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The Role of Working Memory in Phoneme Awareness

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THE ROLE OF WORKING MEMORY IN
PHONEME AWARENESS
BY
BERNADETTE F. EVANS

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY
IN
PSYCHOLOGY

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ABSTRACT

The primary goals of this study were to examine the association between working memory and phoneme awareness, and to explore the relationships of these phonological processes with decoding and comprehension components of reading ability. Previously, only a few studies had examined the role of working memory in phoneme awareness, and the findings were inconclusive. A further goal of the present study was to examine whether simple phoneme awareness tasks (requiring counting or segmenting of phonemes) relate differently to reading skills than do compound phoneme awareness tasks (requiring deletion or manipulation of phonemes).

Second-grade children whose reading skills were normally distributed served as subjects ($n=140$). In addition to examining the abilities of the entire subject pool, two subgroups of skilled and less-skilled decoders were compared to determine if children having difficulty learning to read perform differently on phoneme awareness and working memory tasks. The subjects were given three working memory measures, three simple phoneme awareness tasks, and three compound phoneme awareness measures.

The results suggested that working memory ability is not strongly linked to performance on phoneme awareness tasks. Thus, these constructs represent relatively independent phonological processes. Second, the simple phoneme awareness tasks were found to factor separately from the compound phoneme awareness measures, suggesting it is important to distinguish between these two levels of metaphonological awareness.

For the entire pool of subjects, the working memory, simple phoneme awareness, compound phoneme awareness, and IQ measures were differentially related to decoding and comprehension performance. Decoding, a more basic skill, related highly to expertise on compound phoneme awareness measures, with simple phoneme awareness making a smaller contribution. Similarly, the subgroups of skilled and less-

skilled decoders were significantly differentiated by their performance on both simple and compound phoneme awareness measures, but not on working memory. Comprehension performance, in contrast, was best predicted by compound phoneme awareness, verbal and nonverbal IQ, and working memory. The value of phoneme awareness measures for prediction and assessment purposes was discussed, as was the issue of how to control for IQ when examining phonological processes related to learning to read.

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CHAPTER I.

INTRODUCTION

The intent of this study is to examine the degree to which phoneme awareness relies on phonological codes in working memory. This investigation was conducted within the context of Wagner's (1988) models that described the relationship of three phonological processes. Presently, the evidence is inconclusive about how working memory and phonological awareness relate to one another. It is proposed that working memory and phoneme awareness are independent processes, but that each latent ability makes a unique contribution to reading performance. This conclusion was based on the well-supported evidence that measures conjectured to rely on a phonological code are highly discriminating of good and poor readers (e.g., verbal working memory and phonological awareness). Also, it has been hypothesized that phoneme awareness tasks can be classified according to the degree of cognitive complexity the task involves (Yopp, 1988). Therefore, multiple measures reflective of these latent constructs, were administered in order to assess the factorial structure of these manifest variables and the relationship of their respective constructs.

In addition to exploring the relationship of the constructs to overall reading ability, the skill requirements for decoding versus passage comprehension are contrasted. Also, the profiles of less-skilled and skilled decoders are examined on a subset of indicator variables.

Background

It is well-documented that children who efficiently process the phonological information in oral and written language tend to be better readers (e.g., in working memory and phonological awareness) (cf., Brady, 1988; Liberman, 1973; Lundberg, Frost, & Peterson, 1988; Stanovich, 1986; Torgesen, 1989; Vellutino & Scanlon, 1987; Wagner, 1988). This finding has been consistently demonstrated across training, longitudinal and cross-sectional studies (e.g., Bradley & Bryant, 1978;

Lundberg, et al., 1988; Mann & Liberman, 1984; Stanovich, Cunningham, & Cramer, 1984).

Phonological Awareness

Phonological awareness refers to a conscious awareness of the sound structure of one's language. For example, given the word "dog," one would say it consists of three sounds or phonemes, or is one syllable, and rhymes with bog. Phonological awareness tasks generally require analysis or synthesis of word units. An "analysis" task, for instance, requires a child to segment a word into its respective speech units (phonemes or syllables). In contrast, a "synthesis" task requires a child to blend speech units to form a word.

It seems natural that the beginning reader who possesses a good understanding of the sound structure of words is apt to reveal better decoding skills than the child who experiences difficulty with phonological awareness tasks. This hypothesis has been substantially supported by prediction, reading-level matched, and training studies (Backman, 1983; Ball & Blachman, 1988; Bradley & Bryant, 1983; Fox & Routh, 1980; 1983; Mann & Liberman, 1984; Liberman, 1973; Lundberg, et al., 1988; Olson, Wise, Connors, Rack & Fulker, 1989; Pratt & Brady, 1988; Share, et al., 1984; Stanovich, Cunningham & Cramer, 1984; Stanovich, Cunningham, & Feeman, 1984; Vellutino & Scanlon, 1987).

With respect to prediction studies, Liberman (1973) found that second graders' reading progress was significantly related to their performance on phonological awareness segmentation tasks in first grade. Stanovich, Cunningham, and Cramer (1984) administered a series of phonological awareness tasks to kindergarten nonreaders and later measured their reading performance in first grade. They found that the more cognitively complex tasks (i.e., tasks requiring a child to perform more than one cognitive operation) predicted first grade reading as well as a standardized readiness test. In fact, two of their phonological awareness tasks accounted for 62% of the variance with respect to

reading ability (e.g., word-to-word matching -- the subject hears two words and is asked, "Is the initial consonant different?"). Similarly, Share, Jorm, Maclean, & Matthews (1984) found that kindergarten children's performance on two phonological segmentation tasks significantly predicted reading achievement two years later. The children's earlier performance accounted for 39% of the later variance. Fox and Routh (1980) conducted a three year follow-up study on first graders. They found that the children who evidenced problems with segmentation tasks in first grade were severely reading disabled three years later. Other prediction studies have had similar findings (Calfee, Lindamood, & Lindamood, 1973; Vellutino & Scanlon, 1987).

Prediction studies are not sufficient, however, to determine a causal relationship between phonological awareness and reading acquisition. In fact, some have argued that early reading experience may confound the observed relationship between phonological awareness and reading. In order to assess this latter hypothesis, Bradley and Bryant (1978) incorporated a reading-level match design. Essentially, this design involves matching good and poor readers by reading achievement scores. Specifically, Bradley and Bryant (1978) matched six-year-olds with ten-year-olds who were reading at the same level. Thus, the ten-year-olds are likely to have had more reading and language experience than the six-year-olds. The children were administered a sound categorization task (i.e., three of four words share a common sound and the child selects the word that does not belong). Bradley and Bryant (1978) found that the poor readers had significantly deficient segmentation skills relative to the six-year-olds. This finding provided support for a unidirectional relationship between phonological awareness and reading performance.

Lastly, training studies have offered further evidence to suggest phonological awareness skills are a necessary prerequisite to learning to read (Ball & Blachman, 1988; Bradley & Bryant, 1978; Fox & Routh, 1976; Lundberg, et al., 1988; Vellutino & Scanlon, 1987; Williams,

1980). Lundberg, et al. (1988) trained preschoolers to attend to the phonological structure of language. Posttest measures in first and second grade indicated that children involved in the training program performed significantly better on phonological awareness tasks than the control group. Simultaneously, these children attained higher reading and spelling scores than their control counterparts. Thus, training in phonological awareness had a positive impact on reading and spelling acquisition.

To investigate the factorial structure of the phonological awareness measures, Lundberg et al. (1988) also conducted a factor analysis. Two latent variables were found. One variable represented phonological awareness measures that required subjects to analyze word units into syllables. The other variable represented tasks that required phonemic analysis/synthesis. The phoneme tasks were more effective at discriminating the experimental and control groups. Lundberg et al. (1988) concluded that the more cognitively demanding phonological awareness tasks (e.g., phoneme) were better measures for differentiating reading groups.

Another training program was instituted by Ball and Blachman (1988) whereby kindergarten children were assigned to three different treatment groups. Those children taught phoneme segmentation outperformed the other two groups on phoneme segmentation tasks and reading achievement several months later. Ball and Blachman (1988) concluded that phoneme segmentation training should be included in all reading programs and that phoneme awareness appears to be a necessary prerequisite to early reading acquisition.

As noted, there is a sizeable body of literature that supports phonological awareness as a necessary skill for learning to read. In turn, such researchers encourage practitioners to incorporate phonological awareness measures as either a predictive index of future reading performance, allowing for early intervention, or in diagnosing potential reading disabilities. Also, these researchers recommend that

phonological awareness training be included in preschool programs. Since phonological awareness has received extensive attention empirically and in practice, this construct should continue to be examined in more depth. This issue will be addressed shortly.

Working Memory

A second category of phonological processing pertains to the use of a phonological code in verbal working memory. Essentially, a reader engaged in decoding words must maintain the phonological code or sound-based representation of phonemes or syllables in working memory long enough to process whole words and, subsequently, phrases and sentences. Memory span tests are most commonly used to determine one's working memory capabilities (e.g., span of numbers, letters, words or nonsense syllables).

A large percentage of working memory studies indicate that poor readers recall less information from working memory tasks than good readers (cf., Brady, 1988; Share, et al., 1984; Stanovich, 1982; Torgesen, 1978; Torgesen & Houck, 1980; Wagner & Torgesen, 1987). This performance deficit is especially evident with tasks dependent on verbal recoding (Cohen & Netley, 1981; Katz, Shankweiler, & Liberman, 1981; Rapala & Brady (in press); Shankweiler, Liberman, Mark, Fowler, & Fisher, 1979; Vellutino, 1987). Katz, et al. (1981), for instance, contrasted the recall of verbally codable versus noncodable items (e.g., doodles). They found that only the verbally codable condition discriminated reading groups. This finding has been confirmed by others (cf., Rapala & Brady (in press); Vellutino, Smith, Steger, & Kaman, 1975), thus suggesting that poor readers do not experience a general memory impairment, but rather a specific deficit with respect to phonological codes. This type of memory deficit potentially impacts on such reading skills as decoding (Dreyer, 1989; Wagner, Balthazor, Hurley, Morgan, Rashotte, Shaner, Simmons & Stage, 1987) and use of contextual information (cf., Brady, 1988; Torgesen, 1982). In fact,

memory measures typically account for 10 to 12 percent of the variance found in reading achievement tests (Brady, 1988).

Some researchers interested in the nature of the phonological code deficit with poor readers initially incorporated a phonological similarity effect or rhyme effect paradigm in their studies (Baddeley, 1966; Brady, Shankweiler, & Mann, 1983; Mann & Liberman, 1984; Shankweiler, Liberman, Mark, Fowler, & Fisher, 1979). Lists of words are compiled such that they either rhyme or do not rhyme with each other. If a phonological code is being used in working memory, then rhyming words are apt to interfere with recall more so than nonrhyming words. In fact, good readers did evidence inferior recall with the rhyming word condition compared to the nonrhyme lists, and poor readers, in contrast, were less affected by the rhyme manipulation (Shankweiler, et al., 1979; Siegel & Linder, 1984). They still recalled less than good readers, however, given either condition. Such results suggested that poor readers do use a phonological code but less efficiently than good readers.

Besides analyzing the effect of rhyme on recall performance, Brady et al. (1983) examined good and poor readers' errors when recalling rhyme and nonrhyme word lists. Also, in a second experiment, they manipulated the clarity with which words were heard on a speech perception task (i.e., words were presented in either a noise-masked or unmasked condition). This manipulation was designed to examine the effect of increased phonological demands on poor and good readers' skill in processing phonological information.

With respect to errors, poor readers made errors similar to those of good readers but more of them. Specifically, poor readers committed more transposition errors (e.g., components of words are recombined) (see also Brady, Mann, & Schmidt, 1987).

Also, as predicted, poor readers experienced more difficulty than good readers when perceiving words in noise. There was no substantial difference between reading groups when words were presented clearly.

Both of the above findings supported the conclusion that poor readers use phonological codes but inefficiently, and most notably, when phonological demands are greater (cf., Rapala & Brady, in press).

To further confirm the hypothesis that poor readers use phonological codes inefficiently in working memory, Rapala and Brady (in press) examined the relationship between a verbal short-term memory, and speech perception and production task. The demanding perception and production tasks were most effective in discriminating reading groups and significantly correlated with verbal short-term memory. Rapala and Brady concluded that poor readers were less efficient at processing phonological information and, thus, memory span performance was impeded.

The studies cited above support the current theory regarding working memory -- operational efficiency theory --which suggests that poor readers are less efficient at using phonological codes (Baddeley, 1986). Baddeley's operational efficiency theory proposes that working memory is comprised of at least three limited capacity systems: an overriding executive control system; an articulatory loop; and a visuo-spatial scratchpad. The less resources allocated to encoding information, the more resources available for storing information. A person who inefficiently processes phonological information in the articulatory loop, for example, has fewer resources reserved for storage. Baddeley's theory, with respect to reading performance, is supported by additional studies that have also examined speech perception and production (Snowling, 1981) and articulation rate (Baddeley, 1986; Blachman, 1983; Spring & Capps, 1974; Torgesen & Houck, 1980).

A recent study by Dreyer (1989) proposes an interesting paradigm that seems suitable for assessing efficiency in verbal working memory. Dreyer presented skilled and less skilled decoders with a nonsense syllable; gave them an articulatory suppression task to prevent rehearsal; and then asked them to recall the syllable over a five, ten or fifteen second interval. Dreyer (1989) found a strong correlation

between this single syllable memory task and decoding ability ($r = .65$, $p < .01$). The other memory tests she employed (e.g., digit and syllable span) were only moderately correlated with decoding skill, thus, less likely to discriminate skilled and less skilled decoders. Dreyer concluded that "the ability to [efficiently] retrieve phonemic representations from memory appeared to play a primary role in phonological decoding."

In conclusion, within the domain of reading acquisition and working memory performance, the operational efficiency theory has gained a range of empirical support. Poor readers apparently are less efficient in using phonological codes in working memory and, therefore, reveal inferior memory spans.

The Relation between Phonological Awareness and Phonological Coding in Working Memory

Phonological awareness and the use of phonological codes in working memory both seem to impact on reading performance. An interesting question to pursue is the degree to which these constructs relate to one another. To what extent do phonological awareness tasks rely on working memory? Many of the most discriminating phonological awareness tasks require subjects to hold a word in memory while simultaneously removing or manipulating its' phonemes or syllables, and subsequently, verbalize the new word that incorporated the manipulation (e.g., deletion or Pig Latin task). By the nature of these tasks, it is apparent that they must rely to some degree on working memory. Also, do these two constructs represent two separate latent variables or one general ability? Answers to these questions are not only theoretically important but have practical implications as well. It is important to know whether these measures are redundant in order to determine their relative usefulness in screening batteries. Also, given a better understanding of what factors influence reading failure, proper methods for remediating reading problems can be determined.

Few researchers have investigated the interrelationship of these two constructs. Wagner et al. (1987) proposed five models that could potentially describe the relationship among phonological processes. (The Wagner models included a third process -- phonological coding in lexical access.) Of interest to this study, model number one suggests there is a unitary deficit common to all phonological processes; model number two proposes that all the processes are independent; and model number four describes phonological awareness and working memory as variables related to a common factor (i.e., phonological awareness requires one to use an efficient code in working memory).

The empirical evidence is presently inconclusive and contradictory with respect to which of Wagner et al.'s (1987) models sufficiently explains this relationship. In this particular study, Wagner and his colleagues administered five phonological awareness tasks, three working memory tests, and four lexical access measures to preschool nonreaders. They conducted a factor analysis and found two latent phonological processes existed. Working memory and phonological awareness tests loaded onto one factor, with lexical access loading onto the second factor. Thus, Wagner et al. (1987) concluded model number four best represented the relationship of working memory and phonological awareness. They further suggested that efficiency in working memory affects performance on phonological awareness tasks.

Others have supported this conclusion (Dreyer, 1989; Mann & Liberman, 1984). Dreyer obtained a significant correlation between a syllable blending task and her single syllable memory test. Syllable blending did not, however, correlate with any of the other memory tests (e.g., syllable and digit span, and sentence imitation). This finding suggested that the Single Syllable Memory test may be a more sensitive measure than the other common memory tests. Mann and Liberman (1984) obtained a moderate correlation between a simple phonological awareness measure (syllable counting) and a memory span test for rhyming and nonrhyming word lists.

In contrast to these findings, Mann (1984) conducted another study to assess the relationship between a phoneme reversal and word string memory task. Mann (1984) found these tasks were minimally correlated. Each variable accounted for a unique portion of the variance with respect to first grade reading achievement.

Similarly, Share et al. (1984) found two phoneme segmentation tasks to account for 39% of the variance in predicting reading achievement in second grade. In contrast, a sentence memory test uniquely accounted for 3% of the variance. Neither was significantly related to the other.

Lastly, Wagner (1988) conducted a meta-analysis, examining longitudinal and training studies that incorporated phonological processing and reading achievement measures. A path analysis, with reading achievement as the criterion measure, revealed working memory and phonological awareness tasks to be relatively independent of each other, contradicting his earlier findings.

A number of methodological problems with the studies to date impede an interpretation of what the relationship is like between phonological awareness and working memory. For example, some of the studies have used only one phonological awareness or working memory test. Multiple measures would be preferable to enhance the validity of the constructs assessed. A second problem is that sometimes an inadequate number of subjects for an insufficient number of measures have been used given the statistics employed (e.g., factor analysis). Also, some studies based their conclusions on the results of several t-tests conducted on simple correlations (Dreyer, 1989; Wagner & Torgesen, 1987). This method of analysis is prone to capitalize on error in order to obtain significant outcomes. Another element to consider is the impact of intelligence on subjects' performance. Some studies controlled for IQ while others did not.

The issue of IQ becomes especially important when one considers the relationship hypothesized to exist between it and working memory,

and reading achievement. Gathercole, Willis, and Baddeley (1990), for example, argue that a child's knowledge base or vocabulary influences his or her performance on a working memory task (also see Pennington, Orden, Kirson, & Haith, 1990; Share, Jorm, Maclean, & Matthews, 1984). Also, reading ability and vocabulary acquisition likely share a reciprocal relationship with one another. Therefore, differences noted between good and poor readers on memory measures may be influenced by general cognitive ability which is heavily weighted by verbal skill.¹ Given the potential influence IQ can have on working memory and reading performance it would seem IQ should be controlled for more often in studies. Also, the removal of IQ would increase the validation of the working memory construct if the above is true. Some researchers, however, believe that controlling for IQ is too stringent (Gathercole, Willis, & Baddeley, 1990). Removing its effect from analyses simultaneously excludes cognitive capabilities related to memory and reading ability. Others assert that IQ is an ill-defined concept and, therefore, should not be considered in reading research (Stanovich, 1990). Overall, the inclusion of an IQ measure in this study would allow for further analysis of its relationship with the other constructs.

A further methodological shortcoming is that the memory measures used in studies have varied widely in task demands, possibly contributing to the inconsistent findings. Recall can be immediate or delayed; and the stimuli can be either one item or a string of items. In addition, tasks have differed in the stimuli utilized. Some contained words or pseudowords; others presented numbers or pictures for recall. The modality of presentation and mode of response also varied (e.g., aural or visual presentation, and spoken or written response).

Similar problems exist with phonological awareness tasks (e.g.,

¹Nonverbal ability is infrequently mentioned in the literature as it relates to reading in spite of some authors finding a significant relationship between it and reading achievement (Gathercole & Baddeley, 1989).

range of cognitive demands and modality of presentation). Some researchers, however, have investigated the relationship between various phonological awareness tasks (Backman, 1983; Fox & Routh, 1976; Lundberg, et al., 1988; Stanovich, Cunningham & Cramer, 1984; Vellutino & Scanlon, 1987; Yopp, 1988). As mentioned before, Lundberg et al. (1984) performed a factor analysis in an attempt to examine the underlying factors with the phonological awareness tasks. They found two factors: Syllable and phoneme. The phoneme segmentation tasks were viewed as more cognitively demanding than the syllable ones and were more predictive of later reading achievement.

Similarly, Yopp (1988) examined ten phonological awareness tasks by conducting a factor analysis. She discovered two factors that apparently represented degree of task complexity: simple versus compound tasks. The "simple" phonological awareness tasks required a child to perform only one cognitive operation (e.g., phoneme segmentation). The "compound" tasks required more than one cognitive operation (e.g., phoneme deletion). Yopp reported that a compound task (phoneme deletion) was the most significant in predicting reading achievement. She also suggested that the compound tasks may rely more on working memory than the simple tests.

In sum, while both phonological awareness and working memory have been found to be significantly related to reading ability, the relation between these phonological processes remains unclear. Those phonological awareness measures that are most strongly associated with reading performance also stress memory by requiring the stimuli to be stored and manipulated. Attempts to assess the link between phonological awareness and memory processes have suffered from a number of methodological shortcomings. Yet it remains important, both as a theoretical and practical matter, to explore the relationship between phonological awareness and working memory.

A final issue to consider is how these processes relate to different elements of reading such as decoding and passage

comprehension. Some researchers have found working memory to be more strongly related to comprehension than decoding skill (Mann, Cowin, & Schoenheimer, 1989; Turner & Engle, 1989; Share, et al. 1984). Others claim phonological awareness affects comprehension indirectly. In consideration of the above, it seems an analysis of how phonological processes differentially affect decoding versus comprehension is necessitated. Such an analysis would enhance our understanding of these reading processes.

Hypotheses

The intent of this study is to explore the role of working memory in various phonological awareness tasks. Secondly, the relationship between these two processes, general cognitive ability, and elements of the reading process are explored.

To examine the construct validity of both phonological awareness and working memory, each is assessed by a number of measures. For phonological or phoneme awareness, the tasks are categorized as either simple or compound. This distinction is based on the theoretical grounds that compound tasks are apt to rely more on working memory than simple tasks. Both real words and pseudowords are used as stimuli. Similarly, the working memory measures vary in task demands and require recall of words and pseudowords. This battery of tests permitted an evaluation of the latent factors that potentially underlie them as well as provide information regarding the relationship between phonological awareness and working memory.

The second purpose of this study is to evaluate how performance on phonological awareness and working memory tests related to reading achievement in second grade, and to assess the degree to which IQ influenced the other constructs. Therefore, it was hypothesized that given the various measures utilized, five latent variables surface: working memory, simple phoneme awareness, compound phoneme awareness, reading achievement, and general intelligence. Emanating from this

general hypothesis, several predictions were determined:

(1) Phoneme awareness tasks will distribute themselves according to the degree of complexity involved in the specific task (e.g., simple or compound).

(2) All working memory tasks will load onto the working memory latent variable, with Dreyer's Single Syllable Memory Test accounting for most of the variance.

(3) All three reading measures will load onto the reading achievement latent variables with word identification accounting for the larger portion of the variance.

(4) The two subtests intended to reflect general intelligence will primarily load onto the IQ construct with vocabulary more strongly related to IQ.

(5) A reciprocal relationship will exist between IQ and working memory.

(6) A unidirectional relationship will be present between working memory with the simple and compound phoneme constructs and, subsequently, reading achievement. Similarly, this directional pattern applied to the IQ construct.

(7) The latent variable for working memory will account for a large portion of the variance in the compound phoneme awareness variable and a moderate to small portion of the variance in the simple variable.

(8) Simple and compound phoneme awareness and working memory constructs will affect reading achievement independently of one another, with compound phoneme awareness accounting for more of the variance in reading achievement than the other two constructs.

The model hypothesized to fit the given data is suggested by the above predictions and represented in Figure 1. Two alternative models are proposed in Figures 2 and 3. The alternative models differ from the primary in that phoneme awareness tasks are considered as one construct that cannot be classified according to complexity. The only difference between models two and three is that in model 2 working memory and

phoneme awareness are independent while in model 3 a bidirectional relationship is considered.

Figure 1. Model hypothesized to best fit data.

Figure 2. Alternative model number one.

Figure 3. Alternative model number two.

CHAPTER II

METHOD

Subjects

One hundred and forty second grade children from three suburban school systems in Rhode Island were selected to participate in the study. Children were included if they met the following criteria:

IQ. Eligible subjects had to have composite standard age scores (SAS) that were in the range of 80 to 120, as measured on the Stanford-Binet Intelligence Scale: Fourth Edition, Vocabulary and Pattern Analysis subtests (Thorndike, Hagen, & Sattler, 1986). This estimate assured the inclusion of children functioning from slightly below average to above average in intellectual ability (z-score of 1.25 from the mean).

Word Attack. Reading achievement standard scores on the Word Attack subtest of the Woodcock-Johnson Reading Mastery Test/Revised, Form G, had to be between 76-123 (grade equivalent: 1.2 to 6.7). This range was chosen in order to include a distribution of poor to superior decoders (i.e., 6th to 94th percentile, reflecting a z-score of 1.5 from the mean).

Hearing. Since many of the tasks used in this study were aural-dependent, no children with hearing impairments were included. An audiometer was used to screen for hearing deficits. Each potential subject's right and left ears were tested with tones at five different frequencies: 50 Hz (25 dB), 1000 Hz (20 dB), 2000 Hz (20 dB), 4000 Hz (20 dB), and 8000 Hz (20 dB). Children who could not detect two or more of the ten tones were excluded from the study.

Additional criteria. Students participating in "English as a second language" classes were excluded. Also, students' records had to indicate that they had no behavioral, emotional, or attentional problems, nor any physical handicaps.

One hundred eighty children were screened in order to obtain the sample of 140 subjects. Of those children included in the study, there

were 58 females and 82 males. Descriptive statistics of the composite IQ scores, word attack scores, and ages are provided in Table 1.

Table 1.

Means, Standard Deviations, and Range of Composite IQ and Reading Achievement Scores

	<u>Composite IQ^a</u>	<u>Word Attack</u>	<u>Age</u>
M	105	100	7 yrs. 9 mos.
SD	9	10	4 mos.
Range	80-120	76-123	7 yrs.-9 yrs.

^an=140 subjects

^bStanford-Binet Intelligence Scale: 4th Ed., composite scores

Measures

The instruments used were the Stanford-Binet Intelligence Scale: Fourth Edition (Stanford-Binet) (Thorndike, Hagen, & Sattler, 1986), the Woodcock Reading Mastery Test-Revised (WRMT-R) (Woodcock, 1987), six phoneme awareness measures, and three working memory tests.

Selection Measures

Stanford-Binet. The Stanford-Binet was used to assess the children's cognitive ability and to ensure that their scores fell within the preset 80 to 120 composite SAS range. The Stanford-Binet is a widely used and accepted means of assessing general intelligence. Its construct validity was assessed with "non-exceptional" samples; the Stanford-Binet composite score correlated .83 with the Wechsler Intelligence Scale for Children-Revised and .89 with the mental processing composite of the Kaufman Assessment Battery for Children. An abbreviated test battery of the Stanford-Binet was used consisting of Vocabulary and Pattern Analysis subtests. The manual provided information about the psychometric properties of these two subtests. This dyad correlated .88 and .91 for seven- and eight-year-olds,

respectively, with full composite scores, indicating its validity as an IQ measure (Thorndike, Hagen, & Sattler, 1986). A factor analysis revealed vocabulary to correlate .72, and pattern analysis .69, with the general intelligence factor. The intercorrelation between vocabulary and verbal reasoning was .90 and the correlation between pattern analysis and abstract/visual reasoning was .87.

Internal reliability appeared to be adequate with alpha coefficients of .82 for vocabulary and .91 for pattern analysis for eight-year-olds. Test-retest measures after three months were .75 for vocabulary and .78 for pattern analysis subtests. Also, upon examination, both vocabulary and pattern analysis had an adequate sampling of items per level of task difficulty.

Woodcock Reading Mastery Test-Revised. The Woodcock Reading Mastery Test-Revised (WRMT-R) is a nationally-standardized, reliable and valid measure of reading achievement. The three subtests administered to the children were Passage Comprehension, Word Identification, and Word Attack subtests (split-half reliability coefficients for the end of second grade: .95, .99, and .97, respectively). In the normative study, test-retest correlations after nine months in second grade were .97 (passage comprehension), .94 (word identification), and .90 (word attack). Also, each subtest substantially correlated with the total reading score: .95 (passage comprehension), .98 (word identification), and .82 (word attack).

The manual provides limited information about the validity of these subtests. The content of each subtest, however, is adequate for evaluating a range of reading skills as indicated in the manual. Word Identification requires the child to name common words. The Word Attack subtest presents nonsense words and measures the child's decoding skills. Passage Comprehension requires a child to read a passage and orally fill in the blank with the most appropriate word. Each subtest provides a converted standard score.

Experimental Measures

The various phonological awareness and working memory instruments are described below. It is important to note that there are few standardized measures available to assess phonological awareness and working memory, particularly in the manner necessitated by this study. Most of the measures that have been used in previous studies were designed with the intention of examining a specific research question and have not been standardized. For the tests used in the present study, reliability was assessed with either an alpha coefficient or Kuder-Richardson Formula 20. With respect to validity, these instruments are generally predictive of reading achievement and the content is consistent with their respective hypothetical constructs.

Each category below (i.e., simple phoneme awareness, compound phoneme awareness, and working memory) contains three tests. Also, for both phoneme awareness and memory measures, there are two complementary tasks such that one consists of pseudowords and the other contains common or familiar words. The use of pseudoword tasks reduces the effect language experience or orthographic knowledge can have on these tests.

Phoneme Awareness Measures

Tasks were divided according to Yopp's simple and compound distinction (1988). Simple phoneme awareness measures require one cognitive operation while compound phoneme awareness tasks require a minimum of two cognitive operations for completion. Each task was designed to progress from easier to more difficult items.

Simple phoneme awareness measures.

1. Segmentation Task. (See Appendix A.) The Segmentation task used in this study was a modified version of the "Yopp-Singer" (1988). In this task, subjects were asked to verbalize the individual phonemes heard in a real word. For example, given the test item "may," the child would say "/m/-/ay/." Twenty-seven words were presented for analysis.

The modification of the Yopp-Singer task allowed for an equal distribution of words containing particular syllabic patterns (e.g., consonant-vowel, vowel-consonant, consonant-vowel-consonant, etc.). Three items were included for each syllabic pattern (consonant-vowel, vowel-consonant, vowel-consonant-consonant, consonant-consonant-vowel, consonant-consonant-vowel-consonant, consonant-vowel-consonant-consonant, consonant-consonant-vowel-consonant-consonant) except for the consonant-vowel-consonant pattern for which six items were used. All responses were recorded on tape to allow for accurate scoring and to assess interrater reliability. Yopp (1988) indicated this segmentation task's internal reliability to be .95 (Cronbach's alpha). Interrater reliability in this study was $r=.97$. The 27 phoneme items were scored as either correct or incorrect. Percentage correct scores were used in the analyses.

2. Counting Segmentation Task (pseudowords). (See Appendix B.)

Counting tasks were initially developed to assess a child's ability to count the number of phonemes heard in an utterance (e.g., Liberman, Shankweiler, Fischer, & Carter, 1974). This test, likewise, required a child to count the number of sounds heard. For example, given the word "thoo" a child would indicate it had two sounds. The stimuli were 27 pseudowords designed to parallel the syllabic construction of the segmentation task (e.g., CV, VC, CVC, etc.) (see Appendix B). The child indicated the number of speech sounds by placing tiles on an index card in front of him or her. The responses were scored as either correct or incorrect. A percent correct score was used in the analyses. An alpha coefficient indicated the test's internal reliability to be $r = .80$.

3. Dreyer's Blending Task (1989). (See Appendix C.) A modified version of Dreyer's (1989) phoneme blending test was used to assess each child's ability to recall a sequence of sounds and to blend them to form a meaningful word. The modification provided for a more even distribution of syllabic patterns which also made the test more sensitive by increasing the number of items to be analyzed. Eighteen

words were presented with each phoneme in the word said, as much as possible, in isolation. The subject was asked to report the blended word. The items were presented in order of increasing number of phonemes in the target word. For example, given the sounds /k/ and /i/, a child would respond "key." Stimuli were recorded by the experimenter onto audiotape and presented to the subjects through headphones to ensure consistency in presentation. The phonemes that composed the word were presented with a two second delay between phonemes. Items were scored as either correct or incorrect and the percent correct incorporated into the analyses. Dreyer (1989) reported an internal reliability coefficient of .63 for her version of the task.

Compound phoneme awareness measures.

1. Auditory Analysis Task (Rosner & Simon, 1971) (AAT) (See Appendix D). This test, as designed by Rosner and Simon (1971), required children to repeat a word spoken by the examiner without a particular sound (e.g., phoneme or syllable). For example, "say 'smile' without the '/s/'." The AAT, therefore, required a child to perform an additional mental manipulation relative to the tasks categorized as "simple phoneme awareness" tests. The AAT's criterion validity was established by correlating it with the Stanford Achievement Test. It correlated .50 or better in grades two through five. Rosner and Simon estimated the internal reliability to be .96.

On the AAT, Rosner and Simon (1971) distributed their items according to which consonant or syllable was to be deleted. It began with simple syllable deletions from compound words and progressed to deleting phonemes from the beginning, middle, or end of a word. However, they did not include an equal number of items for each deletion position. In the present study, only the phoneme deletion stimuli were used, and the test was expanded to include twelve items that required a child to delete the initial consonant and six items each for which subjects were asked to omit the final and the medial consonants. Items were scored as either correct or incorrect and a percentage correct was

ascertained for each protocol.

2. Deletion Task (Pseudoword Version of AAT). (See Appendix E.) This task had the same requirements and conditions as the AAT, but consisted of pseudowords rather than real words. For example, for the one-syllable pseudoword "pim," subjects were asked to omit the /p/. The internal reliability in this study, as determined by an alpha coefficient, was $r = .84$.

3. Pig Latin Task (Pennington, VanOrden, Kirson, & Haith, in press). (See Appendix F.) The Pig Latin task was derived from one used by Pennington and his colleagues. Subjects were given a word in which they were to remove the initial sound (either a phoneme or syllable) and to add it to the end of the word with the additional sound "ay." For example, "man" is converted to "anmay." In the present study, only the 12 phoneme items were used. Nearly half of the words in the phoneme list began with monographic phonemes (e.g., /d/), while the remaining items began with digraphic phonemes (e.g., /sh/). Subjects responses were recorded on tape. Again, a percent correct score was determined. The Pig Latin's internal reliability for this study was $r = .88$. Interrater reliability was .96.

Working memory tasks.

1. Dreyer's Single Syllable Memory Test (1989). (See Appendix G.) The Single Syllable Memory Test required children to recall a nonsense syllable following either a five, ten or fifteen second interval. During the intervals, children were given an articulation suppression task to prevent rehearsal (i.e., reading a list of digits after hearing each stimulus). The memory test contained 20 items and 2 practice items which included five types of nonword syllables: vowel alone (V), VC, VC, CV, and CV, with four items representative of each category. (Vowels were either single ones or diphthongs.) There were six items for the five second interval and seven items for the ten and fifteen second intervals. The task was recorded by the experimenter. On the audiotape, each stimulus was followed by an electronic beep

signaling the child to read a list of random digits until a second beep was heard at either a 5, 10, or 15 second interval. At the second beep the child spoke the syllable previously heard into a microphone. A percentage correct score was determined for the overall total (i.e., number correct out of 20) and separately for /the 5, 10, and 15 second intervals. The test took approximately ten minutes to complete. Dreyer indicated the task's internal reliability to be .89 via a Spearman-Brown calculation. The internal reliability for this sample, however, was .56.

2. Familiar Word Span Test (Brady, Shankweiler, & Mann, 1983).

(See Appendix H.) This Word Span Test contained 10 lists of five one-syllable words. Brady, et al. (1983) used a list of fifty common nouns as their source for designing this test and controlled for word frequency, word length, and phonetic structure. The word strings were presented on audiotape at the approximate rate of one item per second. The children were asked to recall the words in each list in the order presented. Correct responses were scored: (1) in terms of the items recalled in the correct serial order, and, (2) for item recall only without consideration of serial order. For example, given the list "cat, fly, score, meat, scale" and a recall performance of "fly, cat, score, meat," a score of two correct for order, and four correct without consideration of order, would be given. Interrater reliability was .99. Internal reliability, as assessed with an alpha coefficient, was .82.

3. Nonsense Word Span Test. (See Appendix I.) This test was

designed to be similar to the Familiar Word Span Test. Each list, however, was composed of four monosyllabic pseudowords constructed to parallel the syllabic patterns in the familiar word memory task. (Trial runs of this test indicated that second graders had a difficult time retaining five pseudowords, requiring a reduction to four-word lists.) Each list was recorded on tape by the experimenter and presented over headphones to the subjects. Scoring procedures and administration were the same as the Familiar Word Span test. The interrater reliability was

.99. The alpha coefficient for its internal reliability was .76.

Additional Measure

Reading Curriculum Survey. (See Appendix J.) Teachers from the nine classrooms used in this study completed a reading curriculum survey. This survey informally assessed the comparability between instruction methods for the different classes and schools that participated in the study.

Procedure

After obtaining parental consent, each subject was tested individually on three separate occasions. Each session lasted fifteen to forty minutes and occurred within three to seven days of the other sessions. All participants in the study received a nonmonetary expression of appreciation at the conclusion of each session (i.e., stickers).

During the first session, the children were administered a hearing screening, the Stanford-Binet Vocabulary and Pattern Analysis subtests, and WRMT-R Word Attack, Word Identification, and Comprehension subtests, in that order. Each test was administered by the experimenter in the standardized manner recommended in the respective manuals.

Experimental measures were administered in the second and third sessions. The second session consisted of five tests and the third session contained the remaining four measures. To reduce potential order effects, three different test orders were used in sessions two and three. Each of the test orders was given to approximately one-third of the total number of subjects. Specifically, in the second session, one block of children was administered the Blending, Counting, Familiar Word Span, Pig Latin, and Yopp Segmentation measures, in that order. In the third session, they completed the remainder of tests -- Nonsense Word Span, Deletion, Single Syllable Memory, and AAT tests -- in that sequence. The second block of children completed the Counting, Nonsense Word Span, Yopp, Single Syllable Memory, and AAT tests in the second

session. The third session consisted of the Deletion, Pig Latin, Blending, and Familiar Word Span tasks. The third and last block of subjects received Familiar Word Span, Counting, Blending, Yopp and Pig Latin first and then finished Single Syllable Memory, AAT, Nonsense Word Span, and Deletion in their third and last session.

As noted above, the Counting test always preceded the Yopp and Pig Latin tests. This ordering of tests was necessary in order to facilitate the children's comprehension of the Yopp and Pig Latin tests.

All experimental measures were administered in a prescribed, standard manner (see respective appendices). Two trained research assistants administered a majority of the tests to one-third of the subjects. The experimenter gave the remaining measures and tested the remaining two-thirds of the subjects. Each measure was aurally presented (either in person or on audiotape) and required an oral response. (The counting task was an exception in that children placed tiles on a card instead of responding orally.) As mentioned earlier, some responses were tape recorded to facilitate accurate scoring. At the completion of the testing phase, the two trained assistants rescored eighty percent of all protocols for the experimental measures. This process enabled us to obtain interrater reliability scores.

CHAPTER III

RESULTS

Table 2 provides the mean and standard deviation for each of the fourteen measures utilized in this study. The Single Syllable Memory task provided an overall recall score and was further broken down into three units to examine differences in recall performance between five, ten, and fifteen second delays. A skewed distribution was noted with the Single Syllable Memory and Pig Latin tests, with a number of children obtaining zero or near zero scores.

Table 2.

Means and Standard Deviations of Memory, IQ, Reading, Simple Phoneme Awareness, and Compound Phoneme Awareness Measures

Measures	Mean	SD
1. Nonsense Word Span	40.78 ^b	13.98
2. Familiar Word Span	61.80 ^b	14.55
3. Single Syllable Overall score	35.41 ^b	14.23
4. Single Syllable Five Seconds	55.26 ^b	19.52
5. Single Syllable Ten Seconds	28.81 ^b	18.11
6. Single Syllable Fifteen Seconds	24.82 ^b	20.77
7. S-B Vocabulary subtest	107.36	12.22
8. S-B Pattern Analysis	101.89	9.51
9. S-B Composite IQ	105.19	9.21
10. W-J Word Identification	109.66	13.56
11. W-J Word Attack	100.93	10.60
12. W-J Passage Comprehension	105.60	10.22
13. Counting Task (pseudowords)	60.24 ^b	17.98
14. Segmentation Task	53.38 ^b	19.22
15. Blending Task	39.59 ^b	11.88
16. Auditory Analysis Task	63.22 ^b	20.37
17. Deletion Task (pseudowords)	51.16 ^b	20.12
18. Pig Latin	37.03 ^b	30.51

^an=140

^bscores based on percentage correct

Before most analyses were conducted, it was necessary to determine which scoring procedure to use in the analyses with respect to Nonsense and Familiar Word Spans. All protocols provided two recall scores. One method scored responses as correct if the words were recalled in correct order and the other scoring method did not consider order. The two

measures yielded very similar results, though the percent correct was lower for the nonsense word task. Further, the correlation between the two scores was .85 for Familiar Word Span and .89 for Nonsense Word Span. A reliability test was conducted and both scoring measures provided the same estimate of reliability -- alpha coefficient of .76. Therefore, since either scoring method appeared adequate, the score that did not consider order was incorporated into all further analyses unless otherwise stated.

A correlation matrix is provided in appendix K indicating the interrelationships and degree of significance between the observed variables. The Single Syllable Memory measures were examined to assess which component would be used in further analyses. The 15 second measure was selected as the more sensitive of the other three, and revealed similar relationships with other variables as the memory test did.²

Correlations

First, we looked at the measures indicative of the hypothetical constructs utilized in this study. Multiple measures of each construct were examined (i.e., simple phoneme awareness, compound phoneme awareness, working memory, IQ and reading). Significant correlations between all pairs of measures tapping a given construct were obtained. In addition, the correlation matrix indicated that a strong relationship existed between the variables labeled as compound phoneme awareness measures (i.e., AAT, Deletion, and Pig Latin) and the reading measures (i.e., Word Identification, Word Attack, and Passage Comprehension) (e.g., $r=.64$ for AAT and word attack). Fairly strong correlations also existed between Vocabulary (i.e., Verbal IQ) and the reading measures

²For those interested in using the Single Syllable Memory test it is important to realize that this task, at the 15 second interval, was highly frustrating for our sample of second graders. A semi-flat distribution was obtained which suggested that this sample may be too young for this test. It is also recommended that the number of test items per second delay conditions be equal. The present test included 7 items for the 10 and 15 second delay conditions but only 6 items for the 5 second delay.

($r=.40$ with comprehension and $r=.27$ with word attack), and Pattern Analysis (i.e., Nonverbal IQ) with passage comprehension ($r=.34$).

A strong relationship between compound phoneme awareness tasks and reading skill is well-documented in the literature, and is supported here. Also, vocabulary knowledge has been cited as a relevant factor in predicting a child's reading performance. In this case, vocabulary surfaced as being strongly related to comprehension, in particular, as was pattern analysis. A child's proficiency in decoding words, however, was less related to degree of vocabulary acquisition and unrelated to nonverbal, analytical skill.

Further review of the matrix reveals a moderate relationship between the designated compound phoneme awareness tasks with those labeled as simple phoneme tasks (i.e., Counting, Segmentation, and Blending) (e.g., $r=.27$ between counting and AAT and $r=.36$ between Yopp and AAT). Also, a moderate relationship surfaced between vocabulary and working memory tasks (i.e., Familiar Word Span, Nonsense Word Span, and Single Syllable Memory-Fifteen Seconds) (e.g., $r=.38$ with FWS, and $.23$ with NWS).

By the nature of the phoneme awareness measures, one would expect them to share some common variance. Yet given the moderate correlation between the two, one would expect them to separate as constructs since each is apparently tapping something different. The moderate relationship between vocabulary and the working memory tasks is also of interest. Familiar Word Span had a stronger correlation with vocabulary than did Nonsense Word Span, possibly reflecting shared lexical processing.

A significant correlation was found between Familiar Word Span and Word Identification ($r=.23$) and between Familiar Word Span and Comprehension ($r=.31$). The other two memory measures also had a significant relationship with comprehension. There was no apparent relationship, however, between working memory and compound phoneme awareness tasks (except between Nonsense Word Span and Deletion and

Single Syllable Memory 15 seconds and Deletion). This finding suggests that performance on compound phoneme awareness tests are not determined by one's working memory capacity.

Lastly, simple phoneme awareness measures did not significantly correlate with comprehension but did with word attack. This result suggests that decoding relies on a basic awareness of the phonemic structure of words.

While some interesting associations were obtained, the simple correlations need to be interpreted cautiously since other variables have yet to be statistically controlled. For example, given the significant correlations between (1) working memory and vocabulary, (2) working memory and comprehension, and (3) vocabulary and comprehension, it will be important to consider the shared effects of IQ in the memory and comprehension association. Also, due to the likelihood of finding an inflated number of significant correlations through multiple t-tests, it is necessary to use more robust analyses that were less prone to capitalize on error.

Factor Analysis

The next step was to determine how these variables factored together and whether they loaded into the five constructs, as hypothesized. Therefore, a factor analysis (oblique rotation) was conducted followed by a series of structural models in which fifteen variables were incorporated: Nonsense Word Span, Familiar Word Span, Single Syllable Memory-15 seconds, Vocabulary, Pattern Analysis, Composite IQ, Counting, Segmentation, Blending, AAT, Deletion, Pig Latin, Word Identification, Word Attack, and Passage Comprehension.

In order to confirm that the measures indeed represented separate constructs, a factor analysis procedure was conducted (See Table 3 for results.) As predicted, measures corresponding to the constructs of IQ, working memory, and simple phoneme awareness factored out separately. The compound phoneme awareness and reading measures, however, factored together. The finding that compound phoneme awareness and reading

measures loaded together supports the existence of a strong link between these two constructs and the skills required in the respective tasks. The results from the factor analysis also supported the hypothesis that a significant distinction exists between simple and compound phoneme awareness tasks. These four factors accounted for 67% of the variance among the variables. Table 4 provides the correlations between factors. Factor one pertains to the reading and compound phoneme awareness factor. Factor two refers to the IQ construct. The construct of working memory is represented by factor three. Lastly, factor four represents simple phoneme awareness.

Table 3.

Factor Loadings for Each Factor's Predictor Variables

	Factor 1	Factor 2	Factor 3	Factor 4
NWS			.845	
FWS			.819	
Single Syllable Memory			.639	
Vocabulary		.636		
Pattern Analysis		.809		
Composite IQ		.930		
Count				.774
Segmentation				.764
Blending				.692
AAT	.809			
Deletion	.748			
Pig Latin	.557			
Word Identification	.879			
Word Attack	.840			
Comprehension	.725			

Table 4.

Intercorrelations between Factors

	IQ	Working Memory	SPA
Reading/CPA	.34	.26	.26
IQ		.29	-.04
Working Memory			.03

Measurement Model

Since the factor analysis supported the existence of at least four factors, the data were examined in the form of a measurement model preceding the computation of structural models (using the Lisrel VI computer program). The measurement model examined the regression of each manifest variable to its respective construct or factor (lambda matrix, λ). The model also looked at the correlations between the latent components (Psi matrix, Ψ). Figure 4 illustrates the relationships among the observed and latent variables for the five constructs: IQ, working memory, simple phoneme awareness, compound phoneme awareness, and reading. Table 5 summarizes the Psi's and their degree of significance.

Table 5.

Psi Coefficients and Level of Significance for Latent Construct Pathways

	Working Memory	SPA	CPA	Reading
IQ	.613*	.113	.506**	.755***
Working Memory		.118	.129***	.224*
SPA			.521***	.255***
CPA				.716***

*p<.05 **p<.01 ***p<.001

With respect to the lambda parameters, verbal IQ (vocabulary) loaded most strongly with the IQ construct ($\lambda = .54$). Familiar word span, similarly, was the most significant marker of working memory ($\lambda = 1.08$).³ The segmentation task loaded most with simple phoneme awareness ($\lambda = .75$), and AAT appeared to be the primary indicator of compound phoneme awareness ($\lambda = .91$). Word Identification had the heaviest loading with reading ($\lambda = .97$). These results, however, do not

³Lisrel VI does not necessarily correct for regression coefficients that exceed 1.0. A lambda slightly greater than 1.0 can be interpreted as an indicator that the variable is nearly equivalent to the construct.

mean these tests are necessarily purer measures of the construct. On the contrary, for example, familiar word span had a heavier verbal IQ component than nonsense word span as noted in the discussion of the correlation matrix.⁴

Figure 4. Measurement model with standardized solutions for lambda and psi coefficients.

⁴The Single Syllable Memory test was not used in computing the measurement or structural models. When the Single Syllable task was included, the program would not converge. Since the communality estimate for the Single Syllable task was the lowest for the working memory factor (.44 vs. .73) it was decided to run the models without it.

As the measurement model indicated, with the Psi parameters, IQ shared a significant relationship with working memory ($\Psi = .613$, $p < .05$), compound phoneme awareness ($\Psi = .506$, $p < .001$), and reading ($\Psi = .755$, $p < .001$). Compound phoneme awareness was significantly correlated with simple phoneme awareness ($\Psi = .521$, $p < .001$) and reading ($\Psi = .716$, $p < .001$), and simple phoneme awareness indicated a significant correlation with reading ($\Psi = .255$, $p < .05$). (Relative to compound phoneme awareness, simple phoneme awareness tasks demonstrated a weaker relationship to reading.) Working memory correlated significantly with reading ($\Psi = .224$, $p < .05$). All other Psi pathways were nonsignificant (e.g., working memory with compound phoneme awareness). Due to the mutual relationship IQ had with reading and working memory, a direct interpretation of the relationship between working memory and reading is not appropriate with such a model. The measurement model essentially provides a general understanding of how each construct independently relates to one another. In order to further assess the direct influence specific constructs had on one another, structural models were executed. Hierarchical stepwise multiple regressions were subsequently executed in which IQ was often forced in at the first step of the analyses. Specific relationships among the constructs were more accurately examined (e.g., working memory with reading).

Structural Models

To test how the hypothesized constructs related to one another, a series of structural models were run using Lisrel VI. Three structural models were initially tested in order to contrast the goodness-of-fit indices and the significance of the beta weights between the original, primary hypothesized model and the two alternative ones. Specifically, the primary model incorporated five latent constructs. The two alternative models included four constructs. The differentiating factor was phoneme awareness. In model number one, phoneme awareness was

distinguished by the degree of cognitive complexity the task involved -- the number of steps mentally required to complete the task (simple vs. compound). In the other two models, phoneme awareness was conceptualized as one construct, with model number two considering the relationship between working memory and phoneme awareness, and model number three excluding this relationship.

Table 6 provides a summary of the goodness-of-fit indices for the above-mentioned models. As hypothesized, the primary model, in contrast to the other two, best fits the data. Based on these results and confirmed by the findings in the factor analysis, an accurate distinction apparently could be made between types of phoneme awareness tasks (simple vs. compound). Whether working memory is excluded or included, however, seems to make no substantial difference in explaining the data.

Table 6.

Chi-squared Values, Goodness-of-fit Indices, Root Mean Square Residuals, and the Incremental Fit Indices for the Initial Three Structural Models

	χ^2	GFI ^a	RMS ^b	IFI(2)(χ^2) ^c
Model No. 1 (Two pa factors)	$\chi^2(55)=89.40$	.92	.06	.96
Model No. 2 (Correlation between wm/pa)	$\chi^2(59)=134.57$	.87	.08	.90
Model No. 3 (No correlation between wm/pa)	$\chi^2(60)=136.02$	.87	.08	.90

^aGFI. The amount of variance/covariance explained by the model.

^bRMS. The average discrepancy between the elements in the sample and predicted covariance matrices.

^cIFI2(χ^2) = $\frac{\chi^2_0 - \chi^2_R}{\chi^2_0 - df}$. The specified model is compared to the null model. The index is less sensitive to sample size and violations of assumptions than χ^2 . An index >.90-1.00 represents a psychometrically sound fit.

To further assess the relationship of the five constructs, the significance of the beta weights was examined. It was at this point in

the analysis that difficulty was encountered in interpreting the outcome. Beta weights with high values, for example, .74 between IQ and reading, were not significant according to t-test results (See Appendix L). The reason for this outcome could be due to high standard error and/or a small sample size. After a number of manipulations⁵ with the parameters, and finding similar results, it was concluded that the sample size was too small to provide an accurate assessment of each construct's regression weight as it related to the others.

Step-wise Multiple Regression Analyses

Therefore, instead of relying on a structural model to explain these interrelationships, several stepwise multiple regression analyses (MRA) were implemented. The multiple regressions fell into two categories. One category examined the relationship of the constructs to one another. The second category looked at the individual predictor variables and their relationship to reading criteria. With respect to the former, each construct was determined by converting the respective manifest variable's scores into z-scores.⁶ The z-scores were then averaged to represent the latent construct. For example, to examine the construct of compound phoneme awareness in relation to reading performance, the scores for each of the compound awareness measures (AAT, Deletion, and Pig Latin) were converted into z-scores and then averaged to represent the construct. This technique allowed us to

⁵Five other structural models were run: (1) word attack as the only indicator of reading; (2) comprehension as the only indicator of reading; (3) verbal IQ as the only marker of IQ; (4) only two variables per construct (excluded blending, pig latin, and word identification tests); and (5) only two variables for each of the four constructs (IQ was excluded from the analysis). Blending and Pig Latin were removed because their loading with their respective factor was the lowest. Word Identification was removed because of its redundancy with word attack and comprehension. The reason four constructs were examined, with the exclusion of IQ, was to see if significant beta's would surface between those constructs by reducing the complexity of the interrelationships.

⁶All original manifest variables were incorporated into the analyses, including Single Syllable 15 seconds, even though it was initially removed from the structural model analyses.

determine: (1) the percent of variance the constructs (i.e., predictors) accounted for within the designated criterion (e.g., reading construct) and; (2) to assess what each predictor's regression weight or contribution to the criterion was.

Relationship between constructs

The first three MRA's equally considered IQ, working memory, simple phoneme awareness, and compound phoneme awareness as predictors with (1) total reading performance as the criterion; (2) word attack as the criterion (decoding ability); and (3) passage comprehension as the criterion. Tables 7, 8, and 9 present the R^2 and Beta weights for each of the three MRA's. Figures 5 and 6 also provide a visual demonstration of the relationship between the aforementioned constructs with decoding and comprehension as separate criteria.

Table 7.

Results of Step-wise Multiple Regression using IQ, Working Memory, Simple Phoneme Awareness, and Compound Phoneme Awareness to Predict Overall Reading Performance

Step	Variable	R^2	Change in R^2	Unstand. b weight	Stand. error	Stand. β weight
1	Compound P. A.	.44	.44	.32	.03	.59***
2	IQ	.51 _a ***	.06	.33	.08	.26***
	Working memory	--	--	.04	--	--
	Simple P. A.	--	--	-.01	--	--

* R^2 at final step, $F(2,137) = 69.89$
 $p < .05$ $p < .01$ $p < .001$

As noted in the tables and figures, compound phoneme awareness made a substantial contribution to overall reading performance and, separately, to decoding and comprehension. Compound phoneme awareness

accounted for 44% of the variance in overall reading ability, which was a highly significant portion of the variance. It, similarly, accounted for 42% of the variance in decoding and 24% of the variance in comprehension.

Table 8.

Results of Step-wise Multiple Regression using IQ, Working Memory, Simple Phoneme Awareness, and Compound Phoneme Awareness as Predictors of Decoding Performance

Step	Variable	R ²	Change in R ²	Unstand. b weight	Stand. error	Stand. β weight
1	Compound P. A.	.42	.42	.31	.04	.57***
2	Simple P. A.	.43	.01	.10	.06	.12
3	IQ	.44 _a ***	.01	.14	.09	.11
	Working memory	--	--	.01	--	--

^aR² at final step, F(3,136) = 36.19
p<.05 p<.01 p<.001

Table 9.

Results of Step-wise Multiple Regression using IQ, Working Memory, Simple Phoneme Awareness, and Compound Phoneme Awareness as Predictors of Passage Comprehension

Step	Variable	R ²	Change in R ²	Unstand. b weight	Stand. error	Stand. β weight
1	Compound P. A.	.24	.24	.21	.04	.40***
2	IQ	.38	.13	.42	.09	.35***
3	Working Memory	.39	.01	.09	.06	.10
4	Simple P. A.	.39 _a ***	.00	-.06	.06	-.08

^aR² at final step, F(4,135) = 21.37
p<.05 p<.01 p<.001

Figure 5. Beta weights of pathways between four predictor constructs with decoding.

Figure 6. Beta weights of pathways between four predictor constructs with comprehension.

Decoding relied less on vocabulary knowledge (verbal IQ) and analytical skill (as evidenced in pattern analysis) than did comprehension. IQ accounted for a significant amount of independent variance (13%), $F(4,135) = 22.24$, $p < .001$, in reading comprehension. (It entered at the second step of the MRA and was weighted significantly,

$B=.35$, $p<.001$). In contrast, IQ accounted for 1% of the variance, $F(3,136) = 2.71$, $p<.05$, in decoding and entered after the phoneme awareness constructs.

Simple phoneme awareness tasks displayed a unique relationship to the two different reading processes. With decoding, simple phoneme awareness contributed an additional 1% of the variance, subsequent to compound phoneme awareness. This amount was viewed as significant at $F(3,136) = 2.93$, $p<.05$. Its standardized beta weight for the regression equation was also significant at $p<.05$ ($B=.12$). With respect to comprehension, simple phoneme awareness entered the equation last, accounting for a nonsignificant amount of variance, and had a nonsignificant, negative weight.

In spite of the initial hypothesis, working memory made a minimal contribution to decoding and comprehension but impacted on each differently. With decoding as the criterion, memory never entered the regression equation. At the zero order level, with the MRA, the F-ratio for memory was significant at $p<.05$. Once the influence of compound phoneme awareness was removed, the F-ratio dropped substantially indicating working memory to be of little predictive significance. With comprehension as the criterion, working memory entered the equation in the third step contributing 1% of the variance, which was not significant, $F(4,135) = 1.87$, with a nonsignificant Beta weight of .10. When examining the F-ratios at each step, working memory made a significant contribution to comprehension before IQ was removed from the regression equation, $F(1,138) = 6.9$, $p<.01$, with CPA entering the equation first. Once IQ entered the equation at the second step, the role of memory was tremendously reduced, $F(2,137) = 1.84$, $p>.05$. Thus, working memory, apparently, was not an essential element in decoding ability and, once the effects of IQ were removed, did not make a significant contribution to reading comprehension, even though it shared 1% of the variance.

Therefore, the best predictive equation for decoding performance need only include compound and simple phoneme awareness measures to account for 43% of the variance. The better a child performs on the phoneme awareness tests the better he or she is likely to do in decoding.

The best predictive equation for comprehension would include compound phoneme awareness scores and IQ, accounting for 38% of the variance. Thus, a child's vocabulary level, nonverbal analytical skill, and awareness of phonemes at a more complex level (perhaps decoding ability), are likely to be good indicators of his or her level of text comprehension.

Given a composite IQ was used in the above regression analyses, six more step-wise MRA's were conducted to assess the differences verbal and nonverbal components of IQ make in the reading process. The correlation between the two IQ measures was low ($r=.16$) and the cognitive processing requirements clearly differ. Table 10, 11, and 12 provide a summary of the results.

As in the other MRA, compound phoneme awareness was the predominant construct which accounted for most of the variance in overall reading (44%). These findings confirmed the results of the factor analysis in which compound phoneme awareness and reading shared such a strong relationship with one another that they factored together. Overall reading performance also significantly involved verbal knowledge, as well as nonverbal, analytical ability (F-ratio of .04 and .03 for individual R^2 's were significant at $p<.001$).

Working memory, as measured in this study, took a significant drop in its contribution to overall reading once verbal or nonverbal IQ was entered into the regression analysis. [Apparently, verbal IQ reduced the influence working memory had on reading more than nonverbal IQ did. The partial correlations and F-ratio changed slightly when nonverbal IQ entered the equation (e.g., F-ratio changed from 3.54 to 2.6) versus a greater change when verbal IQ was entered (e.g., F-ratio changed from

Table 10.

Results of Step-wise Multiple Regression using Vocabulary as a Marker IQ, and, Separately, Pattern Analysis as a Marker of IQ, and Working Memory, Simple Phoneme Awareness, and Compound Phoneme Awareness as Predictors of Overall Reading Performance

Step	Variable	R ²	Change in R ²	Unstand. b weight	Stand. error	Stand. B weight
<u>Vocabulary -- Verbal IQ</u>						
1	Compound P. A.	.44	.44	.33	.03	.60***
2	VIQ	.48 _a ***	.04	.18	.06	.21**
	Working memory	--	--	.05	--	--
	Simple P. A.	--	--	-.02	--	--
<u>Pattern Analysis -- Nonverbal IQ</u>						
1	Compound P. A.	.44	.44	.34	.03	.62***
2	NVIQ	.47	.03	.18	.07	.17**
3	Working memory	.48b _a **	.01	.08	.05	.10
	Simple P. A.	--	--	-.02	--	--

^aR² at final step, F(2,137) = 63.78

^bR² at final step, F(3,136) = 42.16

p<.05 p<.01 p<.001

3.54 to .9).] The only difference between the two equations was that working memory added 1% variance when nonverbal IQ was used; however, this variance made a nonsignificant contribution.

Simple phoneme awareness was the least related to overall reading performance of the four constructs. This outcome paralleled the findings in our first MRA (unstandardized beta weight of -.02).

Therefore, in the MRA which examined overall reading performance, compound phoneme awareness and IQ were the most significant predictors of reading with the final R² in each case having accounted for 48% of the variance (working memory contributing 1% when nonverbal IQ acted as the indicator for IQ). However, the inclusion of verbal and nonverbal

Table 11.

Results of Step-wise Multiple Regression using Vocabulary as a Marker IQ, and, Separately, Pattern Analysis as a Marker of IQ, and Working Memory, Simple Phoneme Awareness, and Compound Phoneme Awareness as Predictors of Decoding Performance

Step	Variable	R ²	Change in R ²	Unstand. weight	Stand. error	Stand. β weight
<u>Vocabulary -- Verbal IQ</u>						
1	Compound P. A.	.42	.42	.31	.04	.57***
2	Simple P. A.	.43	.01	.10	.06	.12
3	VIQ	.44a***	.00	.09	.06	.10
	Working memory	--	--	.02	--	--
<u>Pattern Analysis -- Nonverbal IQ</u>						
1	Compound P. A.	.42	.42	.33	.04	.60***
2	Simple P. A.	.43b***	.01	.09	.06	.11
	NVIQ	--	--	.07	--	--
	Working memory	--	--	.04	--	--

^aR² at final step, F(3,136) = 35.86

^bR² at final step, F(2,137) = 42.16

*p<.05 **p<.01 ***p<.001

IQ measures (versus only one of them) provided a better predictive equation for overall reading performance as observed in the first MRA (51% of the variance accounted for). A second grader's overall reading performance seems best determined by his or her performance on compound phoneme awareness tasks as well as performance on the verbal and nonverbal IQ measures in combination.

Because of our interest in the components of reading we further analyzed the contribution of the constructs to decoding and comprehension with verbal and nonverbal IQ as independent markers of IQ. As noted in Table 11, decoding was primarily influenced by performance on compound phoneme awareness measures. It accounted for 42% of the

Table 12.

Results of Step-wise Multiple Regression using Vocabulary as a Marker IQ, and, Separately, Pattern Analysis as a Marker of IQ, and Working Memory, Simple Phoneme Awareness, and Compound Phoneme Awareness as Predictors of Comprehension Performance

Step	Variable	R ²	Change in R ²	Unstand. b weight	Stand. error	Stand. β weight
<u>Vocabulary -- Verbal IQ</u>						
1	Compound P. A.	.24	.24	.23	.04	.43***
2	VIQ	.32	.08	.20	.06	.24***
3	Working memory	.33	.01	.10	.06	.13
4	Simple P. A.	.33 ^{a***}	.00	-.07	.06	-.08
<u>Pattern Analysis -- Nonverbal IQ</u>						
1	Compound P. A.	.24	.24	.24	.04	.46***
2	NVIQ	.32	.08	.28	.08	.26***
3	Working memory	.35	.03	.13	.06	.17 [*]
4	Simple P. A.	.35 ^{b***}	.00	-.07	.06	-.09

^aR² at final step, F(4,135) = 16.96

^bR² at final step, F(4,135) = 18.47

^{*}p<.05 ^{**}p<.01 ^{***}p<.001

variance. Vocabulary knowledge, nonverbal analytical ability and working memory did not make any significant contributions to it. In contrast, as indicated in Table 12, compound phoneme awareness, verbal ability, nonverbal ability, and working memory all made independent significant contributions to comprehension. When incorporating verbal IQ, the R² at the final step was .33. When only using nonverbal IQ, the R² at the final step was .35.

Since compound phoneme awareness entered the MRA first in all instances, we could not determine the degree IQ or working memory conceptually contributed to it. Therefore, two additional analyses were run with IQ and working memory as predictors and compound phoneme

awareness, and simple phoneme awareness separately, as the criteria.⁷ Table 13 summarizes the findings. Figure 7 demonstrates the relationship between these constructs.

Table 13.

Results of Step-wise Multiple Regression using IQ and Working Memory as Predictors of Compound Phoneme Awareness, and separately, Simple Phoneme Awareness

Step	Variable	R ²	Change in R ²	Unstand. b weight	Stand. error	Stand. B weight
<u>Compound Phoneme Awareness</u>						
1	IQ	.08	.08	.52	.20	.22**
2	Working memory	.10 _a ***	.02	.25	.13	.16
<u>Simple Phoneme Awareness</u>						
1	Working memory	.01 _b	.01	.09	.08	.09
	IQ	--	--	.05	--	--

^aR² in final step, F(2,137) = 7.74

^bR² in final step, F(1,138) = 1.13

*p<.05 **p<.01 ***p<.001

Figure 7. Beta weights of pathways for IQ and working memory with simple and compound phoneme awareness as separate criteria.

⁷Since we know that compound and simple phoneme awareness share a moderately significant relationship with one another, they were not included as a predictor variable for the other (see measurement model). The primary interest was to assess the degree working memory and IQ contributed to the individual phoneme awareness tasks.

As noted in Table 13, IQ accounted for 8% of the variance while working memory accounted for 2% of the variance in compound phoneme awareness. Both percentages were significant (IQ: $F(2,137) = 6.84$, $p < .001$; WM: $F(2,137) = 3.66$, $p < .05$). However, neither of their Beta weights were significant. Therefore, neither IQ nor working memory bear a moderate to strong relationship with compound phoneme awareness measures. These results also enhance the validation of compound phoneme awareness, suggesting it is less confounded by other abilities (i.e., memory and verbal/nonverbal IQ), and attests to its independence as a construct.

Neither IQ nor working memory displayed any relationship to simple phoneme awareness. Working memory, entering the equation first, only accounted for a nonsignificant portion of the variance (1%).

In conclusion, the above series of MRA's has shown that compound phoneme awareness was a very significant predictor of overall reading performance, decoding ability, and passage comprehension. Also, compound phoneme awareness was minimally confounded by working memory or IQ. In subsequent regression steps, simple phoneme awareness was a predictive variable for decoding but of very limited value with comprehension. With comprehension, verbal and nonverbal IQ made a significant contribution. In most cases, working memory did not surface as a predictor of reading, except with comprehension, wherein it only contributed to 1% to 3% of the variance.

Relationship between manifest variables.

The above analyses gave us a good indication of how the constructs related to one another. Additional analyses were conducted to assess the predictive quality of the individual manifest variables in relation to decoding and comprehension, separately.

A step-wise MRA was used, with verbal IQ forced in first, and all remaining predictor variables given equal levels for removal or entry into the MRA. Word attack and comprehension were the criterion measures

in two separate analyses. Tables 14 and 15 provide a summary of the results.

Table 14.

Results of Step-wise Multiple Regression with Word Attack as the Criterion, Verbal IQ Forced in First, and all Remaining Variables as Predictors

Step	Variable	R ²	Change in R ²	Unstand. b weight	Stand. error	Stand. B weight
1	VIQ	.07	.07 ^a ***	.06	.06	.07
2	AAT	.43	.36***	.27	.04	.52***
3	Pig Lat.	.47	.04***	.07	.02	.20***
4	Count	.48	.01	.05	.04	.09
5	Familiar WS	.48 ^b ***	.00	.05	.05	.07
	Yopp	--	--	.03	--	--
	Blend	--	--	.02	--	--
	NVIQ	--	--	.01	--	--
	Delete	--	--	.01	--	--
	Single	--	--		--	--
	Syllable	--	--	.01	--	--
	Nonsense	--	--		--	--
	WS	--	--	-.00	--	--

^aPercent of variance considered significant

^bR² at final step, F(5,134) = 24.69

*p<.05 p<.01 p<.001

The predictor variables distributed themselves somewhat differently with word attack and comprehension. With word attack as the criterion, verbal IQ accounted for a significant portion of variance (7%) but had an insignificant regression weight assigned to it. Once the effects of verbal IQ were removed, AAT, a compound phoneme awareness task, accounted for 36% of the variance with a significant Beta weight of .52. Another compound phoneme awareness measure, Pig Latin, contributed an additional 4% variance and also had a significant Beta weight. The counting and familiar word span measures were last to enter the equation contributing an insignificant amount of variance to the overall R². With the inclusion of VIQ, AAT, and Pig Latin, 47% of a

Table 15.

Results of Step-wise Multiple Regression with Comprehension as the Criterion, Verbal IQ Forced in First, and all Remaining Variables as Predictors

Step	Variable	R ²	Change in R ²	Unstand. b weight	Stand. error	Stand. B weight
1	VIQ	.16	.16 ^{***}	.16	.06	.19 ^{**}
2	AAT	.30	.14 ^{***}	.16	.04	.31 ^{***}
3	NVIQ	.35	.05 ^{***}	.23	.07	.22 ^{**}
4	Pig Lat.	.38	.03 ^{***}	.07	.02	.20 ^{***}
5	Familiar WS	.40	.02 ^{***}	.11	.05	.15 [*]
6	Yopp	.41 ^{b***}	.01	-.04	.04	-.08
	Single Syllable Nonsense WS	--	--	.01	--	--
	Delete	--	--	.00	--	--
	Count	--	--	-.01	--	--
	Blend	--	--	-.03	--	--

^aPercent of variance considered significant

^bR² at final step, F(6,133) = 15.21

*p<.05 **p<.01 ***p<.001

second graders decoding performance was accounted for.

In contrast, with passage comprehension, nonverbal IQ and familiar word span were significant contributors to the regression equation. VIQ was entered first accounting for 16% of the variance. AAT contributed another 14% (versus 36% with decoding). Then nonverbal IQ entered in at the third step accounting for a significant 5% of the variance. Pig Latin accounted for 3% and then Familiar Word Span accounted for an additional 2%. Only the Beta weights for the compound phoneme awareness tasks -- AAT and Pig Latin -- were significant. Therefore, in this instance, five predictor variables accounted for 40% of the variance in passage comprehension but only two had significant regression coefficients assigned to them.

Essentially, comprehending text is a more complex process than decoding words. As indicated in this study, it apparently involves, at

a near equivalent level, adequate word knowledge and compound phoneme awareness, nonverbal analytical ability, and some adequate degree of working memory for familiar words. Decoding nonsense words seems a more basic skill which requires awareness of phonemes at a complex level -- not just a simple awareness of phonemes, per se, but the ability to mentally manipulate them -- and, less importantly, word knowledge.

Up to this point, we have gained a better understanding of how the four proposed hypothetical constructs (i.e., verbal working memory, simple phoneme awareness, compound phoneme awareness, and IQ) relate to reading and to one another, and which observed variables are preferred indicators of their construct and best predictors of decoding and comprehension. All of the above analyses incorporated a sample of subjects whose reading performance ranged in a normal distribution from poor to superior. Another important question to address was whether the relationships among the variables changed when contrasting the least skilled group of subjects with the skilled ones. For example, is a less-skilled decoder (LSK) apt to experience more problems with memory tasks than a skilled decoder (SK)? Or, do simple phoneme awareness task significantly discriminate these reading groups even though simple phoneme awareness plays a minor role in decoding for most second graders? Essentially, on which variables do the profiles of these two reading groups differ? Is there a difference in how the observed variables relate to decoding performance in these subgroups or does the relationship remain relatively the same?

Analysis-of-Covariance

To partially answer the above questions, six analyses-of-covariance (ANCOVA) were run. The LSK and SK decoding groups were selected based on their decoding ability (independent variable). The LSK decoders' standardized scores ranged from 76 to 89 (n=24, grade equivalent: 1.2 to 1.8, age equivalent: 6 yrs. 5 mos. to 7 yrs. 0 mos.). The SK decoders' standardized scores ranged from 111-123 (n=25,

grade equivalent: 3.7 to 6.7, age equivalent: 9 yrs. 1 mo. to 11 yrs. 11 mos.). Composite IQ was covaried out from all of the analyses. The dependent variables were AAT, Counting, Yopp, Nonsense Word Span and Familiar Word Span (with and without order of recall), and Single Syllable Memory-15 seconds. The results for each ANCOVA can be found in Table 16.

With IQ covaried out, verbal memory measures did not significantly discriminate reading groups, which supported the findings of the prior analyses. (Some additional analyses were run in which verbal IQ and nonverbal IQ were separately covaried out. When verbal IQ was covaried out working memory measures did not discriminate decoding groups. Familiar Word Span did, however, approach significance, $F(1,49) = 3.79$, $p = .06$. Similarly, when nonverbal IQ was covaried, none of the memory measures significantly discriminated groups. These additional findings provided further confirmation of our prior results, in that working memory was minimally related to decoding skill.)

In contrast, simple phoneme awareness tasks did significantly differentiate reading groups, with Yopp significant at $F(1,46) = 21.17$, $p < .001$, and Counting proving significant at $F(1,46) = 7.48$, $p < .01$. This finding supports the notion that LSK decoders are deficient in basic phoneme awareness skills in spite of simple phoneme awareness measures being less strongly linked with reading proficiency among our larger sample of second graders. And, lastly, AAT, a measure of compound phoneme awareness, was a significant discriminator of decoding groups $F(1,46) = 49.05$, $p < .001$.

Again, we find support for the conclusion that verbal working memory is not strongly related to decoding skill among second graders, whereas phoneme awareness measures are highly related to decoding performance. These latter measures are extremely sensitive variables for discriminating between LSK and SK decoders.

Table 16.

Means and Standard Deviations for Skilled and Less-skilled Decoders on Three Phoneme Awareness Tasks and Three Working Memory Measures, and the Respective F-ratio's with IQ as the Covariate^a

Dependent Variable	Reading Group	Adjusted Means $\pm$ SD		F-ratio ^b
AAT	LSK	40	14	49.05***
	SK	77	17	
Counting	LSK	51	13	7.48**
	SK	65	17	
Yopp	LSK	41	8	21.17***
	SK	60	11	
Nonsense WS	LSK	36	16	1.09
	SK	42	13	
Familiar WS	LSK	55	15	1.61
	SK	64	15	
Single Syllable-15"	LSK	18	17	.79
	SK	29	23	

^aLSK decoders were designated as those children with standard word attack scores between 76-89 and skilled decoders scores fell between 111-126.

^bdf(1,46) **p<.01 ***p<.001
^cp<.05

CHAPTER IV

DISCUSSION

The main goals of this study were to explore the relationship between working memory and phoneme awareness measures (simple and compound), and to investigate the relationships of these phonological processes to decoding and comprehension components of reading performance. Second-grade children whose reading skills were normally distributed served as subjects. In addition to examining performance of the entire subject pool, two subgroups of skilled and less-skilled decoders were compared to address whether a different pattern of relations was evident in children who have difficulty learning to read.

In order to investigate these questions, multiple measures were used to assess the hypothesized constructs. The first step in analyzing the results was to evaluate whether the anticipated factors were present. It is noteworthy that each manifest variable loaded into its respective latent construct, as predicted, yielding four constructs: simple phoneme awareness, compound phoneme awareness (loaded with reading), IQ, and verbal working memory. These findings supported Yopp's distinction between simple and compound levels of phonological awareness. Essentially, the six phoneme awareness tasks separated into two factors defined by degree of complexity. While these constructs were significantly related, they were best construed as two distinct factors. It is also interesting that compound phoneme awareness loaded with reading performance. Two explanations seem plausible. First, research on reading acquisition suggests a bidirectional relationship between phoneme awareness and reading skill; that is, that each facilitates further development of the other (e.g., Perfetti, Beck, Bell, & Hughes, 1987). Second, subjects may be inclined to use a spelling strategy to execute awareness measures, particularly if the tasks are somewhat demanding. Thus, the degree of literacy a child possesses would influence performance in reading and with compound phoneme tasks. The verbal and nonverbal IQ measures factored

together, though the low correlation between these tasks ($r=.16$) underscores the distinct cognitive requirements of each. Lastly, the construct validity of working memory was confirmed: Three measures selected to assess verbal working memory factored together. This outcome of four separate factors supports a number of previous results indicating several, relatively independent, factors that may make unique contributions to reading acquisition and reading performance (Blachman, 1983; Mann, 1984; Pennington, et al., in press; Wagner, 1988).

Having added to the construct validity of the four factors, the next questions were concerned with how they related to each other and to reading. In particular, a central goal of this study was to determine whether working memory ability contributed to performance on phonological awareness tasks. The results indicated that at least for this stage of reading development, performance in these two domains is not significantly related. Thus, despite the memory demands of phonological awareness measures, performance on phoneme awareness tasks is determined primarily by other abilities.

On the other hand, working memory performance did correlate significantly with IQ, particularly with the vocabulary task. Gathercole and her colleagues (1990) suggest that vocabulary acquisition may be closely related to one's working memory capacity. This association between verbal memory processes and IQ raises complex questions about how to appropriately control for individual differences in general cognitive ability. If the verbal IQ task taps many of the same cognitive processes as memory tasks do, controlling for verbal IQ may eliminate sources of variance that are theoretically relevant to an understanding of factors influencing abilities in phonological awareness. The verbal IQ task used in the present study required the production of definitions for provided words. For second graders, this task may tax memory span, lexical retrieval, and syntactic processing, all of which make demands on memory resources. In any case, in the present study concerns about the nature of the relationship between IQ

and working memory were addressed by controlling separately for verbal IQ and for nonverbal IQ as discussed later.

Turning to the important issue of how the factors of verbal memory, IQ, and phoneme awareness relate to reading achievement, one outcome was particularly compelling. Corroborating the research literature to date, compound phoneme awareness as a construct accounted for 42% of the variance in decoding and 24% of the variance in comprehension, entering multiple regression equations first in all instances. When examining the individual variables for this construct, AAT accounted for the greatest portion of the variance in decoding (36%), and after the contribution of verbal IQ, it accounted for a unique 14% of the variance in comprehension. Thus, a child's ability to segment and manipulate phonemes in a complex way significantly related to how well he or she decoded unfamiliar words. Also, compound phoneme awareness skills were clearly linked with comprehension levels. The construct of simple phoneme awareness accounted for an additional 1% of the variance with decoding and the respective manifest variables indicated moderate correlations with decoding ($p < .05$). Simple phoneme awareness tasks revealed an insignificant relationship to comprehension.

Examination of the link between facility on working memory tasks and reading skill suggested a significant association when comprehension was the outcome score, but not when decoding was. Given the normal range of reading scores for the subjects in this study, it may be that once a child has mastered a certain degree of decoding proficiency, individual differences in verbal working memory do not impact on decoding performance. (This issue will be considered below when the results of the less-skilled readers are reviewed.) A study by Gathercole, et al. (submitted) reported a significant relationship between memory scores and reading skill only at very early stages of reading acquisition. The present results point to a stronger association in later years between working memory ability and reading comprehension level, although once Composite IQ was included in the

analyses, memory performance only contributed a minimal amount to variance accounted for in multiple regression analyses. Of interest, too, was the finding that when verbal IQ and nonverbal IQ were separate indicators of IQ, working memory made a small but significant contribution to comprehension skill. As noted earlier, the cognitive overlap between IQ and working memory measures makes the interpretation difficult. Further research is necessary to explicate the nature and degree of correspondence between memory measures and the various procedures for assessing components of verbal ability (e.g., receptive versus expressive vocabulary skill).

The construct of IQ demonstrated a significant relationship to the overall process of reading and to passage comprehension. Vocabulary knowledge explained 4% of the variance in overall reading performance and Pattern Analysis explained another 3% of the variance. IQ appeared to have a greater influence on a child's comprehension level than his or her decoding skill. After the effects of phoneme awareness were eliminated in a multiple regression analysis, IQ had no effect on decoding, confirming prior evidence that phonemic awareness is more critical in the acquisition of decoding skills than is general IQ (Stanovich, et al., 1983). In contrast, after compound phoneme awareness entered the predictive equation for comprehension, IQ still contributed a significant 13% of the variance. Such findings support the observation of an association between vocabulary knowledge and reading ability (Vellutino & Scanlon, 1987) and suggest that word knowledge, vocabulary, and other IQ-related variables are significantly correlated with comprehension.

What is less frequently addressed is the influence of a nonverbal task such as Pattern Analysis, an index of analytical ability. Recent articles suggest that nonverbal, visual working memory tasks should be re-examined as factors influencing reading performance (e.g., Stanovich, 1990). Since we did obtain a significant relationship between a nonverbal measure with comprehension, it might be worthwhile to further

explore the influence of this variable on certain aspects of reading.

To augment our understanding of how these individual variables related to the reading process, differences in performance between less-skilled and skilled decoders were also examined. A similar picture emerged from this comparison as for the entire subject pool. Reading ability was most associated with performance on the compound phoneme awareness measures. However, scores on the simple phoneme awareness measures also clearly differentiated the two decoding groups. The Yopp test was the best simple phoneme task for discriminating between the reading groups. Thus, the simple phoneme awareness construct seems to be important for early reading acquisition and for assessing decoding deficiencies. (See Adams, 1990, for a discussion of the predictive value of simple phoneme measures at the preschool and early elementary levels.) When comparing working memory ability between the two groups, no significant difference was detected.

These results have a number of practical implications. One important implication from this study is with respect to the matter of specificity in reading disabilities. Do reading disabled children experience a specific deficit? Is this deficit independent of IQ?

There are two independent findings in this study that support a specific phonemic deficit that can be isolated from overall cognitive ability. First, our results indicated verbal/nonverbal IQ measures made a minimal contribution to decoding. However, a significant relationship surfaced between IQ and comprehension. Second, in addition to compound phoneme awareness measures differentiating less-skilled and skilled decoders, simple phoneme tasks also discriminated the two decoding groups. Even though simple phoneme awareness measures contributed very little in predicting performance on the word attack subtest across all readers, they were highly sensitive for differentiating decoding groups. These results suggested that poor readers are impaired in processing phonemes at a very basic level -- a level most second-grade readers have already mastered. Therefore, given a more severe deficit in phoneme

awareness among less-skilled decoders, it would be diagnostically beneficial to standardize a simple phoneme awareness measure.

By researching the relationship of the aforementioned constructs, and through the incorporation of multiple measures, we are now better able to determine which measures are best used in psychoeducational assessments given specific referrals (e.g., reading difficulties). For example, the modified version of the AAT was a reliable and valid indicator of compound phoneme awareness and predicted a large percentage of variance in decoding and comprehension ability. It would serve as an excellent measure to incorporate in preschool assessments (i.e., to predict future reading performance) or to determine the nature of a child's reading problem, given norms are established. Simple phoneme awareness is most likely to be a good predictor of early reading ability, as well as a more severe phoneme awareness deficit, since it discriminated the decoding groups so well.

With respect to instructional intervention, one should always be cautious about which techniques are recommended when they are based on relational research. As a result of this study and others, however, it is apparent that understanding and applying the phonemic principle to decoding words is an essential aspect of learning to read. In addition, a child's vocabulary level seems to affect comprehension of text. Within this study it is not possible to determine the directional relationship between vocabulary and reading skill. In all likelihood, they share a bidirectional relationship with one another. A good reader expands his or her vocabulary through reading and a child with an extensive vocabulary is apt to comprehend more material (Stanovich, Cunningham, & West, in press). These findings suggest, first, that training on phonological awareness combined with a code-emphasis approach to reading instruction would be most valuable, especially in early stages of learning to read. Second, they indicate that this instruction would be facilitated by literacy activities designed to build vocabulary and conceptual knowledge.

In closing, the results of this study support a phonological processing model that conceptualizes verbal working memory and phoneme awareness as two independent processes. Further, the results confirm an extension of the model such that phoneme awareness should be defined on the basis of how cognitively demanding such tasks might be.

What emerges is a strong and consistent outcome that phoneme awareness is importantly related to reading performance with simple phoneme awareness measures more sensitive to early stages of reading acquisition. These findings support the growing evidence that instruction in phoneme awareness could provide a valuable complement to current methods of reading instruction. The relation of verbal working memory to learning to read is less clear. Here a weak association with reading success was attained, and that was limited to performance on reading comprehension measures. The results of prior studies yield an inconsistent pattern (e.g., Brady, in press; Pennington, et al., in press). Therefore, the hypothesis that poor readers experience a general phonological coding deficit requires further investigation. We are also left with the need for better measures of working memory and inconclusive evidence as to whether to control for the effects of verbal IQ when investigating the role of working memory in reading development. However, the present study underscored the value of evaluating the contribution of phonological processes to both decoding and comprehension measures of reading skill since different relations may be present. Future longitudinal research would help delineate whether the pattern of relations differs for particular stages of reading acquisition.

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APPENDIX A

SEGMENTATION TEST

Instructions: I'm going to say a real word and I want you to tell me what sounds you hear in the words -- not letters. For example, in the word "cat," there are three sounds -- /c/, an /a/, and a /t/. Now, when you say the sounds, I want you to say them slowly and far apart from each other like I did with the word "cat." Now, let's try some together.

Practice: go, man, fish.

(After each item say: What are the smallest sounds you hear? If the child is wrong with the practice trials, tell him/her how many sounds there are and ask him/her to try again. If still incorrect, give corrective feedback.)

Now, I'm going to say some more words and I want you to tell me their separate sounds. Listen carefully! (Do not correct child with test items. Repeat word only once if child requests.)

(Items were presented in random order.)

cv show do may

vc up edge all

cvc dog teach five ship ran mile

vcc old act inch

ccv draw snow stay

ccvc green small close

cvcc find just soft

ccvcc stump bland frost

APPENDIX B

SEGMENTATION COUNTING TEST

Instructions: Here's a card and ten tiles. I'm going to say some words that aren't real words and I want you to show me how many sounds you hear in the words -- not letters but sounds. You'll show me how many sounds there are by placing the same number of tiles on this card. For example, with the word /ot/, there are two sounds /o/ and /t/, so I'll place two tiles on this card. OK, now let's try some together.

Practice: How many sounds do you hear in the word "ru?" You hear two sounds. What are they? (If child says the letters, correct him/her and say: I want you to give me the sounds, not the letters. OK, now how many tiles would you put on your card? (Correct) Continue with the same instructions for: tat and pog.

Now, I'm going to say some more words and I want you to count the number of sounds you hear so listen carefully. (Correct child on practice trials only. Do not correct child with test items. Repeat word only once if child requests. Make sure the card is cleared away before each item.)

(The items below were randomly presented.)

cv thoo fi sa
vc ut im af
cvc seach wob sive thip med kile
vcc ild oct unch
ccv dray clow smaw
cvcc rond bift fust
ccvc clop gleek smat
ccvcc spand flump trost

APPENDIX C

PHONEME BLENDING TEST

Instructions: Now you will hear me say a word in smaller parts -- their separate sounds. I want you to put the sounds together to make a real word. For example, if you heard the sounds /c/, /a/, and /t/ and put them together, it sounds like "cat." Now, let's try some together.

Practice: (Present phonemes at two second intervals.)

u-p (What word do these sounds make?)

b-oo-k

d-u-ck

Now, on this tape you will hear more sounds that I want you to put together to make real words. Listen carefully and say the word after you hear the sounds. (Do not repeat items. State only once. If the child does not respond after hearing the sounds ask, "What word is it?") (The items below were presented in the order given.)

vc e-g (egg) ae-z (as)

cv k-i (key) s-ei (say)

cvc d-ai-v (dive) s-a-k (sock) k-i-t (kit)
n-ou-z (nose)

ccvc g-l-ai-d (glide) k-l-ae-p (clap)
s-n-ei-k (snake) s-m-oo-th (smooth)

cvcc v-e-s-t (vest) m-o-l-d (mold)

ccvcc k-l-i-t-s (cleats) p-l-ae-n-t (plant)

cccvc s-k-r-ei-p (scrape)

cvccc d-e-s-k-s (desks)

APPENDIX D

AUDITORY ANALYSIS TEST

Instructions: Now, on this test I'm going to want you to say a word without saying part of it. For example, can you say cowboy without saying boy? OK, now let's try some more.

Practice: (1) say homework without saying home
 (2) say rug without saying /g/
 (3) say chair without saying /ch/.

(Give corrective feedback on practice trials but not on test items.)

Now, let's do some more. Listen carefully.

(Items below presented randomly.)

Initial Consonant

(m)an (w)ill (g)ate (c)lip (s)mile (b)lock (b)reak (t)rail
 (g)rain (sh)rug (s)train (g)low

Final Consonant

bel(t) ro(de) to(ne) ti(me) plea(se) stea(k)

Medial Consonant

s(m)ell c(r)eate s(m)ack s(k)in st(r)eam c(l)utter

APPENDIX E

DELETION TEST

Instructions: On this test I'm going to say a word, but not a real word, and have you say it without saying part of it. For example, can you say "mowcoy" without saying /mow/? OK, let's try some more.

Practice: (1) bafmot without saying /mot/

(2) ko without saying /o/

(3) pim without saying /p/.

(Give corrective feedback on practice trials but not on test items.)

Now, let's do some more. Listen carefully.

Initial Consonant

(l)an (d)ilt (j)ate (th)rike (s)lote (c)raik

(b)lun (t)row (g)lowt (s)tope (d)roon (b)lirg

Final Consonant

mu(n) sa(de) ha(ne) nis(t) ril(k) pril(t)

Medial Consonant

sc(r)eel t(r)up s(m)ake c(r)ite c(l)isk s(n)ook

APPENDIX F

PIG LATIN TEST

Instructions: On this test I will be saying a word that I want you to say without its first sound. I also want you to say another word by adding the first sound you hear to the /a/ sound -- long a. So, let's practice this first. If I say the word "so" you would say o-say. You would take away the /s/ sound and have the /o/ left. Then you would add it to the /ay/. Then put it all together and you get -- osay! Now, let's try some together for practice.

- (1) go (o-gay)
- (2) do (o-day)
- (3) me (e-may)
- (4) be (e-bay)
- (5) red (ed-ray)
- (6) blend (lend-bay)

(Give corrective feedback on practice trials only. If the child gets two correct go on with the test items. Otherwise, stop. If necessary, give corrective feedback on item #1 below and then go on to #2. If the child cannot do #2 -- stop administering the test.)

Alright, now I'm going to give you some more so listen carefully.
(Presented in order of difficulty.)

Monographs

	<u>Word</u>	<u>Answer</u>
CV	day	aday
	cow	owcay
CVC	man	anmay
	game	amegay
CVCC	list	istlay

Digraphs

CVC	that	atthay
	shone	oneshay
CVCC	third	irdthay
CCVC	brake	rakebay
	star	tarsay
CCVCC	skirt	kirtsay
	blast	lastbay

APPENDIX G

SINGLE SYLLABLE MEMORY TEST

Instructions: You are going to hear me say some sounds through your headphones. They are the kinds of sounds we use when we talk. Right after you hear what I say, you will hear a beep. Then you start reading these numbers (point) outloud as quickly as you can. Read across the page. At the next beep, tell me what you heard me say through the headphones. Let's do some for practice first.

Present the first practice item with a 5-second interval.

Present the second practice item with a 10-second interval.

Practice: (1) tae (2) oup

(Presented in the order listed below.)

1. /na/ (10)
2. /gi/ (5)
3. /eiv/ (15)
4. /a/ (10)
5. /de/ (15)
6. /ae/ (5)
7. /kai/ (15)
8. /ez/ (10)
9. /as/ (5)
10. /ait/ (10)
11. /id/ (15)
12. /vae/ (5)
13. /in/ (10)
14. /tei/ (10)
15. /oug/ (5)
16. /e/ (15)
17. /si/ (10)
18. /zou/ (15)
19. /aek/ (15)
20. /i/ (5)

APPENDIX H

FAMILIAR WORD SPAN MEMORY TEST

Instructions: This is a memory test. I'm going to play a tape that has lists of words. After each list is finished I want you to repeat the words back as best as you can in the order that you heard them. Let's try practicing some together. (Present at one second intervals.)

Practice: (1) stop home light
(2) stove jump help blue

(Correct wrong responses on practice trials only. Also, if the child pauses as if he/she is not finished and has already recalled three or four items, wait five seconds and ask, "Do you remember any other words from that list?")

List

1)	cat	fly	score	meat	scale
2)	roar	wheat	fat	tail	sky
3)	tie	hat	nail	floor	sheet
4)	mail	pie	store	cap	feet
5)	treat	door	eye	sail	map
6)	bell	state	knee	pain	chair
7)	bee	cell	train	air	plate
8)	gate	brain	pair	tea	well
9)	bear	key	weight	shell	chain
10)	rain	hair	spell	fate	tree

APPENDIX I

NONSENSE WORD SPAN MEMORY TEST

Instructions: This is a memory test. I'm going to play a tape that has lists of words -- words that aren't real, for example, pog. After each list is finished I want you to repeat the words back as best as you can in the order that you hear them. Let's try practicing some together. (Present at one second intervals.)

Practice: (1) nat tiff ib
(2) mell jox leck hap

(Correct wrong responses on practice trials only. Also, if child pauses as if he/she is not finished and has already recalled three items, wait five seconds and ask, "Do you remember any other words from that list?")

List

1)	lat	slee	flim	geat
2)	joar	wheam	fut	sko
3)	ni	quat	floun	sheeg
4)	paim	stas	bap	feep
5)	doot	ah	paik	mab
6)	gell	stame	skow	nain
7)	tay	pell	treek	plid
8)	gade	braip	gow	lell
9)	meeb	filt	shill	whib
10)	jate	spull	ter	skay

APPENDIX J

School _____
 Teacher _____
 Date _____

READING CURRICULUM SURVEY

The questions below are intended to assess which reading method you rely on most in your classroom. This information will remain confidential. This feedback will be informative as to whether children in various classes are being taught according to similar or different reading instruction methods.

Thank you again for your cooperation and assistance. After you complete this survey, please return it to me in person or in the enclosed stamped, self-addressed envelope.

Key to Numbers
 Scale:

- 1 = minimally: never or less than 1 on
 time per month
 2 = periodically: two or three times
 per month
 3 = frequently: once or twice per week
 4 = regularly or extensively: three or
 four times per week
 5 = always: daily

1. Do you use a basal series? yes _____ no _____

If so, which one? _____

2. Do you teach phonics as a separate unit of study?

1 2 3 4 5

Comments: _____

3. If you teach phonics, do you provide additional reading material that enables the student to practice the phonics lessons within context?

1 2 3 4 5

Comments: _____

4. Do you emphasize phonics in your other daily curriculum, when appropriate?

1 2 3 4 5

Comments: _____

5. Do you use children's literature/tradebooks to supplement reading lessons and the basal reader?

1 2 3 4 5

Comments: _____

6. During this year have you used the Language Experience Approach (i.e., "Today's News" or other stories related by students)?

1 2 3 4 5

Comments: _____

7. Do you use Process Writing (e.g., emphasize elements of story composition)?

1 2 3 4 5

Comments: _____

8. Do you use Big Books (e.g., classics)?

1 2 3 4 5

Comments: _____

9. Do children in your class write individual or class books?

1 2 3 4 5

Comments: _____

10. Do children in your class write in journals?

1 2 3 4 5

Comments: _____

11. Do you use thematic units to integrate content areas with language arts (reading, writing, speaking, listening, math/problem-solving)?

1 2 3 4 5

Comments: _____

12. Which reading method(s) do you personally prefer?

THANK YOU!

APPENDIX K

Pearson Correlation Coefficients of All Observed Measures

Measures	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Reading Measures																	
1-Word Identification	.76***	.82***	.19	.15	.11	.64***	.59***	.43***	.19	.23*	.17	.07	.14	.17	.38***	.23*	.42***
2-Word Attack		.65***	.28**	.32**	.23*	.64***	.55***	.44***	.14	.18	.10	.07	.03	.14	.27**	.13	.28**
3-Comprehension			.11	.08	.09	.46***	.38***	.38***	.21*	.31**	.22*	.11	.19	.20*	.40***	.34***	.49***
Simple Phoneme Awareness																	
4-Phoneme Counting				.48***	.35***	.27**	.28**	.18	.03	.07	.13	.14	.16	.02	.09	.06	.09
5-Yopp Segmentation					.35***	.36***	.35***	.24*	.03	.06	.06	.08	.02	.04	.03	-.04	-.01
6-Slending						.22*	.27**	.24*	.06	.15	.06	-.01	-.07	.15	.05	.03	.03
Compound Phoneme Awareness																	
7-Auditory Analysis Test (AAT)							.80***	.37***	.10	.10	.06	-.02	.05	.09	.24*	.16	.27**
8-Deletion								.38***	.22*	.17	.17	.10	.05	.22*	.24*	.08	.22*
9-Pig Latin									.14	.15	.11	.07	-.00	.16	.23*	.06	.20*
Memory Measures																	
10-Nonsense Word Span										.62***	.35***	.33***	.15	.30***	.23*	.04	.19
11-Familiar Word Span											.37***	.17	.26**	.36***	.38***	.16	.35***
12-Dreyer Total												.73***	.74***	.73***	.23*	.11	.23*
13-Dreyer 5"													.43***	.28**	.10	-.01	.07
14-Dreyer 10"														.25*	.20*	.14	.23*
15-Dreyer 15"															.22*	.11	.22*
IQ Measures																	
16-Verbal SAS																.16	.82***
17-Performance SAS																	.69***
18-Full Scale SAS																	

*p<.05. **p<.01. ***p<.001.

APPENDIX L

Beta Values for Model No. 1

	<u>IQ</u>	<u>WM</u>	<u>CPA</u>	<u>SPA</u>	<u>Reading</u>
IB	.00	.00	.81	.27	.66
WM			.49	.19	.38
CPA				.00	.25
SPA					.23

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