 children included in the study were divided into two subgroups on the basis of their RAN:D scores. Children in the single deficit group had difficulties only in phonemic awareness, and their naming speed scores fell at or above the 40th percentile in the original sample. Children in the double deficit group had difficulties not only in phonemic awareness, but also in rapid naming, as evidenced by RAN:D scores below the 30th percentile for the original sample. The final sample consisted of 23 children who have a single deficit in phonemic awareness, and 26 children with a double deficit in both phonemic awareness and rapid naming, as well as two children with RAN:D scores falling between the 30th and 40th percentiles for the original sample. These two children were included in regression analyses examining the full range of naming speed scores but not in analyses examining differences between children with single versus double deficits. These children were evenly divided between the trained and untrained groups.

Measures

Screening Measures

Phoneme Deletion. All children completed an abbreviated version of Rosner and Simon's (1971) Auditory Analysis Test (AAT), which consisted of 29 items from the original test. These 29 items were all items from the first seven types of words included in the original AAT, and included deleting phonemes from the beginning, middle, and end of words. Stimuli for this task are given in Appendix A.

Rapid Naming Speed. Children completed a continuous rapid naming test. Rapid Automatized Naming: Digits (RAN: D) (Denckla and Rudel, 1976). Two trials of the RAN were given, one before and one after the AAT, and an average of the two scores (in digits per second) was used for analysis. This task is presented in Appendix B.

Standardized Test Measures

Word Identification. Children completed the Letter-Word Identification subtest of the Woodcock-Johnson Achievement Battery (Woodcock & Johnson, 1989), a standardized measure of word recognition skills. Reliabilities are not reported in the W-J manual for age eight; however internal consistency reliabilities for age six and age nine range between .91 and .94 for this task and the Word Attack task.

Word Attack. The Word Attack subtest of the Woodcock-Johnson Achievement Battery (Woodcock & Johnson, 1989) was also administered. This standardized measure of decoding skills involves reading pronounceable nonwords.

Vocabulary. Children completed the Vocabulary subtest of the WISC-III as a measure of general verbal ability. This task requires the child to provide oral definitions of words and correlates .88 with Verbal IQ at age 8 (Wechsler, 1991). Spearman-Brown corrected split-half reliability is .88 at age eight (Wechsler, 1991).

Similarities. Children also completed the Similarities subtest of the WISC-III. This task requires the child to state the similarity between two objects and concepts and correlates .87 with Verbal IQ at age 8 (Wechsler, 1991). Spearman-Brown corrected split-half reliability is .84 at age eight (Wechsler, 1991).

Posttest Measures

Reading. Following training, children completed posttest reading measures, involving four 14-item sets of stimuli. These stimuli are presented in Appendix C. Each stimulus was printed in 80 point Avant Garde print on a 7 by 11 cm card. The first set of words (base words) included the training words. The three additional sets formed the transfer measures. One set (single onset words) included low frequency words which rhyme with the training words and have a single consonant onset, while another (bigram onset words) included low frequency words which rhyme with the base words, but begin with a consonant blend. The respective mean frequencies of these lists of words in English text are 378 and 362 out of

5,088,721 (Carroll et al., 1971). The final set consisted of single onset pseudowords which rhyme with the training words. These stimuli were the same as were used in Bowers' (1996) rime transfer task, with the exception that two transfer words with relatively high frequency were eliminated.

Word Choice. Children also completed a posttest word choice task using the training words. The child was asked to point to the correct spelling of each training word from a set of three alternatives presented in random order. The three alternatives included: the correct spelling of the training word, the letters of the training word presented in scrambled order, and a third choice which consisted of either a homophone of the training word, or a vowel substitution.

Phoneme Deletion. This test involved 12 items which required the child to remove the initial phoneme from a single onset word, and 12 words which required the child to remove the initial phoneme from a bigram onset word. This measure shared 12 items with the pretest AAT measure.

Naming Speed. Children completed the RAN: D task given in screening again at posttest.

Procedure

Screening

In screening, children met individually with the researcher on one occasion to complete the Auditory Analysis Test and Rapid Automatized Naming: Digits task. The screening session lasted approximately 10 minutes per child.

Pretesting and Condition Assignment

During the main phase of the study, 51 children selected as described above, met individually with the researcher on two separate occasions in a small room at school. The first session lasted approximately 15 minutes, and the second session lasted between 15 and 40 minutes (depending on experimental condition). In the first session, participants completed the Letter-Word Identification and Word Attack tests, as well as the two standardized tests of verbal ability: Vocabulary and Similarities.

Prior to the second session, children within the single and double deficit groups were assigned to experimental and control conditions, such that the two conditions were matched on Word Attack raw scores.

Training

In the second session, children in the experimental group completed a training program. The training words consisted of 14 high frequency words. The mean frequency of these words in text is 1,549 out of 5,088,721(Carroll, Davies & Richman, 1971). All 14 training words were four-letter words with a single-consonant onset followed by a three-letter rime. These stimuli are presented in Appendix C.

The first part of training was designed to encourage breakdown of words into onset and rime and to remind the child of some basic orthographic rules in English. Training for each word began with a task that was analogous to the AAT task. In this task, the child was asked to remove the initial consonant from the orally presented word. If the child was unable to do so correctly after the first trial, he or she was asked to listen carefully and try the task again. If the child was still unable to complete the task correctly after the second trial, the researcher told the child the correct answer and explained how the task was completed.

Subsequently, the child was shown a set of letters randomly displayed on the table and asked to spell the training word with the letters. If the child spelled the word incorrectly on the first trial, he or she was told to look carefully at what he or she had spelled, and change it so that it spelled the target word. If he or she was unable to spell the word correctly on the second trial, the researcher demonstrated the correct spelling of the word to the child. Then, with the correct spelling of the word in front of the child, the researcher gave the child a short lesson about the target word, first showing how the printed word could be broken down into onset and rime just like the spoken word and then describing an orthographic rule which applied to that particular word. For the first three words (fast, best, jump), the child was told that each letter in the word makes its own sound. For the next two words (sunk, back), the child was told that the final three letters blend together to make the rime. For the next two words (pick, dock), the child was told that in these words, it takes two letters to make the /k/ sound. For the following three words (lake, side, late), the child was told that sometimes when a vowel in a word says its name, there is an e at the end of the word that does not make its own sound, but tells the vowel to say its name. For the subsequent three words (feed, main, beak), the child was told that another way that a vowel can say its name is to have another vowel beside it which does not make its own sound. For the final word (more), the child was told that some words do not follow the rules as well as other words, and the spelling of those words just has to be remembered.

The second part of training was designed to provide the child with further exposure to the whole word orthographic patterns in the training words. This part of training was presented in game-like form, using speed of performance as an incentive. In the practice game, the child was presented with three sets of 14 sheets of 8 1/2 by 11 inch paper. Each sheet had one training word and five foils printed in random order. Each foil shared at least two letters with the training word. The child's task was to point to the training word on each sheet as quickly as possible. The researcher presented each sheet in succession and pronounced aloud the training word on each sheet. If the child was unable to find the training word on the first trial, he or she was told to look carefully and try again. If the child was unable to find the training word on the second trial, the researcher pointed to it and proceeded to the next sheet. This procedure was completed three times, with the child being encouraged to go faster each time. The time to complete all 14 sheets was recorded for each of the three trials, primarily as a motivational factor for the child. Children in the control group did not participate in training, but they did complete the post-training measures.

Post-training

Following training, children completed posttest reading measures of the training and transfer stimuli. Each child received the sets of words in the following order: training words, single onset transfer words, bigram onset transfer words, nonwords. Although the training and transfer stimuli were presented close together in time, words within each set were presented in mixed up order. Children were not given feedback about the correctness of their responses. Thus, it was unlikely that "priming" of the transfer stimuli by the training stimuli occurred. Each child was presented with the stimuli in one of two orders.

Following the completion of the reading outcome measures, all children completed the three other posttest measures: Word Choice, RAN:D and Phoneme Deletion.

Results

Pretest

Mean pretest scores and standard deviations for each of the training and deficit groups are presented in Table 1.

TABLE 1

Mean Pretest Scores (and Standard Deviations) by Training Condition and Deficit Group

		Single Deficit		Double Deficit	
		Experimental	Control	Experimental	Control
n		12	11	13	13
AAT (raw score /29)	M	11.00	11.73	10.92	11.54
	SD	(2.70)	(2.37)	(2.62)	(2.18)
RAN:D (digits/sec)	M	1.96	2.07	1.43	1.36
	SD	(.18)	(.22)	(.19)	(.14)
Word Identification	M	93.17	91.36	83.92	86.92
	SD	(7.92)	(10.86)	(9.79)	(13.83)
Word Attack	M	88.75	88.45	83.62	84.46
	SD	(6.26)	(7.99)	(6.79)	(6.41)
Vocabulary	M	8.83	8.91	8.23	9.38
	SD	(2.03)	(2.58)	(1.88)	(1.23)
Similarities	M	9.83	8.27	9.00	9.00
	SD	(2.66)	(2.10)	(3.60)	(4.04)

Note. Word Identification and Word Attack scores are standard scores for grade (mean = 100, standard deviation = 15); Vocabulary and Similarities are scaled scores (mean = 10, standard deviation = 3)

Analysis of variance (ANOVA) of these data indicated no differences among conditions on the AAT or verbal ability measures, F's < 1. In addition to being higher on the naming speed measure on which the two groups were selected, $F(1, 45) = 139$, $p < .001$, children in the single deficit group also scored higher on measures of word recognition and nonword decoding (F's (1, 45) = 4.83 and 5.40, p's = .033 and .024 respectively). Similarly, if a poor reader is defined by performance below the 25th percentile on the word recognition measure, then 20 of the 26 double deficit children are poor readers, while only seven of the 23 single deficit children are poor readers. This difference is consistent with previous work showing children with deficits in both phonemic awareness and naming speed to be more impaired than children with a deficit only in phonemic awareness on a variety of reading measures (Bowers et al., 1999; Lovett & Steinbach, in press; Wolf & Bowers, in press). The stronger reading of the single deficit group in the current sample is particularly remarkable in light of the fact that the two deficit groups did not differ on phonemic awareness.

No differences between the experimental and control groups within each deficit type were significant (all F's < 1). Therefore, matching on Word Attack scores did not produce spurious differences on other variables.

Reading - Training Words

A comparison of the mean number of training words read correctly in each of the deficit and training conditions is given in Table 2. To assess whether training enabled children to read more of the training words, a 2 x 2 ANOVA with Training Condition (Experimental versus Control), and Deficit Type (Single versus Double) as independent factors was conducted on these data. Results yielded a main effect of training condition, F (1,45) = 23.27, $p < .001$, and a marginal effect of deficit type, F (1, 45) = 3.35, p = .058, but no interaction between the two variables. Children who received training were able to read more training words at posttest than children who did not receive training. In addition, regardless of training, children with poor naming speed tended to read fewer words than children with relatively good naming speed, a result which is similar to that obtained on the standardized reading measures.

TABLE 2

Mean Scores on Training Words and (Standard Deviations)

Deficit Type		Experimental	Control
Single Deficit	M	13.67	11.64
	SD	(.65)	(2.11)
		n= 12	n=11
Double Deficit	M	13.30	10.00
	SD	(1.11)	(2.94)
		n=13	n=13

Note. All scores out of 14

Regression analyses on these data indicated that after controlling for condition at step one and for either RAN or AAT at step 2, AAT predicted 3.5% unique variance (p =.097) at step 3, RAN predicted 5% unique variance (p =.040) at step 3, and the interaction of AAT and RAN predicted an additional 3.5 % of variance at step 4 (p =.086). That RAN predicted unique variance in ability to read the training words is notable given that children's reading of the training words was at or near ceiling levels.

Children's performance on the posttest word choice task was comparable to their performance on reading of the training words. Mean number of training words correctly identified in each deficit and training condition are given in Table 3. Like the reading data, there was evidence of ceiling effects on this task, as on average, children were able to identify approximately 12 of the 14 training stimuli.

TABLE 3

Mean Scores on Word Choice Task and (Standard Deviations)

Deficit Type		Experimental	Control
Single Deficit	M	13.17	11.72
	SD	(1.98)	(2.33)
		n= 12	n=11
Double Deficit	M	11.46	10.84
	SD	(2.03)	(1.86)
		n=13	n=13

Note. All scores out of 14

Results of ANOVA on these data revealed a main effect of deficit type, F (1,45) = 5.77, p =.020, and a marginal effect of training condition F (1,45) = 3.64, p =.063, with no interaction between the two variables (F < 1). Single deficit children identified the correct spelling of the training words more often than children in the double deficit group. There was a trend toward the trained group showing better performance than the untrained group. When reading of the training words was controlled (using ANCOVA), however, no effects remained, suggesting that the word choice task was an alternate measure of training word reading.

The effect of training on reading of the training words was statistically significant, but the magnitude of this effect was not large. Examination of means reveals that, on average, children learned to read two or three words in training. This relatively small increase is likely related to the difficulty level of the training words for this sample. The sample was selected on the basis of low phonemic awareness; however, many of the children in the sample were not poor readers. At a mean level, children scored below grade level on the reading measures, but further analysis of the pretest data revealed that only 29 of the 51 children in the sample had reading scores below the 25th percentile for their grade on word recognition. In other words, 22 children in the sample had word recognition scores in the broad average range. Many of these children were able to read most of the training words without training, including four children in the control group who were able to read all 14 training words. Thus, the small magnitude of the training benefit may have resulted from ceiling effects.

Reading – Training Words (poor reader sample)

Table 4 shows the mean scores on the training words for each of the groups, when only those children with below average word recognition scores were included (those with grade standard scores below 90 on Letter-Word Identification). This selection criterion resulted in a sample size of four in the single deficit experimental group, three in the single deficit control group and ten in each of the double deficit groups. Examination of these scores revealed that the maximum number of training words read by any of the poor readers in the control group was 13, with the majority of children reading only seven or eight. Therefore, when only poor readers were included in the sample, ceiling effects were reduced.

TABLE 4

Mean Scores and (Standard Deviations) on Training Words for Poor Readers Only

		Experimental	Control
Single Deficit	M	13.25	9.33
	SD	(.96)	(2.08)
		n = 4	n = 3
Double Deficit	M	13.20	9.50
	SD	(1.23)	(3.06)
		n = 10	n = 10

Note. All scores out of 14

Reading - Transfer Stimuli

Mean reading scores on the transfer words and nonwords for each of the training and deficit conditions are given in Table 5. In order to assess whether children with single versus double deficits differ in their ability to read similar words and pseudowords following training, ANOVA was conducted on the number of words of each of the three types that the child was able to read. Training Condition (Experimental versus Control) and Deficit Type (Single versus Double) were between-subjects variables, and Stimulus Type (Single Onset, Bigram Onset and Pseudoword) was a within-subjects variable. Results of this analysis revealed a main effect of deficit type, F (1,45) = 8.02, p = .007, and stimulus type, F (2,90) = 44.37, p < .001, but no effects or interactions involving Condition (p.'s >.20). Therefore, when allowing the children's initial reading scores to vary, training enabled the children to read more training words, but the skills learned in training appear to be instance-specific and do not include the reading of other words and pseudowords in the same family.

TABLE 5

Mean Scores on Transfer Stimuli and (Standard Deviations)

	Single Onset		Bigram Onset		Pseudowords	
	Experimental	Control	Experimental	Control	Experimental	Control
Single Deficit	11.58	10.45	10.41	9.36	9.33	7.09
	(3.36)	(2.69)	(2.78)	(2.97)	(3.31)	(3.11)
Double Deficit	9.23	8.46	7.30	6.46	6.38	5.69
	(3.00)	(3.38)	(3.54)	(3.40)	(3.73)	(3.37)

Note. n = 12 for Single Deficit Experimental group: n = 11 for Single Deficit Control group: n = 13 for each of the Double Deficit groups. All scores out of 14.

Although the above analysis did not differentiate between the training groups in terms of ability to read the transfer stimuli, one possible reason for this null result is that there was too much variability in the children's initial reading performance. As noted above, several children in the sample were not poor readers, and these children may have been able to read the majority of the training and transfer words even without training. In order to control for preexisting differences in reading skill, ANCOVA was conducted, using the same factors as the above analysis and pretest Letter Word Identification Scores as a covariate. Mean reading scores, controlling for initial word reading, are given in Table 6.

The results of the ANCOVA revealed a main effect of Condition, $F(1,44) = .29$, $p = .026$, but no effects or interactions involving either Deficit Type or Stimulus Type (p's > 0.1). Therefore, when initial word recognition scores are controlled, training enabled children to read more words and pseudowords sharing a common rime pattern.[1] These results are important as they show that even with brief training, children are able to transfer skills to novel stimuli. The lack of an interaction with deficit type indicates that the amount of transfer was not moderated by the child's status on the naming speed variable. Given a fixed amount of practice, trained children of both deficit types were able read more words and pseudowords sharing a rime with the training words than children who did not receive training. This finding goes against the hypothesis that children with a deficit in naming speed as well as phonological awareness would require more practice in order to learn orthographic rime patterns.

TABLE 6

Mean Scores on Transfer Stimuli and (Standard Deviations) Controlling for Initial Word Recognition Skills

	Single Onset		Bigram Onset		Pseudowords	
	Experimental	Control	Experimental	Control	Experimental	Control
Single Deficit	10.68	9.91	9.38	8.74	8.33	6.49
	(2.36)	(2.32)	(2.08)	(2.06)	(2.49)	(2.45)
Double Deficit	10.18	8.80	8.40	6.86	7.44	6.07
	(2.35)	(2.31)	(2.09)	(2.06)	(2.49)	(2.42)

Note. n = 12 for Single Deficit Experimental group; n = 11 for Single Deficit Control group; n= 13 for each of the Double Deficit groups. All scores out of 14.

Reading – Transfer Stimuli (Poor reader sample)

Examination of the mean scores for the poor readers in Table 7 suggests a somewhat different conclusion. These data, while only speculative given the small number of children in the single deficit group, suggest that children with a deficit only in phonemic awareness show a greater improvement in reading following training than children with deficits in both phonemic awareness and naming speed.

TABLE 7

Mean Scores on Transfer Stimuli (and Standard Deviations) for Poor Reader Sample

	Single Onset		Bigram Onset		Pseudowords	
	Experimental	Control	Experimental	Control	Experimental	Control
Single Deficit	9.25	7.00	8.75	5.67	7.75	4.43
	(4.99)	(1.00)	(3.20)	(1.15)	(4.34)	(1.53)
Double Deficit	8.80	7.60	6.60	5.70	5.50	4.80
	(3.12)	(3.34)	(3.72)	(2.83)	(3.81)	(2.86)

Note. n = 4 for the Single Deficit Experimental group; n=3 for the Single Deficit Control group; n= 10 for each of the Double Deficit groups. All scores out of 14

The difference in results between the analysis of covariance and examination of the means for poor readers may be related to the different ways of looking at the data. When controlling for variability in initial word reading performance, any variability in phonemic awareness or naming speed that is shared with initial word reading is also controlled. In other words, all children are artificially assigned the same initial word recognition score, even though the children in the single and double deficit groups would have different patterns of underlying skills. In this sample, naming speed is a stable variable (correlation between pretest and posttest RAN scores = .94), therefore controlling for initial word reading also controls for some of the variability associated with RAN levels at posttest. Thus, it is not surprising that effects of RAN on posttest reading performance were not found in the analysis of covariance.

In summary, training affected not only children's ability to read the training words, but also their ability to read other words and pseudowords in the same families, provided that initial reading scores are controlled. These results do not support the hypothesis that among children with a deficit in phonemic awareness, those with an added deficit in naming speed show less transfer than those without this additional skill weakness. However, it may be important to further investigate this hypothesis within a sample of poor readers given the presence of ceiling effects on the training words for some children.

Phoneme Deletion

In addition to encouraging the development of word identification skills, training also included explicit instruction in phonemic analysis. Children were asked to delete the first sound from the training words and when unable to do so correctly, the experimenter told them the answer and explained the process. Thus, one would expect children who received training to show better posttest phoneme deletion skills than children in the control group. All training words consisted of a single consonant onset followed by a three-letter rime. If children were simply learning what is explicitly taught in training, the trained group should have higher scores than the control group only for the items requiring deletion of a single consonant onset. If children were showing general phonological skill improvements, then training effects would also be observed on the items requiring them to delete the initial consonant from a bigram consonant blend (e.g, say "block" without the "b"). Although children were not explicitly taught how to analyze consonant clusters, they were taught how letters can represent each sound even within a cluster.

TABLE 8

Mean Posttest Phoneme Deletion Scores and (Standard Deviations)

	Single Onset		Bigram Onset	
	Experimental	Control	Experimental	Control
Single Deficit	11.58	11.45	3.50	1.73
	(.99)	(.93)	(2.58)	(1.79)
Double Deficit	11.00	10.00	1.30	1.86
	(1.41)	(3.05)	(1.65)	(2.07)

Note. n = 12 for Single Deficit Experimental Group; n= 11 for Single Deficit Control Group; n= 13 for Double Deficit Groups. All scores out of 12.

Mean scores for each of the training and deficit groups on the posttest phoneme deletion task are shown in Table 8. In order to assess whether the phonological skills encouraged in training affected phoneme deletion skill, a Condition by Deficit type by Deletion Type (Single versus Bigram) mixed-model ANOVA was conducted. Results of this analysis yielded a reliable 3-way interaction between the factors, $F(1, 45) = 4.04$, $p = .050$, as well as main effects of deficit type, $F(1,45) = 6.68$, $p = .013$, and deletion type, $F(1,45) = 1937.59$, $p < .001$). Simple effects analyses indicated that children with deficits only in phonemic awareness (but relatively strong naming skills) who received training scored higher on the bigram onset deletions than children in the other three groups. In other words, children with deficits in both phonemic awareness and naming speed who received training did not learn sound deletion skills; however, children with a single deficit in phonemic awareness did learn to analyze consonant clusters as a function of training. These results support previous findings (Lovett & Steinbach, in press) suggesting that children with deficits in both areas have more difficulty learning phonological skills than children with only one deficit.

Use of Rime Knowledge Measure

In addition to examining effects of training on phonological skills, this study was designed to examine the orthographic side of the double deficit hypothesis. All of the children in the study scored poorly on a measure of phonemic awareness, but some children had stronger naming skills than others. Would children with a single deficit in phonemic awareness draw upon their hypothesized relative strength in orthographic processing and use rime pattern information to help them read words in the same families? Use of rime pattern information may be related to knowledge learned in training, but it may also be independent of training effects, being the result of preexisting knowledge of rime patterns.

In order to assess these questions, "use of rime knowledge" analyses were conducted. In these analyses, only use of rime knowledge from base training words known to the child was considered. Thus, if a child knew 10 of the 12 training words, only transfer words from these 10 word families were analyzed. Words sharing rimes with unknown base words were ignored. The proportion of base words for which a transfer word was known formed the unit of analysis.[2] The question addressed by the use of proportion scores was as follows: Given that a child could read a training word, would s/he be able to read lower frequency untrained words with the same rime or pronounce accurately a pseudoword with that rime? These scores, therefore, controlled for initial differences in ability to read the training words. The same procedure was used by Bowers (1996). It was assumed that these measures, while tapping a similar construct to the raw scores on the transfer stimuli reported above, were more theoretically pure, as they were thought to reflect a child's ability to use orthographic knowledge when reading words sharing a common rime pattern.

TABLE 9

Mean Rime Use Proportions (and Standard Deviations)

	Single Onset		Bigram Onset		Pseudowords	
	Experimental	Control	Experimental	Control	Experimental	Control
Single Deficit	.84	.82	.75	.68	.67	.55
	(.23)	(.16)	(.20)	(.19)	(.23)	(.18)
Double Deficit	.68	.66	.54	.47	.48	.42
	(.20)	(.27)	(.23)	(.29)	(.25)	(.24)

Note. n = 12 for Single Deficit Experimental Group; n = 11 for Single Deficit Control Group; n = 13 for Double Deficit groups

Table 9 shows the proportion of untrained stimuli correctly identified given that the child identified the training word in that family. A Deficit Type by Training Condition by Word Type mixed-model ANOVA was conducted on these data. This analysis yielded a main effect of Deficit Type, F (1, 45) = 8.81, p = .005, and Word Type, F (2, 90) = 43.63, p< .001, but no effects or interactions involving Condition (p's >.3) [3] Similar results were found in regression analyses using the full range of naming speed scores. These results indicate that regardless of training, children with fast naming skills were more likely than children with slow naming skills to use knowledge of rime patterns.

These results support the hypothesis that among children with poor phonemic analysis skills, those with slow naming speed use orthographic pattern knowledge less often than those with fast naming speed. The lack of an effect of training condition suggests that the type of training used here does not encourage the learning and use of rime patterns. Examination of mean scores indicates differences between the training groups, but the differences were small and power to detect reliable differences was low. It is possible that training which more explicitly emphasizes the use of rime knowledge when reading new words might yield more consistent results.

In order to assess the extent to which phonemic analysis and rapid naming skills are independent predictors of use of rime pattern knowledge, whether or not the knowledge is gained during training, a series of hierarchical multiple regression analyses was conducted. The pattern of relations was similar for all three types of stimuli; therefore, results will be reported using the mean proportion score for the three word types in order to increase reliability. Scores on Word Identification were entered first in order to control for reading skills. These scores accounted for 58% of variance in rime use. When entered after AAT and Word Identification in the equation, RAN accounted for 4% unique variance ($p = .029$). When entered after RAN and Word Identification, AAT accounted for 2% unique variance ($p = .085$). The interaction between AAT and RAN accounted for an additional 3% of variance ($p = .031$). Therefore, unlike the results reported by Bowers (1996) using a classroom sample spanning the full range of reading skills, in the present sample of children who are poor on phonemic analysis skills, rapid naming skills are an important predictor of use of rime pattern knowledge. Phonemic analysis skills do not predict significant unique variance in use of rime knowledge; however, this result is not surprising given the restricted range of AAT scores in the current sample.[4] The interaction between AAT and RAN is particularly interesting. Inspection of the regression equation involving the interaction term suggests a pattern of compensation. Phonemic awareness is most important in predicting use of rime knowledge at low levels of RAN. Similarly, rapid naming skills are most important in predicting use of rime knowledge at low levels of AAT. At higher levels of either skill, the predictive value of the other variable is weak.

Relation between Use of Rime Knowledge and Phoneme Deletion

So far, results of this study indicate that after controlling for initial reading skills, children show improved ability to read the training and transfer stimuli after training. In addition, children with relative strength in naming speed show some improvement in phonemic analysis skills after training (as shown by higher scores for the experimental than the control group for single deficit children on the harder bigram consonant onset words). Furthermore, single-deficit children are more likely to apply rime knowledge when reading (regardless of training). To assess whether final phonemic awareness and use of rime knowledge scores are related, a series of multiple regression analyses was conducted. As in previous analyses, given that the pattern was similar across the three word types, mean scores for untrained words and pseudowords (across the three levels of word type) were used to provide increased reliability. In the analyses reported here, proportion scores (which are assumed to reflect use of rime knowledge) were used as the dependent variable[5].

To control for pretest performance, initial AAT scores were entered at the first step of the regression equation, accounting for 15% of variance ($p = .005$). When entered as a second step in the regression equation, training condition accounted for a non-significant 3% of the variance ($p = .687$). This result is consistent with the lack of a main effect for training condition in the ANOVA on these data. When entered at the third step, posttest phoneme deletion scores accounted for 25% of variance (p <.001), despite these scores being correlated with pretest AAT scores (r = .39, p = .005) Thus, although the posttest phoneme scores themselves were affected by training, these skills have an effect on use of rime knowledge independent of training. When the order of entry of posttest phoneme deletion and training condition was reversed, posttest AAT accounted for 27% of variance at step 2 (p < .001), with training condition accounting for less than one percent of variance at step 3. Interestingly, initial RAN scores predicted an additional 7% of variance in untrained stimuli (p = .013) when entered at step 4. Therefore, even after taking into account the amount of growth in the skill most directly taught in training, RAN scores predicted how well a child would apply knowledge about a common rime pattern to other words and pseudowords sharing that pattern.

In addition to time of testing, pretest and posttest phoneme deletion tasks also differed with respect to the similarity of items to the type of analysis skill required to complete the transfer task. The posttest task included items involving removal of a phoneme from the beginning of words, while the pretest version included deletions from the beginning, middle, and end of words. Therefore, to ensure that the unique predictability of the posttest measure was not due to type of stimulus, regression analyses were conducted using a shortened version of the original AAT including only those items involving the deletion of an initial phoneme as a predictor at step one. The correlation between this measure and the original measure was .67 (p < .001), and between this measure and the posttest phoneme deletion measure was .56 (p < .001). Essentially the pattern of results remains as in the previous analyses using the complete AAT. [6] A similar pattern of results was found when either the single onset or the bigram onset type of final phoneme deletion scores was entered in place of the overall measure, indicating that the predictive qualities of this measure are present across difficulty levels. Therefore, results of these regression analyses indicate that a child's final status on the phoneme deletion variable plays an important role in predicting his or her ability to apply knowledge of a common rime pattern, over and above initial performance on the AAT and training condition.

Predicting Final Levels of Phoneme Deletion

Given the importance of a child's final level of phoneme deletion skill in predicting use of rime knowledge, knowing what variables contribute to this final skill level provides information relevant to understanding some of the processes related to learning phonemic awareness. Hierarchical regression analyses were conducted predicting to the posttest phoneme deletion variable. When entered at the first step in the regression equation, the shortened version of the AAT (including only those items most like those included at posttest), predicted 32% of variance in the posttest measure ($p < .001$). At the second step, training condition accounted for an additional 8% of variance ($p = .026$). Initial RAN scores predicted an additional 5% of variance at step three ($p = .058$). When the order of entry of training condition and RAN was reversed, RAN predicted 5% of variance ($p = .058$) and training condition predicted an additional 6% ($p = .026$). Together, initial sound deletion scores, training condition and RAN account for approximately 43% of the variance in the final sound deletion measure. The pattern of prediction is similar when controlling for the full AAT at step one, although the overall percentage of variance accounted for is somewhat lower (30%). Thus, the primary variables of interest in this study account for a substantial proportion of variance in the final sound deletion measure, which in turn, accounts for a substantial proportion of variance in the use of rime knowledge measure. RAN scores predict use of rime knowledge scores, not only through shared variance with the final phoneme deletion measure, but also independently of phoneme deletion skills and training condition.

Discussion

Double Deficit Hypothesis

This study provides some support for the double deficit hypothesis of reading difficulties. Among a sample of children with poor phonemic awareness, a number of differences were observed between those children with a single deficit and those with a double deficit (in phonemic awareness and naming speed). In general, combined deficits were associated with weaker performance than a single phonological deficit, suggesting that the two deficits are primarily additive rather than overlapping.

In this sample, the single and double deficit groups were equally low on phonemic awareness, yet children in the double deficit group showed weaker reading skills than children in the single deficit group. While the mean reading score for both groups of children was somewhat below average for their grade level, many more children in the double deficit than single deficit group were poor readers. These results, which replicate those of Wolf and Bowers (in press) and Lovett and Steinbach (in press), suggest that many children in the single deficit group possess skills which allow them to read adequately despite their weak phonemic awareness. It is assumed that at least some of these skills are tapped by processes underlying symbol naming speed. Although this finding does not help to reconcile the debate about whether naming speed taps primarily phonological skill or whether the precise timing aspects of the task predominate, it does emphasize the importance of including measures of rapid naming ability in early screening programs. Having deficits in both phonemic awareness and naming speed clearly places a child at greater risk of reading difficulties than having a single deficit in phonemic awareness.

Do Children Show Benefits from Brief Training?

In this study, after brief training, children not only learned to read the training words, but when controlling for initial levels of reading skill, they also showed transfer of this knowledge to other words in the same families. These results are remarkable given the brief nature of training. Previous research has shown that transfer effects are difficult to obtain, and typically occur only after extensive training over long periods of time (e.g., Lovett et al., 1994, Levy & Lysynchuk, 1997; Roth & Beck, 1987).

One possible reason for the success of the current training program is the limited number of words taught and practiced. In a study of poor readers in Grade Two, Levy & Lysynchuk (1997) showed that generalization of skills was based not on the specific type of training that the children received, but rather on children's final level of proficiency with the training words. They also reported that maintenance of reading gains over time is also based on how well children learn the training words, rather than the type of training used. Therefore, limiting the number of words trained to 14 may have allowed children to learn the words sufficiently well for transfer to occur. It is possible that even when a child was able to read a training word initially, training affected how well a child knew that word. In other words, training may have fostered a more analytic understanding of the onset-rime components of that word, thus encouraging transfer.

Do Children with Deficits in Both Phonemic Awareness and Naming Speed Show Poorer Performance on Transfer Items than Children with a Single Deficit in Phonemic Awareness?

The results of this study did not support the hypothesis that children with deficits in both phonemic awareness and naming speed would show weaker knowledge of transfer items than those with a single phonemic awareness deficit. Examination of mean outcome scores for the single and double deficit groups suggests small differences that were not statistically reliable in this sample.

Although the main hypothesis of the study regarding knowledge of transfer items was not supported, the results do provide some evidence that may lead to a better understanding of why children with deficits in both areas struggle to learn to read. Analyses of the use of rime knowledge measures revealed that double deficit children are less likely to use knowledge of rime patterns when reading words within the same family. In other words, even when they know a word with a common rime (whether that word was previously known or learned in training), they are less likely than single deficit children to use the knowledge of that rime when reading other words or pseudowords sharing that rime pattern. It is acknowledged that use of rime knowledge may depend, in part, on word-analysis skills, or more specifically on the ability to segment words into onset and rime. Nevertheless, this finding, along with others showing that naming speed is related to orthographic processing skills (Manis & Doi, in press; Manis et al., 1999; Sunseth & Bowers, 1997; Torgesen et al., 1997b) is consistent with predictions made by the double deficit hypothesis (Bowers & Wolf, 1993; Wolf & Bowers, in press). Not only were phonemic awareness and rapid naming skills independent predictors of use of rime pattern knowledge, but there was also an interaction between the two variables, suggesting that children with stronger naming skills may be able to partially compensate for the deficit in phonemic awareness.

Without the benefit of orthographic skills to compensate for weak phonological skills, children with both deficits are doubly disadvantaged. They struggle to decode novel words, yet they also struggle to use information about common letter patterns to supplement the decoding route. Thus, without intervention, children with double deficits may be forced to rely more often on an instance-based word recognition strategy. This strategy requires large amounts of exposure to print, which is rare among poor readers, resulting in a further decline in reading abilities over time, otherwise known as Matthew effects (Stanovich, 1986).

Are Children with Slow Naming Speed "Treatment Resistors"?

This study provided some evidence to support suggestions made by Blachman (1994) that slow naming differentiates "treatment resistors" from those children who do benefit from intervention. Following training, children in the single deficit group, but not those in the double deficit group, showed improved phoneme deletion skills. This improvement was small, but meaningful, given that it involved the difficult task of splitting an initial consonant blend. Without training, children in both deficit groups were essentially unable to complete this task. With training, children in the single deficit group were able to complete a few such deletions, although they still had a great deal of difficulty with the task. Thus, it appears that children in the single deficit group were beginning to acquire an understanding of the complexities of the individual sounds in spoken language, moving them beyond the preliminary understanding that syllables can be divided into onset and rime. Given the presence of ceiling effects on the single onset words, it is difficult to determine whether a similar pattern holds on these easier stimuli.

Although the learning differences between the single and double deficit groups were not as strong as predicted, being confined to sound analysis skills rather than involving reading directly, the fact that the resistance to instruction of the double deficit group fell in the phonological domain is notable. Similar findings were reported by Lovett and Steinbach (in press), who demonstrated that children with combined deficits in phonological and rapid naming skills showed less improvement in nonword decoding following intensive training than children with either deficit in isolation.

Understanding the mechanism by which naming speed inhibits the learning of phonological skills remains an important research question. Children with slow naming speed may simply need more practice in order to consolidate learning. Alternatively, this finding may support the notion that in addition to assessing timing mechanisms, rapid naming tasks also measure important phonological skills. In other words, one reason that children with double deficits have difficulties learning phonological skills is that instead of having a deficit in only one phonological skill (phonemic awareness), they have two different kinds of limitations on their phonological skill. Finally, the connection between RAN and learning phoneme deletion skills may be related to the demands for rapid processing on both tasks. Although phoneme deletion is not a timed task, successful completion of the task requires the ability to quickly represent individual phonemes in order to blend them more efficiently and bypass working memory limitations.

The poor outcome of the double deficit group on the phonemic awareness task has important implications for remediation. Most current intervention programs emphasize phonological skills, the very skill that children with double deficits struggle to learn. Wolf (1997) argued that children with slow naming speed are not well served by current interventions, which do not target their core deficits in word retrieval and orthographic skills. The present study, in conjunction with the findings of Lovett and Steinbach (in press), carries this claim one step further by showing that children with slow naming speed have more difficulty picking up the phonological skills which are targeted by such intervention programs. In other words, not only do children with double deficits suffer because one of their core deficits is ignored by most interventions, but they suffer the added blow of greater difficulty learning those skills related to the core deficit which has been targeted by intervention.

Limitations of the Study and Directions for Further Research

Several limitations of Study One support the need to further explore the hypothesis that children with deficits in both phonemic awareness and naming speed are "treatment resistors." Many children in the sample were not poor readers, and some children, more often the single deficit children, scored close to ceiling on the training words even without training. The small sample size combined with differential ceiling effects for the deficit groups may have precluded finding the hypothesized interaction between deficit group and training condition.

The pattern of results of this study still leaves open the question of factors influencing knowledge of untrained items. Although training improved children's ability to read the trained words, and children increased their knowledge of untrained words and pseudowords in the same families, training was not significantly associated with increases in use of rime pattern knowledge. Instead, it improved the single deficit children's phoneme deletion skills, which in turn, predicted knowledge of untrained words and use of rime pattern knowledge. The small treatment effects suggest that the single deficit control group was also learning something over the period between screening and testing which allowed them to respond well to untrained words, almost as well as those for whom training had led to improved phoneme deletion skill.

In this study, use of rime pattern knowledge was predicted by final scores on the phoneme deletion task, independent of training condition and initial phonemic awareness scores. While initial AAT scores, training condition, and RAN accounted for a large proportion of variance in the final phoneme deletion scores (43%), a substantial amount of variance was left unexplained. Whatever skills are represented in this leftover variance may also be related to use of rime knowledge, given the substantial predictability of posttest AAT over and above training condition and initial AAT. Thus, although this study has identified initial phonemic awareness and rapid naming skills as two variables which are important in predicting which children benefit from training in phonological skills, understanding what other variables influence final levels of phonemic awareness is needed.

Although this study did not provide evidence that rapid naming ability affects how much a child learns from training, it is possible that status on the naming speed variable affects what is learned in training. Understanding what is learned in training may be key to developing the most effective forms of intervention for various subgroups. The current study showed that children in the double deficit group did not learn how to remove the initial consonant from a word beginning with a consonant blend, but children with deficits only in phonological awareness did. This finding is consistent with previous research describing children with poor naming speed as "treatment resistors" with respect to learning based on training of phonological skills (Badian, 1993; Blachman, 1994; Lovett & Steinbach, in press). However, in this study, double deficit children did learn something from training, as children in the experimental group (regardless of deficit type) were able to read more training and transfer stimuli immediately following training than children in the control group.

Nevertheless, the mechanism for this improvement is not clear, and it may be different for the two deficit groups. For children with a single deficit in phonological awareness, the improvement in reading may be related to the improvement in phoneme deletion skill, but this study provided no evidence for possible mechanisms for the double deficit group.

STUDY 2

Introduction

Study Two further addressed the question of whether phonemic awareness and rapid naming abilities are independent predictors of response to training by extending the findings of Study One. In addition to examining whether phonological awareness and naming speed predict how much a child learns from training and how well these gains are maintained over a one- to two- day period, this study had two secondary goals. These goals were: 1) to examine some of the possible mechanisms of improvement due to training, and 2) to investigate whether these mechanisms are related to initial phonological awareness and rapid naming abilities.

Study One showed that among children with poor phonemic awareness, those with added weakness in naming speed are not only worse readers, but they also show less use of orthographic knowledge when reading words with a common rime pattern. In addition, children with difficulties in both areas struggle to learn phoneme deletion skills, despite the two groups being matched on initial skills in this area. However, some children with poor phonemic awareness were average readers and did not need training in order to read the training words; therefore, it is unclear whether the same pattern of results would hold when looking at a population of poor readers. Given that school-based intervention programs are most often geared toward poor readers, regardless of their skill level on the various skills underlying reading, it is particularly important to understand treatment outcome within this population. In addition, selecting children on the basis of poor word identification scores allows for more variability on phonemic awareness scores than in Study One. This variability is important in understanding the differential correlations among measures as it is possible that the higher correlations between reading outcome and RAN than reading outcome and AAT in Study One were related to lower variability on the AAT measure.

Previous research has shown phonemic awareness and rapid naming skills to be particularly important predictors of reading skill within the poor reader population. In a study examining the relations among naming speed, phonemic awareness, verbal ability and reading in third and fourth grade, McBride-Chang and Manis (1996) found substantial differences between good and poor reader samples. For good readers, phonemic awareness and verbal ability were associated with word reading, but naming speed was not. In contrast, in the poor reader sample, verbal ability was not associated with word reading, but both phonemic awareness and naming speed had independent variance associated with reading. Furthermore, poor readers demonstrated greater variability on naming speed tasks than good readers, despite the fact that the range of reading scores within the poor reader sample was smaller than that in the good reader sample. Similar results were reported by Meyer et al. (1998) who reported that naming speed had predictive power for single word reading in later grades for poor, but not for good readers. These results held even when IQ, socioeconomic status, and earlier single word reading were controlled. On the basis of the McBride-Chang and Manis (1996) and Meyer et al. (1998) findings, it was expected that naming speed would show unique prediction of training outcome within a sample of poor readers, despite the restriction of range in reading scores.

Primary Aims of Study Two

Study Two was designed to build upon the findings of Levy & Lysynchuk (1997) showing good maintenance and generalization of training gains, by looking at whether naming speed and/or phonemic awareness predict the maintenance and transfer of training gains over a short period of time (one to two days). Levy & Bourrassa (1998) reported that poor readers with slow naming speed took longer to learn the training words than children with fast naming speed, but once the words were learned, the groups did not differ on maintenance or generalization. In Study One, the practice game portion of training may have addressed the retrieval and fluency difficulties of the double deficit group, making it difficult to find differences between the two deficit groups following training. Nevertheless, including this part of training is important in ensuring that children learn the training words sufficiently well to allow for maintenance and transfer to occur. It was expected that those children who show maintenance over this short period of time would have learned the training word to a sufficient degree for transfer to occur, and initial levels of phonemic awareness and naming speed were expected to predict maintenance and transfer over this period of time.

Secondary Aims of Study Two

In addition to examining whether phonological awareness and naming speed predict maintenance and transfer of training gains, Study Two was designed to examine some possible mechanisms for these effects. While many studies have shown improvements in reading and phonological skills following training, little research has addressed the question of what is learned in training to allow those improvements to occur. Three specific mechanisms of transfer of skills to reading were proposed in this study: 1) improvement in sound analysis skill, 2) increased sensitivity to the orthographic rime patterns which are common to the training and transfer words, and 3) improved knowledge of the whole-word orthographic representations of the training words.

Study One demonstrated that children with relatively strong naming speed skills showed improved phonemic awareness scores following training. Study Two attempted to replicate this effect using a measure of phoneme segmentation skill rather than phoneme deletion. Phoneme segmentation is a more difficult task than phoneme deletion (McBride-Chang, 1995); thus, the use of this task was thought to reduce the likelihood of ceiling effects on the trained items. In addition, this task is a better measure of transfer of sound analysis skills than the phoneme deletion task, because phoneme deletion was explicitly taught during training. It was expected that children would show improved ability to segment the training words after training. Improvement on untrained stimuli would indicate that children have learned more general sound analysis skills that can be applied to novel stimuli and might be related to improved ability to read the transfer stimuli, particularly the pseudowords.

The results of the use of rime knowledge analyses in Study One did not provide support for the hypothesis that training benefits are mediated through increased use of a known rime pattern when reading other words sharing that rime. However, these analyses are not pure measures of use of newly-acquired rime knowledge, as they did not rule out the possibility that children knew the untrained stimuli before training. In order to determine whether training effects are related to increased sensitivity to the orthographic rime patterns, a more specific measure of a child's sensitivity to the rime patterns was used in Study Two. This task, developed by Golden (1997), measured the child's ability and speed to detect whether a target letter is present in a given rime compared to less frequent letter patterns. Golden (1997) showed that frequency difference effects begin to emerge by Grade 3, although only for good readers. In the current study, it was expected that if poor readers become more sensitive to the letters in trained rime patterns as a function of training, frequency difference effects for the trained items would be present at posttest. This increased sensitivity to letters within the trained rimes was expected to be related to posttest reading of the training and transfer stimuli.

An alternative explanation for improved reading scores at posttest is that children did not learn the sublexical orthographic rime patterns, but they did become more familiar with the whole word orthographic patterns of the training words. Study One included an experimental word choice measure, but many of the foils were not pronounceable. Thus, the task was not a pure measure of orthographic processing skills as children may have used phonological processing skills to select the correct item. In addition, children performed at close to ceiling on accuracy on this task, and latencies were not included. In order to address these limitations of the original measure, a variation of the Olson, Kliegl, Davidson and Foltz (1985) orthographic choice task was used in Study Two. This task measures orthographic processing by requiring that the child distinguish words from nonword letter strings that would be identical in sound if pronounced. Children were asked to identify the correct spelling of the training words, as well as of a set of untrained words. It was expected that children's accuracy and latency to choose the correct spelling of the trained and untrained items would not differ prior to training, but increased knowledge of the training words should result in higher accuracy and faster latency scores for the trained than the untrained items at posttest. If posttest performance on this task is related to posttest reading of the training words but not the transfer words or pseudowords, then the task is indeed a measure of orthographic knowledge at the whole word level. If it is related to reading not only of the training words but also of the transfer stimuli, then one could conclude it also includes a measure of orthographic knowledge of the rime patterns common to the training and transfer stimuli.

In addition to determining whether children show improvements in any of the above three areas following training, a secondary goal of Study Two was to examine the relation of initial phonemic awareness and rapid naming scores to these three skills. Based on previous research, it was expected that at pretest, rapid naming scores would predict unique variance in the word choice task (Sunseth & Bowers, 1997). It was expected that phonemic awareness would predict unique variance in the rime sensitivity task at pretest, based on findings by Golden (1997). Initial AAT performance was also expected to be related to pretest performance on the phoneme segmentation task. Based on the results of Study One, as well as evidence provided by Badian (1993) and Lovett and Steinbach (in press), it was expected that following training, both variables would emerge as independent predictors of rime transfer and phoneme segmentation performance.

To summarize, Study Two was designed to address the following questions:

1) Do poor readers benefit from brief training, and do they show maintenance and/or transfer of training gains one or two days following training? Is learning, maintenance, or transfer predicted by a child's status on the phonemic awareness or naming speed variables?
2) Do children show gains on any of the three mechanism tasks one or two days following training? Is improvement on any of the mechanism tasks related to improvements in reading? Is improvement on the mechanism tasks related to initial status on the phonemic awareness or naming speed measures?

Method

Participants

A total of 144 children (69 males, 75 females) in seven regular Grade 3 classrooms in four different schools participated in the screening phase of the study. These children were all the children whose parents gave permission for participation in the study and who themselves consented to participate. Participants were recruited through letters describing the study to parents. Children who were receiving English as a Second Language Services participated in the screening session but were not included in the final sample.

Participant Selection

Selection for the main phase of the study was based on children's performance on the Letter-Word Identification subtest of the Woodcock-Johnson Psycho-Educational Battery – Revised (Woodcock & Johnson, 1989). Children receiving a standard score of 89 or less (24th percentile and below) based on grade norms were classified as poor readers and eligible for the main phase of the study. These children were all at least eight months below the average for a grade three student in reading. Forty-five children received such scores. Within this group, one child was excluded from the sample because of emotional difficulties, and four additional children were excluded because they were receiving English as a second language support services at school. Thus, the final sample consisted of forty children, with roughly equal numbers of males and females (17 males and 23 females).

Measures

Standardized Test Measures

Word Identification. Children completed the Letter-Word Identification subtest of the Woodcock-Johnson Achievement Battery (Woodcock & Johnson, 1989), a standardized measure of word recognition skills.

Word Attack. The Word Attack subtest of the Woodcock-Johnson Achievement Battery (Woodcock & Johnson, 1989) was also administered. This standardized measure of decoding skills involves reading pronounceable nonwords.

Vocabulary. Children completed the Vocabulary subtest of the WISC-III as a measure of general verbal ability. This task correlates .88 with Verbal IQ at age 8 (Wechsler, 1991).

Phonemic Awareness and Naming Speed Measures

Phoneme Deletion. The same short form of the Auditory Analysis Task (AAT) (Rosner & Simon, 1971) that was used in Study One was used as the phonological awareness measure in Study Two.

Rapid Naming Speed. The Rapid Automatized Naming Speed:Digits task (Denckla & Rudel, 1976) which was used in Study One was also used in Study Two.

Experimental Reading Measures

Word Recognition - Training and Transfer Stimuli. Each stimulus was presented individually on cards as in Study One. Children were asked to read the word or pretend word on each card. Stimuli were divided into three types: training words, transfer words (beginning with a consonant blend and sharing a rime with the training words) and transfer nonwords (pseudowords beginning with a single consonant and sharing a rime with the training words). Given that Study 1 showed no effects of order of presentation of the words on reading accuracy, only one random order was used at each time of testing; however, in order to minimize practice effects, stimuli within each group were presented in a different random order at pretest and posttest. The specific items used for each of the three stimulus types are presented in Appendix D.

Word Recognition – Control Stimuli. In order to assess whether gains in trained stimuli from pretest to immediate posttest were indeed related to training, a set of 12 control stimuli was used. These stimuli were four-letter exception words (chosen from the sight word reading list of Adams and Huggins, 1985 and the exception word list of Lovett, Ransby & Barron, 1988). Phonologically-based training should not improve children's ability to read these exception words. Like the training and transfer stimuli, control stimuli were presented individually on cards. Specific items are presented in Appendix D.

Experimental Mechanism Task Measures

Phoneme Segmentation. In this task, words were presented orally to each child. The child was asked to repeat the word to ensure s/he heard it correctly, and then to pronounce separately, in order, each sound heard in the word. Three practice trials were given to ensure that the child understood the task. Stimuli for this task consisted of 8 training words, and 16 untrained words matched in frequency with the training words (Carroll et al., 1971). The untrained words consist of 8 words beginning with a single consonant onset and 8 words beginning with a consonant blend. Stimuli were presented in a different random order at pretest and posttest. Items used on this task are presented in Appendix E.

Word Choice Task. This task is similar to a task designed by Olson et al., (1985). Children were asked to view pairs of letter strings that sound alike and indicate which one is spelled correctly. Stimuli included 10 training words and 10 untrained words matched in frequency with the training words (Carroll et al., 1971). Each stimulus had a sound-alike foil. Untrained stimuli shared with the trained stimuli the letter pattern differing between the correct and incorrect spellings. For instance, the trained stimulus "hide", whose sound alike foil was "hied" was matched with the untrained stimulus "bite" with sound alike foil "biet". The specific stimuli are shown in Appendix F. Computer administration of the task provided response latencies, as well as accuracy. Three practice trials were given to ensure that children understood the task prior to administration of the test items.

Rime Sensitivity Task. An adaptation of a task developed by Golden (1997) was used to measure children's sensitivity to individual letters within orthographic clusters. On a computer screen, children viewed a single target letter for 1500 ms. Following the presentation of this letter, a mask appeared on the computer in the same location as the target. Then, a stimulus appeared, and the child was required to indicate whether the target letter appeared in the stimulus. The stimulus remained on screen until the child responded. Three types of stimuli were used: trained rimes, untrained rimes, and low frequency trigrams. Trained rimes consisted of the last three letters of each of the training words. The rime "eed" was eliminated because of the presence of a double "e". Untrained rimes were equated at the mean level with trained rimes on frequency of appearance as the last three letters of a four letter word (Mayzner, Tresselt & Wolin 1965), as well as on summed trigram frequency (Mayzner et al., 1965). Low frequency clusters (selected from those used by Golden, 1997) consisted of letters rarely seen together in English. All stimuli are presented in Appendix G.

Each child received two trials for each stimulus: one in which the target letter appeared in the stimulus (a "yes" trial), and one in which the target letter did not occur in the stimulus (a "no" trial), but only the "yes" trials were used in the analyses. All trials were presented in random order, and accuracy and latency of responses were recorded. Five practice trials were given to ensure that the child understood the task prior to administration of the test items.

Procedure

All children were tested individually in a small room in the child's school. All 144 children participated in the screening session, which lasted approximately ten to fifteen minutes. The forty poor readers selected for the main phase of the study participated in two additional sessions, the first lasting approximately one hour and the second lasting approximately forty minutes. The order of tasks within each session was fixed across participants.

Screening

In the screening session, children completed measures in the following order: Trial one of RAN: D, Auditory Analysis Test, Trial two of RAN: D, Letter-Word Identification, and Word Attack.

Pretest

In the first session of the main part of the study, which occurred four days to three weeks following the screening session, children completed pretest measures of their ability to read the training, transfer, non- and control words. They also completed pretest measures of the mechanism tasks. The mechanism tasks were always completed in the same order: phoneme segmentation, rime transfer, and word choice.

Training

Immediately after completing the pretest measures, children participated in the training phase of the study. Training was similar to that used in Study One (see Appendix H for training script). For each training word, the child first stripped the initial consonant from the orally-presented word. He or she was then asked to spell the word using letters printed on small cards. If s/he spelled the word incorrectly on the first trial, s/he was asked to look carefully at the word, and change it so that the word was spelled correctly. If the word was spelled incorrectly after the second trial, the experimenter demonstrated the correct spelling. The experimenter then demonstrated how the phoneme deletion task applies to the printed word. Each child was then presented with four coloured letters corresponding to the letters in the training word and asked to arrange the letters so that the training word was spelled correctly. The letters were arranged in standard order for all children. The colours on the letters corresponded to the phonemes in the training words. The child was then given an explanation about the colours and how they are helpful in reading the word. Following this explanation, the child was presented with the letters of the training word in black and white (arranged in the correct order) and asked to identify the word. All children were presented with the training words in the same order (nest, cast, bump, seed, leak, pain, gate, cake, hide, sank, lark, bunk) in order that words of the same type were always taught together.

Following completion of the first part of training, children then completed the "practice game" as in Study One. Finally, children completed immediate posttest measures of their ability to read the training words, transfer nonwords and control words

Delayed Posttest

In the second session, all children completed delayed posttest measures. All efforts were made to schedule the posttest session on the day following the training session; however, for seven children, the posttest session occurred two days later. Children were asked to read the training words, the bigram onset words and the other set of single onset pseudowords sharing a rime with the training words. After completing reading posttest measures, children completed posttest versions of the phoneme segmentation, rime sensitivity and word choice tasks. Children also completed a posttest measure of naming speed, as well as the Vocabulary subtest of the WISC-III. The posttest measures were administered to all children in the following order: reading of training words, transfer words and transfer pseudowords, phoneme segmentation, rime sensitivity, word choice, trial one of RAN, WISC-III Vocabulary, trial two of RAN.

To counterbalance the order of presentation at the three time periods, three orders of presentation were used for the training words and two orders were used for each of the transfer and control words. Each child was assigned to one of six counterbalanced orders. The entire list of 24 nonwords was read at pretest, but only half of these words were read at immediate posttest and the other half at delayed posttest. Children in three of the six counterbalanced orders read nonword list A immediately after training and list B at delayed posttest, and children in the other three read list B at immediate posttest followed by list A at delayed posttest.

Results

Screening Data

Descriptive statistics for the full sample of 144 children who completed the screening session are given in Table 10. Overall, reading levels in this sample are comparable to what would be expected. Children's scores on the Auditory Analysis Test and Rapid Automatized Naming Tests were also similar to those obtained in other studies using the full range of Grade 3 children (Bowers, 1995; Bowers, Newby-Clark & Sunseth, 1998).

TABLE 10

Screening Descriptives for the Full Sample (n = 144)

Measure	Mean	Standard Deviation
Age (months)	100.3	3.4
Auditory Analysis Test - AAT (raw score /29)	18.1	5.3
RAN:Digits (items per second)	1.78	.33
Letter Word Identification (Grade Standard Score)	99.6	16.9
Word Attack (Grade Standard Score)	95.8	14.8

Table 11 shows the correlations for the four screening measures. AAT and RAN showed a small but significant correlation. This correlation is somewhat lower than in previous studies (Bowers, 1995; Bowers, Newby-Clark & Sunseth, 1998). AAT and RAN both showed significant correlations with the reading measures, which were highly correlated with each other.

TABLE 11

Correlationa Among Screening Measures for the Full Sample (n = 144)

	AAT	RAN:Digits	LWI
Auditory Analysis Test (AAT)			
RAN: Digits (RAN: D)	0.230[b]		
Letter Word Identification (LWI)	0.629[a]	0.434[a]	
Word Attack (WA)	0.643[a]	0.384[a]	0.884[a]

Note. [a] = $p < .001$, [b] = $p < .01$.

Commonality analyses were conducted to determine whether the effects of AAT and RAN in predicting reading skill are independent in this sample. The results of these analyses are given in Table 12. Results indicated phonemic awareness and rapid naming speed are independent predictors of word and pseudoword reading. The two variables also share variance in predicting reading. The interaction between the two variables was not significant, indicating similar relations between the variables at all skill levels. Together, AAT and RAN predict nearly 50 % of variance in both Word Identification and Word Attack scores.

TABLE 12

Commonality Analyses Predicting Standardized Reading Scores (full sample: $n = 144$)

	R^2 Change Word Identification	R^2 Change Word Attack
Unique AAT	.295[b]	.224[a]
Unique RAN	.088[a]	.059[a]
Shared AAT and RAN	.105[a]	.189[a]
AAT*RAN	.001	.001

Note [a] = $p < .001$, [b] = $p < .01$

Given the large amount of unique variance in AAT and RAN in predicting reading. the subgroups of the double deficit model should be easily identified. In this analysis. children were said to have a deficit in a skill if they scored below the 30th percentile for the full sample. This cutoff corresponded to a raw score of 14 or less on the AAT and a score of 1.568 digits per second or less on the RAN. They were said to have relative strength in a skill if they scored above the 40th percentile for the full sample. This cutoff corresponded to raw scores of 17 or higher on the AAT or 1.639 digits per second or higher on the RAN. While it is acknowledged that the 40th percentile is a liberal criterion for a strength. these selection criteria were chosen to for consistency with Study One. Of the 144 children in the sample. 18 fit in the double deficit (DD) group. 20 fit in the naming speed deficit (NSD) group. 17 fit in the phonological deficit (PD) group. and 59 fit in the no deficit (ND) group. Thus. roughly equal numbers of children fell into each of the deficit categories. Mean phonemic awareness. rapid naming, and reading scores for each of the groups are given in Table 13

To determine whether word identification scores differed across the four subgroups. an AAT level (high for the ND and NSD groups and low for the PD and DD groups) by RAN level (high for the ND and PD groups and low for the NSD and DD groups) between-subjects ANOVA was conducted. Results of this analysis indicated significant main effects of both AAT level, $\underline{F}$ (1,110) = 29.65, $\underline{p}$ < .001. and RAN level, $\underline{F}$ (1, 110) = 6.88, $\underline{p}$ = .010. The same pattern of results was obtained using word attack scores as the dependent variable. As shown in Table 12, the pattern of effects was such that the no deficit group had the highest reading scores, and the double deficit group had the lowest scores. Like in the regression results, the lack of a significant interaction between AAT level and RAN level indicates that deficits in the two skill areas are additive rather than interactive. A subsequent t-test comparison between the two single deficit groups indicated that while there was a trend for the NSD group to have higher reading scores than the PD group, this difference was not statistically significant, $t(24.2) = 1.86$, $p = .074$. The apparent difference in the means was not substantiated through statistical analysis because of marked differences in the variability in reading scores in the two single deficit groups.

TABLE 13

Mean Screening Scores and (Standard Deviations) by Deficit Group

		No Deficit (ND)	Phonemic Deficit (PD)	Naming Speed Deficit (NSD)	Double Deficit (DD)
n		59	17	20	18
Auditory Analysis Test	M	21.8	11.7	20.6	11.8
(raw score /29)	SD	(3.64)	(2.46)	(3.15)	(2.29)
RAN: Digits	M	2.00	1.94	1.46	1.37
(items /sec)	SD	(.26)	(.25)	(.09)	(.12)
Letter-Word Identification	M	109.1	89.0	97.7	84.2
(Standard Score for Grade)	SD	(15.4)	(6.7)	(19.6)	(8.6)
Word Attack	M	103.6	88.7	94.6	82.6
(Standard Score for Grade)	SD	(14.4)	(4.8)	(16.4)	(7.59)

Poor Reader Sample

Descriptive scores on the pretest measures for the poor reader sample (consisting of children below the 25th percentile for their grade on the Woodcock-Johnson Letter-Word Identification subtest) are presented in Table 14.

TABLE 14

Descriptive Statistics on Screening Scores for Poor Reader Sample

	n		AAT	RAN	LWI	WA	VOC
Full Poor Reader Sample	40	M	14.20	1.56	82.9	82.73	8.82
		SD	(3.7)	(.26)	(5.32)	(5.51)	(2.91)
Double Deficit (DD)	11	M	11.91	1.35	80.4	81.0	8.36
		SD	(2.2)	(.13)	(5.73)	(5.39)	(2.94)
Phonological Deficit (PD)	9	M	10.9	1.86	84.8	86.3	8.89
		SD	(2.5)	(.20)	(4.97)	(3.39)	(3.92)
Naming Speed Deficit (NSD)	9	M	18.4	1.43	82.7	82.7	8.11
		SD	(1.9)	(.11)	(3.6)	(6.4)	(1.86)
No Deficit (ND)	3	M	18.0	1.90	87.3	87.0	10.00
		SD	(1.0)	(.27)	(1.53)	(2.6)	(2.6)
Not Classifiable	8	M	14.87	1.55	82.9	84.5	9.75
		SD	(2.0)	(.09)	(6.67)	(6.2)	(3.24)

Note. AAT = Auditory Analysis Test (raw score /29); RAN = RAN: Digits (items/sec); LWI = Letter-Word Identification (Standard Score for Grade); WA = Word Attack (Standard Score for Grade); VOC = WISC-III Vocabulary (Scaled Score)

Reading scores were roughly normally distributed, with some children being extremely poor readers (standard scores at or below 70) and others being only moderately poor readers (standard scores 85-89). On average, these poor readers scored at the 13th percentile on the standardized reading measure. The majority of these poor readers fell within one of the three deficit groups as defined by the double deficit hypothesis: 11 of the 40 (28%) fell in the Double Deficit (DD) group, 9 (23%) in the Phonemic Deficit (PD) group, 9 (23%) within the Naming Speed Deficit (NSD) group. Three poor readers fell within the No Deficit (ND) group, and the remaining 8 poor readers could not be classified using the double deficit model, with at least one of AAT or RAN scores falling between the 30th and 40th percentiles for the full sample. Vocabulary scores did not differ significantly across groups.

Correlations between the screening measures and the experimental measures at pretest are shown in Table 15. A number of these correlations are worth highlighting. First, RAN correlated significantly with the standardized reading measures, but did not correlate with reading of the training and transfer stimuli, despite moderate to high correlations between the standardized and experimental reading measures. Second, AAT was not significantly related to standardized or experimental reading measures. Thus, despite both AAT and RAN being related to reading in the full classroom sample from which the poor readers were selected, within the poor reader sample, RAN, but not AAT, predicts variability in reading. In other words, for poor readers, only RAN predicts how low a child's reading score will be. Third, reading scores were generally correlated with one another, but they were generally not correlated with performance on the mechanism tasks. Performance on the various types of stimuli on each of the mechanism tasks showed moderate to high correlations with one another, providing evidence for the reliability of those measures.

TABLE 15

Pretest Correlations for Screening Measures, Experimental Reading Measures, and Mechanism Tasks

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Screening Measures																
1	Auditory Analysis Test (AAT)																
2	RAN: Digits	-.15															
3	Letter Word Identification	.01	.37[c]														
4	Word Attack	-.03	.38[c]	.52[b]													
	Experimental Reading Measures																
5	Training Words	-.05	.11	.62[a]	.38[c]												
6	Transfer Words	.33[c]	.19	.65[a]	.41[b]	.60[a]											
7	Transfer Nonwords – List A	.19	.16	.32[c]	.35[c]	.47[b]	.55[a]										
8	Transfer Nonwords – List B	.21	.10	.35[c]	.36[c]	.54[a]	.54[a]	.70[a]									
9	Control Words	.14	.16	.46[b]	.16	.53[a]	.42[b]	.16	.17								
	Mechanism Tasks																
10	Phoneme Segmentation - Trained	.19	-.13	-.03	-.16	-.08	.11	.30	.29	-.40[c]							
11	Phoneme Segmentation - Untrained	.26	-.04	.04	.05	.05	.23	.49[b]	.46[b]	-.26	.86[a]						
12	Phoneme Segmentation - Bigram	.26	-.06	.22	.07	.07	.19	.47[b]	.41[b]	-.13	.61[a]	.66[a]					
13	Word Choice Trained Accuracy	-.05	-.02	.17	-.11	.11	.05	.23	.08	.13	-.03	.09	.19				
14	Word Choice Trained Latency	.11	-.16	-.34[c]	-.09	-.23	-.05	.04	.14	-.14	.26	.17	.17	-.18			
15	Word Choice Untrained Accuracy	.00	.05	.34[c]	-.00	.26	.23	.03	.00	.20	-.04	-.07	-.01	.55[a]	-.33[c]		
16	Word Choice Untrained Latency	.16	-.11	-.26	-.08	-.13	-.01	.10	.16	-.10	.26	.23	.17	-.02	.85[a]	-.18	
	Other																
17	WISC-III Vocabulary	.11	.15	.07	-.09	-.28	-.08	-.01	-.05	-.09	.26	.09	.03	.01	.02	.09	.22

Note. [a] = $p < .001$, [b] = $p < .01$, [c] = $p < .05$

Training Results - Reading

Table 16 shows the mean reading scores on the experimental reading measures at pretest, immediate posttest (immediately following training) and delayed posttest. The delayed posttest occurred one day after training for 33 of the 40 children, and two days after training for the remaining seven children.[7]

TABLE 16

Mean Scores on Experimental Reading Measures

		Pretest	Immediate Posttest	Delayed Posttest
Training Words	M	6.18	10.57	8.65
	SD	(2.01)	(1.57)	(2.17)
Transfer Words	M	4.85		6.30
	SD	(2.69)		(3.00)
Nonwords – immediate list	M	4.15	6.03	
	SD	(2.05)	(2.89)	
Nonwords – delayed list	M	4.23		4.93
	SD	(2.62)		(2.85)
Control Words	M	3.45	3.85	
	SD	(2.08)	(2.10)	

Note. All scores out of 12

To assess whether training was effective in improving reading skill, a word type (training, nonword or control) by time of testing (pretest, immediate posttest) within-subjects ANOVA was conducted. The nonword variable included only the half of the nonwords that were read at both pretest and immediate posttest. Results of this analysis revealed main effects of both variables, F's (1, 39) and (2, 78) = 226 and 124 respectively, p's < .001; however, these effects were qualified by a significant interaction between the two variables (F (2,78) = 56, p < .001). Subsequent t-tests revealed that children were able to read significantly more of all three word types after training (t (39) = 16.9, 5.5, and 2.4 ; p < .001, .001 and .05 for trained words, nonwords and control words respectively); however, the effect size was much greater for the training words and transfer nonwords than for the control words. Given that children were able to read very few control words prior to training, it is likely that the increase in reading of these words after training is an artifact of regression to the mean rather than a meaningful effect. Therefore, training was effective in teaching children to read the training words, and children did show transfer to untrained stimuli that shared a rime pattern with the training words.

Are these training gains maintained over a one- or two-day period after training? To address this question, a Stimulus type (training word, transfer word, transfer nonword) by Time of testing (pretest versus delayed posttest) within-subjects ANOVA was conducted. Results of this analysis revealed main effects of both time of testing, F (1, 39) = 84.0 p < .001, and stimulus type, F (1, 39) = 41.9, p < .001, which were qualified by an interaction between the two variables, F (1, 39) = 11.1 p < .001. Subsequent t-tests revealed that the difference in reading between pretest and delayed posttest was greatest for the training words and smallest for the transfer nonwords (t (39) = 10.1, 5.3, 2.3 for training, transfer and nonwords respectively, p's < .001 for the training and transfer words and p = .027 for the nonwords).

Given that the above analysis did not include control stimuli, one explanation for children's improved scores on the transfer items at delayed posttest is regression to the mean.

To rule out this explanation, an ANOVA was conducted comparing the increase in the control words from pretest to immediate posttest to the increase in the transfer stimuli from pretest to delayed posttest. This analysis revealed main effects for both Time and Stimulus type, F's (1,39) = 25.8, 26.5 respectively, both p's <.001, which were qualified by an interaction between the two variables F (1, 39) = 15.9, p < .001. This interaction indicates that the increase between pre- and posttest performance differs as a function of stimulus type, and examination of the means indicates that the increase was greater for the transfer stimuli than for the control stimuli. Therefore, the increase in the transfer words from pretest to delayed posttest was greater than expected on the basis of regression to the mean.

To assess whether children's reading scores decreased from immediate to delayed posttest, a Stimulus Type (training word, nonword) by Time of Testing (immediate versus delayed posttest) within-subjects ANOVA was conducted. Results of this analysis revealed main effects of both time, F (1, 39) = 51, p <.001, and stimulus type, F (1, 39) = 166, p < .001, which were qualified by a marginal interaction between the two variables, F (1, 39) = 4.0, p = .053. Subsequent t-test analyses comparing immediate to delayed posttest performance on each of the two stimulus types revealed significant decrements for both types of stimuli, although the effect size was larger for the trained words than for the nonwords, t (39) = 10.1, p < .001, and t (39) = 2.3, p = .027, for the trained words and nonwords respectively. These results, taken together with the significant increase from pretest to delayed posttest demonstrated above, indicate that while children do forget some of what they learned as a function of training over the one- to two-day delay period, they do not forget everything that they learned.

Predicting Training Outcome

Table 17 presents difference scores representing the change in reading scores from pretest to immediate posttest, immediate posttest to delayed posttest, and pretest to delayed posttest. While these difference scores are not useful for statistical analyses, they clearly show the variability in the magnitude of improvement. Not only do scores change at the mean level as a function of training or of delay period, but there is also substantial variability in the amount of change that occurs for each child.

TABLE 17

Change in Reading Scores Over Time

		Pre to Immediate	Pre to Delay	Immediate to Delay
Training Words	M	4.40	2.48	-1.93
	SD	(1.65)	(1.56)	(1.78)
	Min.	1	-1	-6
	Max.	8	6	0
Transfer Words	M		1.45	
	SD		(1.72)	
	Min		-1	
	Max		5	
Nonwords	M	1.88	0.70	-1.10
	SD	(2.16)	(1.92)	(1.96)
	Min.	-3	-4	-6
	Max	6	6	2
Control Words	M	.040		
	SD	(1.07)		
	Min.	-2		
	Max.	3		

One of the major questions of interest in this study was whether improvements in reading scores after training could be predicted by initial status on the phonemic awareness or rapid naming speed variables. To address this question, a series of hierarchical multiple regression analyses was conducted. At the first step, the child's score on the relevant pretest variable was entered. Then either AAT or RAN was entered at the second step of the regression. Results of these analyses are shown in Table 18.

TABLE 18

Regression Analyses Predicting Growth in Reading using AAT and RAN Scores

Outcome Variable	Predictor Variable	Step	R^2 Change
Immediate Postest			
Training Words	Pretest training words	1	.362[a]
	AAT	2	.108[b]
	RAN	2	0
Nonwords	Pretest nonwords	1	.441[a]
	AAT	2	.028
	RAN	2	0
Delayed Posttest			
Training Words	Pretest training words	1	.528[a]
	AAT	2	.032
	RAN	2	.029
Transfer Words	Pretest transfer words	1	.677[a]
	AAT	2	0
	RAN	2	0
Nonwords	Pretest nonwords	1	.571[a]
	AAT	2	.004
	RAN	2	0

Note. [a] = $p < .001$, [b] = $p < .01$

Regression analyses indicated that with the exception of the training words, for which AAT predicts a significant amount of variance in growth in reading immediately after training, AAT and RAN do not predict growth in reading either immediately after training or after the one- to two-day delay. That AAT is a significant predictor of growth only in training words immediately after training and not in other tasks may be due, in part, to variations in AAT's shared variance with pretest measures of reading. Although AAT was not significantly correlated with any of the reading measures, it did show small (but unreliable) correlations with all of the reading scores at pretest with the exception of the training words. Therefore, AAT and initial reading of the training words shared no variance, leaving more room for AAT to contribute to growth in the training words. Nevertheless, its sizeable contribution to initial improvements on the training words is noteworthy.

The above results show that the best predictor of a child's final level on the various reading outcome measures is his or her pretest performance on that variable, despite the fact that mean performance levels increased from pretest to posttest. In other words, it appears that children maintain their relative rank order of knowledge of words after training, even though they are able to read more words after training than before.

This stable rank ordering could occur in one of two ways. First, children starting out as moderately poor and extremely poor readers could show roughly equivalent gains with training. Alternatively, the children who started out as moderately poor readers could show greater gains than those children who started out as extremely poor readers, thereby maintaining the relative rank order of reading scores, but increasing the variability in final reading outcome. In order to distinguish which of these two possibilities is operating in this sample, a series of multiple regression analyses was conducted to determine whether general initial reading skill (as assessed by the Woodcock-Johnson) predicts growth in reading after training. Again, initial skill on the reading outcome variable was entered at the first step of the analysis. At the second step, pretest word identification or word attack scores were entered. Results of these analyses are given in Table 19. Initial word identification skills predict amount learned for both training words and nonwords. One or two days later, initial reading skill is a significant predictor of growth only in the transfer words. In other words, the better a child's general reading skill, the more he or she will benefit from training, and the better his or her ability to read the transfer words at delayed posttest.

TABLE 19

Regression Analyses Predicting Growth in Reading using Initial Reading and Vocabulary

Outcome Variable	Predictor Variable	Step	R^2 Change
Immediate Posttest			
Training Words	Pretest Training Words	1	.362[a]
	Word Identification	2	.076[c]
	Word Attack	2	0
	Vocabulary	2	.029
Nonwords	Pretest Nonwords	1	.441[a]
	Word Identification	2	.159[a]
	Word Attack	2	.092[b]
	Vocabulary	2	.003
Delayed Posttest			
Training Words	Pretest Training Words	1	.528[a]
	Word Identification	2	.015
	Word Attack	2	.014
	Vocabulary	2	.033
Transfer Words	Pretest Transfer Words	1	.677[a]
	Word Identification	2	.051[c]
	Word Attack	2	.007
	Vocabulary	2	.012
Nonwords	Pretest Nonwords	1	.571[a]
	Word Identification	2	.031
	Word Attack	2	.012
	Vocabulary	2	0

Note. [a] = $p < .001$, [b] = $p < .01$, [c] = $p < .05$

Overall, therefore, the results of regression analyses predicting growth in reading scores from pretest to immediate and delayed posttest indicate that RAN does not predict improvements in reading, and AAT predicts only improvements in reading of the training words immediately after training. Vocabulary scores do not predict growth in any of the reading variables. Word Identification scores predict improvement on a number of outcome measures, including the training words. The effects of AAT and Word Identification in predicting growth in the training words are clearly independent in this sample, given that the two predictor variables are not significantly correlated with one another (see Table 15). Word Attack scores predict growth only in the nonwords from pretest to immediate posttest.

In addition to predicting growth in reading scores after training, a secondary question of interest was whether the decline in reading scores over the one- to two-day period between immediate and delayed posttest could be predicted by the individual difference variables in this study. To assess this question, multiple regression analyses were conducted using scores on the training words at delayed posttest as the dependent variable. Scores on the training words immediately following training were entered at step one of the regression, accounting for 35% of the variance. Predictor variables entered separately at step two of the regression were pretest Word Identification, Word Attack, AAT, RAN, and WISC-III Vocabulary scores. The only variable that emerged as a significant predictor at the second step of the equation was word attack (R^2 Change = .069, p = .044), although letter word identification scores approached significance (R^2 Change = .063, p = .055). Neither AAT nor RAN predicted unique variance at step two (R^2 Change = .002 and .041 respectively, p's > .1). Similarly, scores on the WISC-III Vocabulary test were not predictive at step 2 (R^2 Change =

.001, $p > .1$) Therefore, not only do children who are initially poor readers learn less in training, but they also tend to forget more over the delay period after training.

Summary of Reading Results

Results of Study Two confirmed that following brief training, children show improved ability to read the training words. They also showed improved ability to read other words and nonwords in the same family, indicating that the skills they learned were not item-specific, but rather they included transfer to other similar stimuli. In addition, while some forgetting occurred over the one- to two-day delay period, most of the training gains were maintained over this period. Although AAT was associated with immediate gains in trained words, this study did not provide strong support for the hypothesis that AAT and RAN would predict training gains. Instead, initial scores on the standardized word identification test emerged as a predictor of improvement after training as well as forgetting over the delay period. Verbal ability, as measured by the WISC-III Vocabulary test, did not predict growth or forgetting in any of the reading variables.

Mechanism Tasks - Training Effects

In addition to investigating changes in reading after training, this study was designed to investigate performance changes on three tasks that are theoretically related to reading. The mean scores at pretest and delayed posttest on each of the three mechanism tasks are given in Table 20.

TABLE 20

Mean Scores and (Standard Deviations) for Mechanism Tasks

Test	Type		Pretest	Posttest
Phoneme Segmentation	Trained	M	4.18	5.10
		SD	(2.40)	(2.18)
	Untrained	M	4.48	4.88
		SD	(2.42)	(2.32)
	Bigram	M	1.60	2.53
		SD	(1.64)	(2.41)
Word Choice	Trained Accuracy	M	8.35	8.98
		SD	(1.83)	(1.37)
	Untrained Accuracy	M	7.98	7.20
		SD	(1.79)	(1.58)
	Trained Latency	M	7.95	7.78
		SD	(0.49)	(0.48)
	Untrained Latency	M	8.02	7.99
		SD	(0.55)	(0.52)
Rime Transfer	Trained Accuracy	M	9.13	9.53
		SD	(2.02)	(2.14)
	Untrained Accuracy	M	10.28	10.03
		SD	(2.28)	(2.52)
	Low Frequency Accuracy	M	9.28	9.25
		SD	(2.29)	(2.40)
	Trained Latency	M	7.20	7.13
		SD	(.374)	(.293)
	Untrained Latency	M	7.15	7.12
		SD	(.281)	(.293)
	Low Frequency Latency	M	7.16	7.13
		SD	(.270)	(.330)

Note. All latencies are log-transformed. Accuracy scores for Phoneme Segmentation are out of 9, Word Choice are out of 12. and for Rime Transfer are out of 11

ANOVAs were conducted to identify which skills children learned during training. Results of these analyses are given in Table 21.

TABLE 21

Analyses of Variance on Mechanism Tasks from Pretest to Delayed Posttest

Task	Source	SS	Df	MS	F	p
Phoneme Segmentation	Time	33.75	1	33.75	17.11	.000
	Type	358.9	2	179.4	76.84	.000
	Time X Type	3.68	2	1.84	2.03	n.s.
Word Choice – Accuracy	Time	.022	1	.022	.148	n.s.
	Type	46.23	1	46.22	39.82	.000
	Time X Type	19.6	1	19.60	10.20	.003
Word Choice – Latency	Time	.433	1	.433	5.66	.023
	Type	.820	1	.820	23.96	.000
	Time X Type	.208	1	.208	9.16	.004

To summarize these results, main effects of time of testing and stimulus type were obtained for the phoneme segmentation data. Therefore, training effects were obtained for all three types of stimuli, although multiple comparisons on the main effect of stimulus type indicated that children performed better on the trained and untrained items than on the bigram onset items. Therefore, like in Study One, training resulted in an improvement in phonemic analysis skills.

For the word choice task, a significant interaction between word type and time of testing was obtained for both accuracy and log-transformed latency data. Examination of the means revealed an unexpected pattern of results for the accuracy data. After training, children were more accurate in correctly identifying the correct spelling of the training words; $t\ (39) = 2.21$; $p = 0.03$; however, they were also less accurate in correctly identifying the correct spelling of untrained words; $t\ (39) = 2.56$; $p = 0.01$. Latency results were as predicted: children were faster to identify the training words (t (39) = 4.20; $p < .001$), and their speed of identifying the untrained words did not change ($t < 1$).

No differences based on time of testing were obtained for either accuracy or latency on the rime transfer task. In addition, no frequency differences in either accuracy or latency were apparent on this task. In other words, children were as fast and accurate in identifying letters within the low frequency strings as they were in identifying letters within the higher frequency trained or untrained letter strings. In order to use this task as a measure of sensitivity to orthographic patterns, frequency differences are essential (Golden, 1997). The basis for the failure to obtain frequency effects is unclear. One possibility is that children do not learn the orthographic rime patterns within the transfer stimuli sufficiently well for frequency effects to emerge on this task. However, given that the task has only been used in one previous study (Golden, 1997), it is also possible that it is not a good measure of sensitivity to orthographic information.

Predicting Reading Using Performance on Mechanism Tasks

Table 22 shows the correlations between the reading measures and the two mechanism tasks at pretest and delayed posttest. The correlations noted in this paragraph are highlighted in bold type in Table 22. The magnitude of pre-post correlations for the mechanism tasks indicates that the tasks are reliable. However, correlations between the reading tasks and the mechanism tasks are low, and generally non-significant at both pretest and posttest, indicating that while the mechanism tasks were designed to measures skills underlying reading, the connections between reading and the mechanism tasks are weak.

TABLE 22

Correlations between Experimental Reading Measures and Mechanism Tasks

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Pretest Reading Measures																					
1 Training Words																					
2 Transfer Words	.60^a																				
3 Nonword – list A	.47^b	.55^a																			
4 Nonword – list B	.54^a	.54^a	.70^a																		
5 Control Words	.53^a	.43^b	.16	.17																	
Pretest Mechanism Tasks																					
6 P.S. - trained	-.08	.11	.30	.29	-.40c																
7 P.S. - untrained	.05	.23	.49^b	.46^b	-.26	.86^a															
8 P.S. - bigram	.07	.19	.47^b	.41^b	-.13	.61^a	.66^a														
9 W.C - trained acc	.11	.05	.23	.08	.13	-.03	.09	.19													
10 W.C. - untrained acc	.26	.23	.03	.00	.20	-.04	-.07	-.01	.55^a												
11 W.C.- trained lat	-.23	-.05	.04	.14	-.14	.26	.17	.17	-.18	-.33^a											
12 W.C.- untrained lat	-.13	-.01	.10	.16	-.10	.26	.23	.17	-.02	-.17	.85^a										
Posttest Reading Measures																					
13 Training	.73^a	.53^a	.53^a	.47^b	.49^b	-.04	.08	.08	.22	.32^c	-.18	.06									
14 Transfer	.67^a	.82^a	.61^a	.63^a	.46^b	.14	.26	.29	.26	.42^b	-.11	.02	.66^a								
15 Nonwords	.59^a	.60^a	.70^a	.66^a	.19	.32	.35	.29	.03	.20	.08	.10	.61^a	.68^a							
Posttest Mechanism Tasks																					
16 P.S. - trained	**-.21**	**-.13**	**.32^c**	**.28**	**-.44^b**	.77^a	.76^a	.51^b	0	-.09	.16	.10	**.08**	**.11**	**.24**						
17 P.S. - untrained	**-.26**	**.03**	**.36^c**	**.27**	**-.37^c**	.70^a	.73^a	.54^c	.10	-.12	.23	.13	**-.09**	**.02**	**.27**	.88^a					
18 P.S. - bigram	**-.18**	**.12**	**.35^c**	**.22**	**-.17**	.54^a	.59^a	**.81^c**	.19	-.04	.14	.13	**-.16**	**.19**	**.14**	.52^a	.60^a				
19 W.C. - trained acc	**.22**	**.07**	**-.10**	**-.11**	**.30**	-.40^c	-.37^c	-.22	**.41^b**	.56^a	-.21	-.21	**.26**	**.14**	**.02**	-.26	-.26	-.34^c			
20 W.C. - untrained acc	**.24**	**.22**	**.15**	**.10**	**.21**	-.10	.00	-.15	.50^a	.36^c	-.31	-.35^c	**.18**	**.23**	**.09**	-.04	.01	-.12	.28		
21 W.C - trained lat	**-.23**	**-.05**	**-.08**	**-.03**	**-.13**	.13	.07	.00	-.26	-.34^c	**.85^a**	.76^a	**-.19**	**-.09**	**.04**	.01	.07	.07	-.21	-.39^c	
22 W.C. - untrained lat	**.20**	**.01**	**.00**	**.02**	**-.08**	.12	.08	.05	-.20	-.32	.81^a	.77^a	**-.13**	**-.01**	**.04**	-.03	.02	.12	-.19	-.37^c	.14

Note. P. S. = Phoneme Segmentation, W.C. = Word Choice, acc = accuracy, lat= latency. Significance levels are as follows: ^{a} = $p<.001$, ^{b} = $p<.01$, ^{c} = $p<.05$. Correlations presented in bold are referenced in text.

The non-significant correlations between the mechanism tasks and reading at posttest suggest that while children improved on reading and on these two tasks thought to measure skills underlying reading, the improvements are not related. To further investigate whether growth in mechanism tasks is related to growth in reading, regression analyses were conducted using delayed posttest reading of the training words as the dependent variable. Pretest reading of the training words was entered at the first step to control for this variable. At the second step, growth in phoneme segmentation was entered. This growth variable was the residual from the regression of initial phoneme segmentation onto final phoneme segmentation. Results of this analysis indicated that growth in phoneme segmentation is not related to growth in reading of the training words. A parallel analysis was conducted using growth in word choice performance as the predictor variable. Again, growth in reading of the training words was not predicted by growth in speed to identify the correct spelling of the training words. These results further confirm that although children learned three skills as a function of training – reading, phoneme segmentation, and word choice – growth in these three skills from pretest to delayed posttest is not related.

Another surprising finding concerns the correlation between scores on the phoneme segmentation measure and initial phoneme deletion scores. These correlations were non-significant at pretest ($r = .26$) and posttest ($r = .19$), p's > .1. This result is inconsistent with previous studies (e.g., Mc-Bride-Chang, 1995) showing correlations between the two phonemic sensitivity tasks. However, it is important to note that the current sample consists of poor readers; therefore, the range of phonemic sensitivity skills is limited compared to full classroom samples. Thus, lower correlations among variables within this sample compared to other samples including children with a wider range of reading skills are expected.

Predicting Mechanism Task Outcome

Regression analyses were conducted to determine whether the improvements on the mechanism tasks are related to initial status on the phoneme deletion, rapid naming, or reading variables. At the first step of the regression equation pretest scores corresponding to the posttest dependent variable were entered. Scores on the five individual difference variables were each entered separately at the second step of the equation. For the word choice task, AAT was a significant predictor of improvements in accuracy on the trained items (R^2 Change = .13 p.=.013). No other variables (RAN, Word Identification, Word Attack or Vocabulary) emerged as predictors for either accuracy or latency improvements. For the phoneme segmentation task, improvements overall (or on each of the three types of stimuli) could not be predicted by any of the five predictor variables. Therefore, although improvements occurred on these two mechanism tasks, only one of the five individual difference variables included in this study, AAT, predicted which children would improve the most on one of the tasks (word choice accuracy).

Summary of Results

In summary, the results of Study Two indicate that within a full classroom sample, AAT and RAN make independent contributions to reading skill. Four subgroups of children corresponding to the four groups predicted by the double deficit model of reading were identified. A sensible pattern of reading scores was obtained for these four groups, with children with relatively strong skills in both areas being the best readers and children with relatively weak skills in both areas being the worst readers. Results differed, however, when looking only at the poor readers. In this poor reader sample, AAT is not a significant predictor of reading. Only RAN discriminates among very poor to moderately poor readers. All four subgroups predicted by the double deficit model exist within the sample of poor readers, although the majority of poor readers fall into one of the three deficit categories, with only a very few children falling in the no deficit category.

In terms of training effects, poor readers learned three main skills as a function of training: (a) reading (which includes not only the training words but also generalizes to other words and nonwords in the same families), (b) quicker and more accurate recognition of the correct spelling of the training words, and (c) phoneme segmentation. The most consistent predictor of growth in reading after training is initial reading level, as measured by Woodcock-Johnson Letter-Word Identification scores, with very poor readers showing smaller gains and greater decrements over the delay period than moderately poor readers. AAT also predicted growth in knowledge of the trained words from pretest to immediate posttest, but not in other measures. Gains in word choice and phoneme segmentation performance could not be predicted by initial word or nonword reading scores nor by naming speed scores or verbal ability. AAT predicted gains in accuracy on the word choice task, but nothing else. In addition, although children improved on reading and on two skills thought to underlie reading, improvements on the two types of tasks were not related. Therefore, the mechanism of reading improvement after brief training is not clear.

Discussion

The results of the current study address a number of different questions pertaining to the double deficit hypothesis of reading difficulties. The screening data provided a means of examining the relations among the three variables relevant to this model: phonemic awareness, naming speed, and reading. The main portion of the study addressed two questions regarding the implications of the double deficit model for training: "Do poor readers learn from brief training of reading-related skills?" and "What variables predict treatment outcome?" The study also provided some information about one question of secondary interest: "What are the mechanisms of improvement in reading following training?" This discussion section consists of a summary and interpretation of the findings relevant to these questions

Relations among Phonemic Awareness, Naming Speed and Reading in the Full Class Sample

The screening data provide support for the double deficit model of reading difficulties within a sample including children drawn from the full range of reading abilities found in regular Grade Three classrooms. Within this sample, AAT and RAN correlated only weakly with one another, showing that the two measures tap different constructs. In addition, AAT and RAN each predict independent variance in reading skill after controlling for the other variable. AAT and RAN also share variance related to reading. Together, the two variables predict nearly half of the variance in both word identification and nonword decoding scores, highlighting the importance of the skills underlying the two variables in predicting reading achievement.

The independence of phonemic awareness and rapid naming speed in predicting reading is also evident when looking at the data in a more discrete fashion, by separating children into the four skill groups corresponding to the double deficit hypothesis. Children with no deficits are the best readers and children with both deficits are the worst readers. Children in the phonological deficit group tended to have worse reading skills than children in the naming speed deficit group, although this difference was not statistically significant because of marked differences in the variability in reading skills in the two groups. The greater variability in reading scores in the naming speed deficit group compared to the other two deficit groups has been obtained in other studies (e.g., Bowers, Sunseth & Golden, 1999). This finding indicates that some children with slow naming speed are average to good readers, while others are poor readers and suggests that some other variable may predict reading outcome within this group. One possibility worthy of further investigation is that of working memory. Slow naming children may place greater demands on their working memory skills when reading than faster naming children. Therefore, those children with difficulties in both working memory and naming speed may become poor readers, while those with good working memory skills may be able to compensate for their slow naming speed when reading.

Relations among Phonemic Awareness, Naming Speed, and Reading in Poor Readers

Although the double deficit model was supported by the results involving the full classroom samples, results were different when looking only at the poor reader sample. This difference highlights the importance of careful sample definition when evaluating whether certain cognitive skills are related to reading. In the poor reader sample, RAN showed moderate correlations with the standardized reading measures, but AAT showed no correlations with reading. Thus, although poor readers have lower phonemic awareness scores than better readers in the full sample, within this poor reader sample, AAT does not provide information about the extent of the child's reading difficulties. However, within the poor reader sample, those children with poor naming speed skills were worse readers than those with better naming speed skills, emphasizing the importance of naming skills in predicting which children are the worst readers.

In addition to sample characteristics, another variable to consider when investigating the relations between naming speed and reading is that of type of reading skill measured. Previous studies have shown stronger correlations between naming speed and measures of word identification and sight word reading than between naming speed and decoding (Bowers, 1995; Bowers et al., 1988; Bowers & Swanson, 1991; Cornwall, 1992; Manis et al., 1999). In the present study, naming speed was related to initial status on both standardized measures of reading, and the magnitude of the correlation did not differ between the word recognition and the nonword decoding tasks. However, naming speed was not related to initial scores on the experimental reading measures, despite high correlations between the standardized and experimental reading measures. One difference between the standardized and experimental measures is the variability among the stimuli within each measure. The standardized measures included words of increasing difficulty; whereas, all of the experimental words were of similar difficulty and orthographic structure (i.e., they all contained a single consonant onset and three letter rime). Thus, it is possible that within the already restricted range of reading abilities in the poor reader sample, the lack of variability in type of stimulus is partly responsible for the low correlations of AAT and naming speed with the experimental reading measures. Nevertheless, it is puzzling that the standardized reading measures continue to be correlated with these experimental measures despite this lack of variability.

In trying to assimilate discrepant findings about whether naming speed is an independent predictor of growth in reading, Wolf & Bowers (in press) cited a number of relevant variables including: IQ and SES, differences in variability in predictors, quality and type of reading instruction, and age. These same variables might be considered when resolving discrepancies between studies in the relations among phonemic awareness, naming speed, and reading at a particular point in time. None of these variables clearly discriminate the current sample from the one used in the study by McBride-Chang and Manis (1996). However, it is possible that unspecified differences in the teaching strategies used may be an important factor.

In summary, the relations among phonemic awareness, naming speed and reading are complex and best understood when a number of different variables are considered. These variables include (but may not be limited to): 1) sample definition (children with poor phonological skills, poor readers, dyslexic readers, garden-variety poor readers and so on), 2) type of reading skill measured, 3) demographic characteristics (SES), 4) quality and type of reading instruction, and 5) age. Including a description of these variables and a discussion of their impact on the findings may help to elucidate the complex and variable findings across studies.

Do Poor Readers Benefit from Brief Training of Reading Skills?

The major question of interest in this study pertained to children's response to brief training of reading-related skills. Within this poor reader sample, not only was training effective in improving children's ability to read the training words immediately following training, but these poor readers also showed improvements on other words and pseudowords in the same families as the training words. All of these training effects were over and above the small increases observed in the untrained exception words that were included as control stimuli. In addition, while children's reading scores decreased somewhat over the one- or two- day delay period following training, their delayed posttest reading scores were still higher than their pretest reading scores. Therefore, poor readers maintained at least some of the training gains over this time period. These results are notable, given the difficulties in obtaining transfer even to words within the same families reported in other studies (e.g., Lovett et al., 1990). In the past, only intensive training over long periods of time led to transfer (e.g., Levy & Lysynchuk, 1997; Lovett et al., 1994). The maintenance of gains over time is indicative of how well children must have learned the words during training, given Levy & Lysynchuk's (1997) finding that only those words that were overlearned were maintained over a delay period. Therefore, although this training was brief, poor readers showed benefits from the focussed practice on a small number of words.

Predicting Training Outcome

Understanding the cognitive basis of improvements in reading skill remains an important question for reading researchers. In this study, the two cognitive individual difference variables initially hypothesized to predict treatment outcome (phonemic awareness and naming speed) actually predicted little or no variance in growth in reading skills from pretest to immediate or delayed posttest. Phonemic awareness predicted growth in knowledge of the training words from pretest to immediate posttest, but it did not predict growth in any of the maintenance or transfer variables. That AAT predicted growth in the training words is interesting given that training encouraged children to segment the training words into onset and rime. It appears that those children with better initial abilities in this area were better able to consolidate the application of this skill to the reading of the words explicitly taught in training. This finding was also supported by the fact that AAT was a significant predictor of growth in accuracy on the trained items on the word choice task.

Contrary to prediction, rapid naming skills predicted no variance in growth in any of the reading scores. Thus, Blachman's (1994) proposal that children with slow naming speed would be treatment resistors was not supported, at least with respect to predicting response to this brief training protocol. One possible explanation for the results is that training was not purely phonological in nature. According to double deficit theory, poor readers with deficits in both phonemic awareness and naming speed are expected to benefit most from training which addresses both the phonological awareness and the naming or retrieval weaknesses (Wolf, 1997). The current training did include both such aspects: therefore, the role of either variable in predicting training outcome could be expected to be weaker.

Although the two main variables expected to predict training outcome gave little information about which children would benefit from training, some information was gleaned from the other individual difference variables. While vocabulary knowledge was unrelated to treatment outcome, initial word identification skills emerged as an important predictor of gains on the training and transfer stimuli immediately after training as well as forgetting over the delay period. Children who entered the study with weaker word identification skills showed less growth in reading scores following training than children who entered the study with stronger word identification skills. Similarly, they showed greater forgetting over the one- to two-day delay period, suggesting that what they did learn was less well consolidated.

The findings that initial word identification skills predicted growth following training and forgetting during the delay period are consistent with Stanovich's (1986) description of "Matthew effects" in reading. The current study shows that such effects are not purely the result of experiential differences between good and poor readers, as all children received the same training and training was conducted all in one session. In addition, given that the cognitive variables typically related to reading had little value in predicting growth in reading following training, it appears that word identification skills themselves may be the engine of differential growth. Those poor readers whose reading scores fall close to the average range may have known enough about word structure such that brief lessons in phonemic awareness and phonics rules could be better integrated into their knowledge base immediately. In contrast, extremely poor readers have little general knowledge about word structure: thus, they may require more time to consolidate the knowledge picked up in training.

What are the mechanisms of improvement in reading following training?

A secondary aim of this study was to examine some of the possible mechanisms for improvement in reading following training. This aim was partially met. In addition to showing improved reading skills following training, children also showed quicker speed at identifying the correct spelling of the training word from a pair of phonologically-equivalent targets, as well as improved phoneme segmentation skills. Thus, there was some evidence that training resulted in improvements in skills in each of the main routes to skilled reading described by Adams (1990): the phonological route and the orthographic route. However, the improvements in mechanism task scores were not related to improvements in reading scores. Therefore, the question of exactly what children learned in training, and how the skills they learned translated into improved reading skills remains. One possibility is that the improvement in mechanism tasks did not have time enough to be linked to the improvement in reading skills. Longer term training might show this amalgamation of skills.

GENERAL DISCUSSION

Taken together, the results of the two studies indicate that the double deficit model is a valid way of describing patterns of reading skills and subskills, at least at the Grade Three level. In Study One, among children with poor phonemic awareness, the skill traditionally thought to be the cause of reading difficulties, those with an added deficit in naming speed scored lower on most reading measures, even though the two subgroups scored equally low on the phonemic awareness measure. Thus, there is an important additive component to the two deficits in predicting reading. In the full class sample in Study Two, all four deficit subgroups could be identified, with a predictable pattern of reading scores among groups. In addition, in the full class sample, both phonemic awareness and naming speed contribute independent and shared variance to measures of word identification and word attack.

The variance that AAT and RAN share in predicting reading is likely related to the need to access phonological representations in all three tasks. However, the large amount of variance in the two measures which predicts reading independently of the other variable and the ease of identifying both types of single deficit children suggest that an interpretation of the reading – naming speed relationship that relies wholly on phonological variables is insufficient. The question of just what skills naming speed does measure and how those skills are related to reading was not directly addressed by the current studies, although it has been the subject of much current research (e.g., Bowers, Sunseth & Golden, 1999; Cutting, Carlisle & Denckla, 1998; Manis et al., 1999; Scarborough & Domgaard, 1998).

The primary aim of the current studies was to examine the effects of brief training and whether these effects can be predicted by initial phonemic awareness or naming speed scores. Both studies showed that children do benefit from brief training. Two samples of children, one identified by weak phonemic awareness and the other identified by poor word recognition, showed improvements on the training words immediately after training. Children also showed improvements on other words and pseudowords in the same families as the training words, provided that initial reading scores were controlled, either statistically (as in Study One) or by selecting only poor readers (as in Study Two). Study Two also showed that poor readers maintain some training benefits over a one- to two-day delay period. Therefore, focussed training on a small number of words does promote improvements in reading. Further investigation is necessary in order to determine how long these benefits last and how well the improvements in isolated word reading transfer to the reading of those words in connected text. The findings of a study by Levy, Abello and Lysynchuk (1997) suggest that improvements in single word reading should transfer to text reading for poor readers. In their study, benefits to text reading from single word practice included gains in reading fluency and comprehension.

The two studies reported here provide only weak support for the hypothesis that phonemic awareness and naming speed are independent predictors of treatment outcome. In Study One, children in the single (phonemic) deficit group did not show greater training benefits than children in the double deficit group on reading tasks. They did however show greater gains on the phoneme deletion task, indicating that RAN has a role in predicting treatment outcome on this variable. In Study Two, Auditory Analysis Test scores predicted growth in the training words immediately after training, but neither AAT nor RAN predicted maintenance of the training words over the delay period or transfer to other words and pseudowords in the same families. Instead, initial reading skill on standardized tests predicted growth in many of these reading outcome measures. Thus, within poor readers, it appears that reading itself (as measured by performance on the standardized word identification test), rather than one of the two major cognitive variables thought to be related to reading, is the best predictor of training outcome.

The fact that initial reading level is a predictor not only of final reading level, but also of growth following training, has important implications for research. Some researchers control for reading level statistically; others do it through selection into the study. Both methods have limitations for the types of conclusions that can be drawn. Statistically controlling for initial word identification skill also controls for variability in individual difference measures that is shared with initial reading skill. Thus, as demonstrated in Study One, it is more difficult to determine whether those stable individual difference variables predict treatment outcome. In other words, if the relation between RAN and reading does not change as a function of training, controlling for initial reading will result in lack of effects of RAN on final reading. Therefore, when looking for individual differences in training outcome, it may be best to control for reading scores through the criteria for selection into the study. Nevertheless, when selecting a sample with a limited range of reading scores, power to obtain significant correlations is reduced due to the restriction of range. In addition, the use of only poor readers in Study Two made it difficult to directly examine the double deficit hypothesis because of small sample sizes in the single deficit groups. Therefore, in designing studies, it is important to consider the specific question being addressed in order to determine the best means of controlling for individual differences in reading skill level. Similarly, in interpreting results, it is important to consider the means of control of reading scores.

The finding that general reading skill predicts treatment outcome also has important implications for screening and intervention. Early intervention studies providing extensive training to children in Kindergarten and Grade One who are at risk of reading failure have shown large improvements in reading following training (e.g., Byrne & Fielding-Barnsley, 1995; Foorman, Francis, Fletcher, Schatschneider & Mehta, 1998; Vellutino et al., 1996). Although such interventions cannot ensure that no children will become poor readers, they can reduce the number of children who become or remain extremely poor readers. Perhaps those children who received early intervention in Grade One will have reading scores in Grade Three that are closer to the average range, suggesting a greater possibility to benefit from brief interventions at the later time. This finding also emphasizes the importance of including measures of both phonemic awareness and naming speed in early screening batteries, particularly when screening is done before word identification measures are reliable. Early screening that includes only measures of phonemic awareness is likely to miss naming speed deficit children who are at risk of reading problems.

The fact that phonemic awareness and naming speed play little role in predicting the outcome of brief training calls for the identification of other cognitive variables that may predict such outcome. Given the large role of general reading level, the best candidates would be cognitive variables that play a strong role in differentiating relatively good versus poor readers within a poor reader sample. These variables, in turn, may predict response to treatment. The results of recent subtyping and factor analytic studies (Morris et al., 1998; Swanson & Alexander, 1997) suggest that general verbal memory and working memory may be important variables to consider. Memory limitations are particularly problematic for poor readers, as their slow decoding and reading speed places heavy demands on memory. In training, children with working memory problems may not have had time enough to consolidate skills learned before their memory trace deteriorated.

Another variable worthy of further investigation is that of IQ. Olson and colleagues (1999) recently showed that IQ is the strongest predictor of growth in word recognition, phonological decoding, and reading comprehension for children with reading disability. In the present study, WISC-III Vocabulary scores were not related to reading and to treatment outcome; however, results may differ when looking at a broader measure of cognitive abilities, such as Full Scale or Verbal IQ scores, which include measures of fluid as well as crystallized intelligence. One might speculate that children with higher fluid abilities would be able to generalize the rules learned in training to other stimuli. In contrast, children with lower abilities may learn the training words in a more rote fashion, resulting in poorer retention and generalization of skill. The extent to which the brief nature of the current training may emphasize or attenuate the relation between reading and IQ is unclear. One might speculate that high IQ children are able to pick things up even more quickly in the short training program. Long-term training may provide lower IQ children with more practice, allowing them to catch up. Thus, this line of thinking would predict stronger effects of IQ with brief as compared to more extensive training. Alternatively, it is possible that in long-term training, low IQ children will fall even further behind, thereby raising the correlations between reading and IQ after long-term compared to brief training.

One of the main hypotheses of these studies, that children with slow naming speed would have more difficulty learning the orthographic patterns in the training words, could not be directly evaluated in either study. In Study One, the best measure of orthographic rime knowledge was the "use of rime knowledge" measure. This measure used proportion scores to specify orthographic knowledge. Although results indicated that single deficit children were more likely to use orthographic pattern information when reading words in families, differences between the trained and untrained groups were not obtained on this measure. Thus, it is impossible to tell whether the rime knowledge was gained in training or whether children were drawing upon knowledge gathered at some other point in time. In addition, the high correlations between the proportion scores and raw scores on the training and transfer stimuli suggest that the "use of rime knowledge" way of looking at the data confounds word recognition and orthographic knowledge measures. A similar criticism has been leveled at other measures of orthographic processing (Vellutino, Scanlon & Tanzman, 1994).

Study Two included what was thought to be a purer measure of orthographic rime knowledge than the use of proportion scores. This measure, which looked at the probability that a child would be able to state that a given letter was present in a trained rime pattern compared to other low frequency trigrams, was based on a measure developed by Golden (1997). In Golden's study, frequency effects were beginning to emerge by Grade Three, although these effects were only significant for good readers. In the current study, one would expect that if children were learning the trained rimes as a function of training, frequency effects would emerge after training. Poor readers did not show frequency effects on the rime task either before or after training. As this task has shown frequency effects in only one study (Golden, 1997), it is impossible to determine whether the lack of frequency effects is related to problems with the task itself, or whether children did not become more sensitive to rime patterns as a function of training. It is possible that brief training was not intensive enough to produce changes at the level of sensitivity to rime patterns. This possibility is strengthened by the fact that frequency effects in Golden's (1997) study were present only for good readers. It is clear that the training used in this study was not sufficient to make the children good readers. Nevertheless, given that the improvements in reading were not item-specific and transferred to untrained words and nonwords sharing rime patterns with the trained words, one might expect that children would have learned something about those rimes in training. Further investigation of this task is necessary in order to understand what it measures and why it was not useful here.

The failure of Golden's (1997) measure highlights the importance of developing good sublexical measures of orthographic processing. Most of the measures currently in use (e.g., Olson's orthographic choice task) are designed to measure orthographic awareness at the whole word level rather than awareness of specific sublexical letter patterns. The "word likeness" task designed by Siegel and colleagues (1995) is a measure of sublexical orthographic knowledge, but it is difficult to adapt this task to specific letter patterns.

The present studies raise a number of questions about the mechanism of improvements following training. Although improvements were noted in skills thought to underlie reading, only in the case of the phoneme deletion findings for the low phonemic awareness sample in Study One were these improvements related to reading. In the poor reader sample in Study Two, initial AAT levels predicted improvement on the trained words immediately after training, but growth in the phoneme segmentation task from pretest to delayed posttest was not related to growth in reading over the same time period. Similarly, improvements in poor readers' accuracy and latency of selecting the correct spelling of the training words from a sound-alike foil were not related to improvements in reading. Because the mechanism tasks were only administered at delayed posttest, it is unclear whether improvements on these immediately after training would have predicted reading improvements. In addition, in this particular poor reader sample, reading and phonemic awareness are more independent than is typically found in similar samples (e.g., McBride-

Chang & Manis, 1996). Thus, it is not surprising that growth in phonemic analysis was not related to growth in reading skills. In samples with stronger relations between reading and phonemic awareness, one would expect the relations between growth measures to be closer. Nevertheless, the results of these two studies indicate that that at least when considering the effects of brief training, improving phonological skills is not the whole answer to improving children's reading difficulties.

The studies described here were designed with the assumption that the effects of brief training might be related to the effects of more intensive interventions. The validity of this assumption is unclear. In some respects, the results of the current studies closely map on to those of studies involving more intensive interventions. Children learned from training, and showed the greatest transfer to words most like the training words. Children also showed improved phonemic analysis skills, and in Study One, these improvements were related to final reading level. Similar findings have been reported in studies of more extensive interventions (e.g., Lovett et al., 1994). Indeed, the finding that naming speed predicts learning of phonological knowledge in particular is consistent with the reanalyses of the Lovett et al. (1994) data by Lovett & Steinbach (in press).

In other respects, the results of the current studies are quite different from those using more intensive interventions. In particular, the lack of relation between improvements on the phonological task and improvements in reading in Study Two is inconsistent with idea that improving phonemic awareness results in improved reading scores. It is possible that stable individual differences may require long periods of practice to show their effects. For instance, poor readers may require longer periods of practice for improvements in phonemic awareness to become integrated with improvements in reading. Similarly, with more practice, children might show frequency effects for practiced rimes on the Golden (1997) task. The significant effects of training on transfer to other words and nonwords sharing a rime pattern in both studies suggests that children are learning something about those rime patterns; however, the effects may not be sufficiently integrated to show up on Golden's task. Thus, while the use of brief training was thought to provide information about the mechanisms underlying improvements in reading in more intensive interventions, the results of the present studies suggest that brief training may not allow enough time or practice for improvements in various skill areas to become integrated. Longer-term training may allow for this integration to occur.

Although naming speed did not predict reading outcome following brief training, its importance in assessment of children with reading difficulties remains, due to its characterizing the most disabled readers. However, just how to reconcile these two findings is a goal these studies cannot address. One possibility is that naming speed is most important in differentiating treatment outcome among children with extremely poor reading skills, such as the severe dyslexics used in the study by Lovett & Steinbach (in press). In addition, whether its effects appear only after long training or long time periods generally may be a hypothesis worth investigating, as longtitudinal studies and studies of intensive interventions (Badian, 1993; Bowers, 1995; Levy & Bourrassa, 1998; Lovett & Steinbach, in press; Meyer et al., 1998; Torgesen et al., 1997b) have shown that naming speed predicts reading outcome. Alternatively, naming speed may be an important predictor only at particular stages in the consolidation of reading skills (McBride-Chang & Manis, 1996).

Finally, although these studies provide some hints about differences in response to instruction which are predicted by the double deficit model, many questions about the most effective forms of instruction for various types of reading difficulties remain. The training in the current study was brief, and it consisted of a variety of skills, including sound analysis and its application to print, letter-sound correspondences, and practice quickly identifying the correct spellings of words. It is unclear how the various aspects of training influenced the results of the study. One might hypothesize that had training been more purely phonological in nature, RAN-based differences might have been larger. In addition, it is possible that transfer might have been more strongly affected by training had the fluency component of the training been eliminated. In other words, it is possible that the practice quickly identifying the correct spelling of the training words consolidated the whole word orthographic patterns of the words to such an extent that transfer based on information from only a part of that word was less likely. Nevertheless, the multifaceted nature of training was seen as important to ensuring that the children learned to read the training words, and this goal was clearly achieved.

Taken together, the findings of the current research and review of the literature suggest that while the double deficit hypothesis of reading difficulties is a useful way of describing patterns of reading skills and subskills, its application to the outcome of brief training is less clear. In Study One, among children with poor phonemic awareness, children who also had slow naming speed were less likely to use orthographic knowledge when reading words with a common rime. In this study, AAT and RAN interacted in predicting use of rime knowledge such that the predictive value of each skill was highest at low levels of the other skill. These results suggest a pattern of compensation within children with phonemic awareness deficits, such that those with an added deficit in naming speed are less able to compensate for their phonological deficits by using orthographic knowledge when reading words that share rime patterns. These results, which are consistent with predictions made by the double deficit model, shed some light on why double deficit children have more difficulty reading than single deficit children.

The usefulness of the double deficit model in predicting response to training is unclear. While the hypothesis that children with slow naming speed are "treatment resistors" has received support from studies of severely impaired readers using intensive interventions (Levy & Bourrassa, 1998; Lovett & Steinbach, in press), only weak support is found in the current studies of impaired readers from regular classrooms and a brief training protocol. Evidence was found in sample of children with poor phonemic awareness, such that children with slow naming speed had more difficulty learning phoneme deletion skills than those with relatively fast naming speed. However, naming speed was not a significant predictor of reading outcome in either study. Rather, particularly within the poor reader sample, initial scores on standardized tests of reading were the best predictors of treatment outcome. Therefore, much like the debate about whether naming speed is a longitudinal predictor of reading independent of earlier reading skills (Torgesen et al., 1997b; Wolf & Bowers, in press), any discussion of whether naming speed predicts treatment outcome needs to delineate the specific conditions studied. Sample characteristics (including severity of reading impairment), length and nature of training, and type of outcome measure are likely to be particularly important variables, although further research is required to specify other relevant factors.

APPENDIX A

AUDITORY ANALYSIS TEST (AAT) – ADAPTED FROM ROSNER & SIMON (1971)

Instructions:

I'd like you to say **cow(boy)**. Now say it again but without the **boy**. Say **(tooth)brush**. Say it again but without the **tooth**."

Note: If child fails either word, repeat and demonstrate procedures. Always pronounce letter sound not letter name. Items read across rows.

If word articulated incorrectly, note and take into consideration when scoring response. If no response, repeat once, if still no response, score 0 and continue.

"Say birth(day) - now say it again but without the day" ____________

"Say car(pet) - now say it again but without the pet" ____________

bel(t)	____________	(m)an	____________	(b)lock	____________
to(ne)	____________	(s)our	____________	stea(k)	____________
(l)end	____________	(s)mile	____________	plea(se)	____________
(g)ate	____________	(c)lip	____________	ti(me)	____________
(sc)old	____________	(b)reak	____________	ro(de)	____________
(w)ill	____________	(t)rail	____________	(sh)rug	____________
g(l)ow	____________	(st)rain	____________	s(m)ell	____________
de(s)k	____________	st(r)eam	____________	s(m)ack	____________
s(k)in	____________	s(w)ing	____________	c(l)utter	____________

APPENDIX B

RAPID AUTOMATIZED NAMING : DIGITS

2	6	4	9	7	2	6	4	7	9
9	7	2	6	4	7	2	9	4	6
7	4	6	2	9	4	6	2	9	7
4	6	2	7	9	2	4	9	7	6
6	2	7	9	4	7	6	2	4	9

APPENDIX C

TRAINING AND TRANSFER STIMULI USED IN STUDY ONE

Training Words	Single Onset Transfer Words	Bigram Onset Transfer Words	Nonwords
fast	cast	blast	rast
best	nest	crest	dest
jump	bump	slump	tump
sunk	bunk	trunk	lunk
bank	sank	drank	fank
dock	sock	block	zock
pick	sick	brick	fick
main	pain	brain	tain
beak	leak	sneak	feak
feed	seed	bleed	yeed
late	gate	skate	jate
lake	cake	snake	pake
side	hide	bride	jide
more	core	store	jore

APPENDIX D

EXPERIMENTAL READING MEASURES USED IN STUDY TWO

Training Words	Transfer Words	Nonwords List A	Nonwords List B	Control Words
nest	crest	hest	dest	none
cast	blast	gast	rast	soup
bump	stump	cump	tump	lose
seed	bleed	veed	yeed	wool
leak	sneak	deak	feak	shoe
pain	brain	nain	tain	worm
gate	plate	yate	jate	pint
cake	snake	zake	pake	busy
hide	bride	fide	jide	calf
sank	drank	pank	fank	view
lark	spark	jark	tark	tour
bunk	trunk	tunk	lunk	oven

APPENDIX E

PHONEME SEGMENTATION TASK

Instructions:

"I am going to say a word, and I'd like you to say the word, then tell me, in order, all the sounds that make up that word. For example, if I say, "cat", you would say c/ a /t. Let's try a couple for practice.

ball __________ **rain** __________

On practice trials only, give feedback for responses. If correct, say "good". If incorrect demonstrate correct response, and ask child to try again. If child does not understand task, explain it to him/her, and repeat practice trials.

coat	__________(U)	trust	__________(B)	cast	__________(T)
bump	__________(T)	grade	__________(B)	jeep	__________(U)
dust	__________(U)	leak	__________(T)	cake	__________(T)
fist	__________(U)	pain	__________(T)	spoke	__________(B)
lamp	__________(U)	twist	__________(B)	hide	__________(T)
dream	__________(B)	clamp	__________(B)	float	__________(B)
nest	__________(T)	beam	__________(U)	joke	__________(U)
seed	__________(T)	steep	__________(B)	fade	__________(U)

Note. Letters in parentheses represent word type: T= Trained, U = Untrained, B = Bigram

APPENDIX F

WORD CHOICE TASK ADAPTED FROM OLSON ET AL., 1985

Trained Word	Foil	Untrained Word	Foil
pain	payn	sail	sayl
gate	gayt	bade	bayd
sank	sanc	pink	pinc
hide	hied	bite	biet
seed	sead	seek	seak
bunk	bunc	silk	silc
leak	leke	bead	bede
cast	kast	cart	kart
cake	caik	tame	taim
lark	larc	fork	forc

APPENDIX G

RIME SENSITIVITY TASK – ADAPTED FROM GOLDEN (1997)

Practice trials

Target letter	Display	Response
c	gtw	No
b	bim	Yes
l	jhy	No
d	yuf	No
s	kds	Yes
r	erp	Yes

Trained Rimes

	Yes	No
ain	a	p
ate	t	k
ake	e	u
ide	i	t
eak	a	t
ast	t	e
unk	u	a
ark	r	e
ank	k	r
est	e	a
ump	p	n

Untrained High Frequency

	Yes	No
ong	o	t
ure	r	a
ine	e	a
oft	f	n
elp	p	g
ant	a	p
ang	g	o
aid	a	e
int	n	a
ape	a	r
ept	t	a

Low Frequency Controls

rmj	j	b
sdf	f	k
znb	z	c
ctg	c	h
jbm	b	k
lfp	f	t
sbn	n	j
dlj	d	f
gtb	t	n
tgk	k	d
kpc	k	z

* all stimuli were presented in random order

APPENDIX H

TRAINING SCRIPT FOR STUDY TWO

Say ______. Say it again without the ____
If correct: go to spelling
If incorrect: Listen carefully and try it again
If still incorrect "_____ without the ____ is _____. When you take the ____ off of ____, you're left with ______"

Can you spell ________ using these letters?
If incorrect - look closely at what you have. Can you change it so it says _____
If still incorrect - demo correct spelling

For words with alternate spellings - that's one way to spell ____. Can you think of another way to spell _______

Demo how AAT relates to printed word. - that's right - see you've got __ then ______.Look at the whole word. What word is this?

Take away black and white letters - ask child to spell word again using coloured letters

The colours tell you something about this word - see how each letter has its own colour - that tells you that each letter makes its own sound. There are 4 sounds in _____, so there are four colours

or

These two letters are the same colour because they go together to make one sound - it takes both those letters to make the ___ sound. The others are different colours because they make a different sound. Even though there are 4 letters here, there are only 3 colours, so 3 sounds

or

Here - the ___ and the e are the same colour because they work together to make one sound - the e doesn't make its own sound, but it tells the ___ to say its name.

or

Here - the colours tell you that these three letters go together to make the ____ sound. These three letters are all one colour, so they go together to make the ___ sound. The ___ is adifferent colour because it makes its own sound

NOTES

[1] A similar pattern of results held when initial word attack scores were controlled, although the condition effect was only marginally significant in this analysis, $F(1,44) = 3.80$, $p = .058$

[2] Because many of the children read all of the training words, these scores correlated highly with the raw scores on the transfer stimuli (r's range from .73 to .93).

[3] A similar analysis was conducted controlling for initial scores on Letter-Word Identification. Results of this analysis yielded no significant main effects or interactions, although the main effects of deficit type and training condition both approached significance ($p = .067$ and $p = .092$ respectively). Results of this analysis indicate that the initial differences in reading skill between the single and double deficit groups account for much of the difference in use of rime knowledge.

[4] Similar analyses were conducted without controlling for initial performance on the standardized reading test. In these analyses, AAT and RAN predicted unique variance in the rime use measure, and the interaction between the two variables was also significant.

[5] The pattern of results was similar when raw scores on untrained targets were used as the dependent variable.

[6] The shortened version of the AAT predicted 30% of variance in scores on untrained stimuli ($p < .001$) when entered at step one in the regression equation. There was a trend toward significance of experimental condition when entered at step two (R^2 change $= .04$, $p = .095$). Posttest phoneme deletion scores contributed significant unique variance when entered at the third step (R^2 change $= .12$, $p = .002$). Therefore, a child's final status on the phoneme deletion task is a strong predictor of his/her ability to apply knowledge of a common rime pattern to untrained words and nonwords, over and above initial performance on phoneme deletion. Again, RAN predicted unique variance in this application when entered at step 4 (R^2 change $= .13$, $p = .015$), indicating that initial rapid naming scores predict variance in untrained reading scores, independent of training condition and sound deletion skills.

[7] Independent groups t-test analyses revealed that performance on delayed posttest variables did not differ for children who completed the posttest one versus two days following training.

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