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The Nature of Preschool Phonological Processing Abilities and Their Relations to Vocabulary, General Cognitive Abilities, and Print Knowledge

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Abstract

The development of reading-related phonological processing abilities (PPA) represents an important developmental milestone in the process of learning to read. In this cross-sectional study, confirmatory factor analysis was used to examine the structure of PPA in 129 younger preschoolers ($M = 40.88$ months, $SD = 4.65$) and 304 older preschoolers ($M = 56.49$ months, $SD = 5.31$). A 2-factor model in which phonological awareness and phonological memory was represented by one factor and lexical access was represented by a second factor provided the best fit for both samples and was largely invariant across samples. Measures of vocabulary, cognitive abilities, and print knowledge were significantly correlated with both factors, but phonological awareness/memory had unique relations with word reading. Despite significant development of PPA across the preschool years and into kindergarten, these results show that the structure of these skills remains invariant.

In a literate society, learning to read and write are key developmental milestones. Reading and writing skills serve as the cornerstone to acquiring content knowledge in other domains both in school and throughout life. Knowledge about the causes, correlates, and predictors of school-age children's reading successes and failures has increased substantially over the past three decades (see e.g., National Reading Panel, 2000); however, only within the past 10 years have sizable efforts been directed toward understanding the development and contribution of reading-related skills prior to school entry. This growing body of evidence highlights the significance of the preschool period for the development of several critically important early literacy skills (e.g., Snow, Burns, & Griffin, 1998; Whitehurst & Lonigan, 1998). These skills are often referred to as emergent literacy skills, which Whitehurst and Lonigan defined as the "developmental precursors to conventional forms of reading and writing" (p. 849). Although older theories of the causes of reading difficulties posited significant involvement of visual-perceptual systems or hypothesized subtle vision difficulties (e.g., Black, 1973; Brod, 1969; Guthrie & Goldberg, 1972; Roberts, 1958; Rosen, 1965; Snyder & Freud, 1967), most recent conceptualizations of reading difficulties have focused on linguistic factors. There is now a strong consensus that the most common cause of early reading difficulties is a weakness in children's phonological processing skills (Metsala, Stanovich, & Brown, 1998; Morris et al., 1998; Stanovich, 1988, 1992; Stanovich & Siegel, 1994; Stanovich, Siegel, & Gottardo, 1997).

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Wagner and Torgesen (1987), based on research with school-age children, identified three interrelated clusters of reading-related phonological processing abilities: phonological awareness, phonological memory, and phonological access to lexical store. *Phonological awareness* refers to the ability to detect, apprehend, or manipulate the sound structure of oral language independent of meaning, and it is measured commonly by tasks requiring matching, blending, deleting, or counting sounds within words. This ability to access smaller and smaller units of sound within spoken words helps children make the connection between the sounds and the letters that represent them in print (i.e., the alphabetic code).

Phonological memory refers to the coding of information in a sound-based representation system for temporary storage (Baddeley, 1986), and it is typically measured by immediate recall of verbally presented material (e.g., repetition of nonwords). Efficient phonological memory might enable children to maintain an accurate representation of the phonemes associated with the letters of a word while decoding and, therefore, devote more cognitive resources to word decoding and comprehension processes. *Phonological access to lexical store* (“lexical access”) refers to the speed and accuracy (i.e., efficiency) with which children can retrieve phonological codes from long-term memory, and it is typically measured as the rate at which an array of letters, digits, or colors can be named. Efficiency in lexical access might influence the ease with which a child can retrieve the phonological information associated with letters, word segments, and whole words, and increase the likelihood that he or she can use this phonological information in word decoding.

According to the Phonological Core Deficit Model (e.g., Morris et al., 1998; Stanovich & Siegel, 1994), reading difficulties are most often the result of a significant weakness in phonological processing skills. That is, children who have difficulty decoding words accurately and fluently have a significant weakness in one or more phonological processing ability, typically phonological awareness or lexical access. Some poor readers may also have deficits in other reading-related skills (e.g., vocabulary) depending on the degree of discrepancy between their reading skills and the level of their general cognitive and academic functioning (Morris et al., 1998; Stanovich et al., 1997). Some evidence suggests that children with a deficit in both phonological awareness and lexical access, a condition often referred to as a “double deficit,” tend to be at the very bottom of the distribution of reading ability (Bowers, 1995; Bowers & Wolf, 1993; McBride-Chang & Manis, 1996); however, other evidence calls into question the independence of these two skills at the extreme ends of the skill distributions (e.g., children with extremely low levels of phonological awareness who have average to high levels of lexical access; Schatschneider, Carlson, Francis, Foorman, & Fletcher, 2002) as well as the significance of poor lexical access for impaired reading (Vukovic & Siegel, 2006).

In addition to being associated with severe reading difficulties, these phonological processing skills are predictive of growth in reading skills. Regarding phonological awareness, children who are better at detecting or manipulating syllables, rhymes, or phonemes learn to read more quickly than do children who are less able to perform these tasks, and this relation is present even after variability in reading skill due to factors such as IQ, receptive vocabulary, memory skills, and social class are partialled out (e.g., Bryant, MacLean, Bradley, & Crossland, 1990; Lonigan, Burgess, & Anthony, 2000; Wagner, Torgesen, & Rashotte, 1994; Wagner et al., 1997). Measures of lexical access are also significant predictors of growth in word decoding skills in school-age children, and they appear to have an independent effect on growth in word decoding above that of both phonological awareness and phonological memory. Similarly, measures of phonological memory are significant correlates of growth in word decoding skills, but at present, there is little evidence that phonological memory provides unique predictive variance to growth in word decoding beyond that provided by phonological awareness (Wagner et al., 1994, 1997).

Evidence from intervention studies indicates that at least some phonological processing skills are causally related to the acquisition of reading (e.g., Adams, 1990; Byrne & Fielding-Barnsley, 1991; Maridaki-Kassotaki, 2002; Stanovich, 1992; Torgesen, Morgan, & Davis, 1992). For example, Brady, Fowler, Stone, and Winbury (1994) were able to improve the reading skills of kindergarten children by providing the children with an intervention that focused on enhancing phonological awareness. In a notable study concerning teaching phonological awareness skills to preschool children, Byrne and Fielding-Barnsley (1991) found that children exposed to a 12-week program of phonological awareness training resulted in improvements in phonological awareness and decoding skills that endured through the end of the second-grade (Byrne and Fielding-Barnsley, 1993, 1995). In addition to studies demonstrating positive effects of phonological awareness training programs, there is some evidence that programs targeting phonological memory can also improve reading skills. For example, Maridaki-Kassotaki (2002) trained Greek-speaking kindergarteners to repeat lists of nonwords during the course of the school year. At the end of the program, children who received the training outperformed the control group in reading.

In the absence of intervention, differences in phonological processing abilities are highly stable beginning in kindergarten (Speece, Ritchey, Cooper, Roth, & Schatschneider, 2004; Wagner et al., 1994, 1997) or earlier (Burgess & Lonigan, 1998; Lonigan et al., 2000). For instance, Wagner et al. (1997) reported that year-to-year stability coefficients for their latent phonological awareness variable ranged from .83 (kindergarten to first grade) to .95 (second grade to third grade and third grade to fourth grade). Similarly, in preschoolers, Lonigan et al. (2000) found that a latent variable indexing phonological awareness in 4- and 5-year-old children perfectly predicted a latent variable indexing phonological awareness skills measured one year later. Wagner et al. (1997) also reported high levels of stability for a phonological memory latent variable (e.g., $r = .86$ for 3rd to 4th grade to $r = 1.0$ for kindergarten to 1st grade and 1st grade to 2nd grade) and a lexical access latent variable (e.g., $r = .84$ for kindergarten to 1st grade and 3rd grade to 4th grade to $r = .87$ for 1st grade to 2nd grade). Such results suggest that the early childhood period is an important time for the development of phonological processing skills.

Despite a large body of research relating phonological processing abilities to reading and investigating the development of these abilities in school-age children, there is far less systematic research available concerning the development and significance of these abilities in younger children. Given the strong predictive and causal relations between phonological processing abilities and later reading skills, and the high degree of stability of these skills, it is important to understand the nature and structure of phonological processing abilities in children both prior to and at the beginning of children's formal educational experiences (i.e., preschool and kindergarten). Such knowledge might lead to more effective ways to identify young children who are at risk for low reading achievement and lead to the development of early interventions that will help eliminate risk for later reading problems. However, to date, almost all research concerning preschool phonological processing skills has focused on phonological awareness (e.g., Anthony, Lonigan, Burgess, Driscoll, Phillips, & Cantor, 2002; Anthony, Lonigan, Driscoll, Phillips, & Burgess, 2003; Bryant et al., 1990; Burgess & Lonigan, 1998; Byrne & Fielding-Barnsley, 1991; Lonigan, Burgess, Anthony, & Barker, 1998; Lonigan et al., 2000).

The purpose of this study was to examine all three domains of phonological processing abilities in preschool children and to determine the nature of the underlying structure of these phonological processing abilities in young children. Only two prior studies have examined the structure of phonological processing abilities in English-speaking kindergarten or preschool children. In both of these studies, the phonological processing abilities were not as distinct from each other in younger children as they are in older children. Such results

suggest significant developmental differences in the nature of phonological processing abilities between older and younger children. Wagner, Torgesen, Laughon, Simmons, and Rashotte (1993) examined the structure of phonological processing abilities in a sample of 95 kindergarten and 85 second-grade children. Using confirmatory factor analysis, they found that a latent variable representing phonological memory measures and a latent variable representing phonological awareness analysis measures (i.e., measures of phonological awareness that require children to isolate or delete sounds in words) were not distinguishable in the kindergarten sample. In contrast, for the second-grade sample, the latent variables representing phonological memory measures and phonological awareness analysis measures were distinct. For both age groups, additional distinct latent variables represented phonological awareness synthesis measures (i.e., phonological awareness measures that require children to blend sounds presented in isolation into words or nonwords), and lexical access measures. In a study of 111 4- and 5-year-old preschool children, Wagner, Balthazor, Hurley, and Morgan (1987) used confirmatory factor analysis to show that a latent variable representing four phonological awareness analysis tasks and one phonological awareness synthesis task and a latent variable representing phonological memory tasks were indistinguishable.

Findings that phonological awareness and phonological memory are not distinct abilities in younger children may reflect developmental differences in phonological processing abilities as children get older or as they progress from pre-readers to skilled readers. It is also possible that some unique aspects of the studies were responsible for the findings. For instance, Wagner et al. (1993) tested their models with two phonological awareness latent variables, one for analysis tasks and one for synthesis tasks. All but one of the phonological awareness tasks used by Wagner et al. (1987) were analysis tasks. Although we have not found that analysis and synthesis tasks are represented by two factors with younger children (e.g., Anthony & Lonigan, 2004; Anthony et al., 2002; Lonigan et al., 2000), it is possible that there is something unique to synthesis tasks that is not present in analysis and memory tasks. Additionally, most of the phonological awareness tasks used by Wagner et al. (1993) were relatively complex for young children, consisting of phoneme-level manipulations. Research with younger children suggests that phonological awareness develops along a continuum from awareness of large and concrete sound units (i.e., words, syllables) to awareness of small and abstract sound units (i.e., phonemes) and that analysis tasks are more difficult than synthesis tasks (e.g., Anthony et al., 2002; Lonigan, 2006). Hence, at least for Wagner et al. (1993), the phonological awareness tasks might have been near the upper end of children's abilities. In this study, we used a broad array of measures to index phonological awareness at the levels typically displayed by preschool children to test the possibility that something about the phonological awareness tasks used in the Wagner et al. studies were responsible for their results.

Measures that were clear indicators of phonological memory (i.e., those involving orally presented items and more similar to measures used to assess phonological or auditory memory) were used in this study to assess whether there was something unique to the combination of memory tasks used in the studies of Wagner and colleagues. Children in Wagner et al. (1987) completed three tasks designed to index phonological memory, a measure of articulation rate (i.e., repeat "ta-ka" and "cola" as rapidly as possible 10 times over four trials per phrase), repetition of strings of letters presented orally (i.e., three strings each of 2-, 3-, 4-, and 5-letters), and repetition of the names of strings of pictures (i.e., repeat words for strings of 2-, 3-, 4-, and 5-pictures of common objects). Children in Wagner et al. (1993) completed four tasks designed to index phonological memory, an orally presented digit-span task, a visually presented digit-span task, a sentence repetition task, and a working memory task. One could question the construct validity of some of these tasks in terms of both face validity and the empirical relations between these tasks. The tasks used in

Wagner et al. (1987) were likely to involve more than phonological memory. Articulation rate, although requiring children to remember either “pa-ta” or “cola” while repeating, seems to assess more about the speed of speech production than phonological memory. Recalling names of pictures seems to assess both lexical access and phonological memory (i.e., child must retrieve names of the pictures and repeat them once the picture is removed). Letter recall may confound phonological memory with letter knowledge, which is a strong correlate of phonological awareness (Bowey, 1994; Burgess & Lonigan, 1998; Stahl & Murray, 1994; Wagner et al., 1994).

As noted above, the purpose of this study was to examine the structure of phonological processing abilities in young children, using a broad array of measures to index phonological awareness at levels typically displayed by preschool children as well as measures that were clear indicators of phonological memory. Unlike the two previous studies of preschool phonological processing abilities, this study included measures that represented lexical access for preschoolers, allowing an examination of the structure of all three phonological processing abilities in preschool children. These analyses were conducted with both an older group of preschool children (i.e., 4- and 5-year-olds) and a younger group of preschool children (i.e., 2- and 3-year-olds), allowing an examination of the structure of phonological processing abilities at the earliest point during the preschool period and across this period of rapid development of reading-related skills. Both groups of children included a larger and more diverse sample of children than were used in previous studies, increasing the reliability and generalizability of the results. Finally, measures of other reading-related skills and general abilities were included in the study to examine the shared and unique correlates of these early phonological processing abilities. We expected that, similar to Wagner et al. (1987, 1993), measures of phonological awareness and phonological memory would be highly related but that measures of lexical access would be distinct from awareness and memory. We anticipated that all phonological processing abilities would be correlated with measures of language and general abilities but that phonological awareness would be more highly correlated with print-specific measures (i.e., letter knowledge and word reading).

Method

Participants

Two groups of preschool children participated in this study. The first group of children consisted of 129 younger preschool children who ranged in age from 27 to 47 months ($M = 40.88$, $SD = 4.65$). More than half of the children in the younger sample were Caucasian (57%), and the remainder of the sample was either African American (36%) or other ethnicity (7%; mainly Latino/Hispanic). There were 63 girls and 66 boys. Sixty-four percent of the younger sample was recruited from fee-for-service preschools (7 sites) that served primarily middle- to upper middle- income families, and the other 36 percent of the younger sample was recruited from subsidized child-care centers (7 sites), Head Start centers (2 sites), and the local school district’s preschools (5 sites) that served primarily low- to lower middle-income families.

The second group of children consisted of 304 older preschool children who ranged in age from 48 to 71 months ($M = 56.49$, $SD = 5.31$). The majority of the children in the older sample were African American (57%), and the remainder of the sample was either Caucasian (42%) or other ethnicity (1%; Asian and Latino/Hispanic). There were 149 girls and 155 boys. Thirty-nine percent of the older sample was recruited from the fee-for-service preschools, whereas the other 61 percent of the older sample was recruited from the various types of sites serving low- to lower middle-income families. The younger and older samples did not differ in terms of sex, $\chi^2(1, N = 433) = 0.001, p > .97$; however, the older sample was

comprised of more non-Caucasian children than was the younger sample, $\chi^2(2, N = 433) = 19.60, p < .001$, and more children in the older sample were recruited from sites serving lower-income families, $\chi^2(1, N = 433) = 24.36, p < .001$. As expected, the samples differed in terms of mean age, $F(1, 431) = 840.76, p < .001$.

Preschool and Child-care Centers

The preschools and child-care centers were not systematically observed; however, informal observations provided a basis to identify any salient features of these environments. Materials available to children and the activity structure varied between centers. No centers specifically taught children how to read, but many did informally teach basic letter knowledge. The “curricula” generally focused on fostering social and interpersonal skills growth, as well teaching children about letters, numbers, and storybooks. Daily activity schedules were comparable between centers and included free play, story time, and small-group arts and crafts projects. Teacher-directed classroom activities (typically arts and crafts) were incorporated into the daily schedules; however, children primarily spent their time in self-directed activities in and out of the classroom.

Procedures and Measures

After parents provided informed consent for their children to participate, trained research assistants tested children individually in their preschool or child-care centers. Test administration for individual children was conducted over four to six 20-minute sessions within a two- to three-week period to ensure optimal performance on all tasks. Children in both samples completed eight measures of phonological awareness, two measures of phonological memory, three measures of lexical access, two measures of oral language, three measures of nonverbal cognitive abilities, two letter-knowledge measures, and two text-reading measures. The order of test administration varied across children.

Phonological awareness measures—Eight measures were used to assess children’s phonological awareness. Each of the measures included at least two practice trials that were followed by correction, explanation, and readministration if the child gave an incorrect answer, or confirmation and explanation if the child gave the correct answer. Within each measure, all 10 or 11 test trials were administered to all children so that their phonological awareness across all levels of linguistic complexity was assessed. There was no feedback on any of the test trials. All correct responses were real words.

There were two measures of children’s sensitivity to rhyme. *Rhyme Oddity* was patterned after the task developed by MacLean, Bryant, and Bradley (1987), using their word lists. Children were presented with three pictures in a row that were named by the examiner. Children were asked to select the one not rhyming with (or that “did not sound the same as,” or was “different than”) the other two (all three instructions were used for all children). The task consisted of 2 practice trials and 11 test trials. The position of the odd word across trials was randomly determined and was the same for all children. *Rhyme Matching* used the same word list and pictures as the rhyme oddity task. On this task, children were presented with a picture on a small card and had to indicate with which of two additional pictured words it rhymed. The examiner named all three pictures before and during a trial.

Three measures required children to blend sounds to form a new word. *Blending Words* required children to combine single-syllable words to form a compound word. There were two practice items that were presented both verbally and with pictures. For example, the examiner showed the child two pictures and named them (e.g., “This is a cow and this is a boy.”) and then asked the child what word would be produced if he or she said them together (e.g., “What do you get when you say ‘cow’ ... ‘boy’ together?”). During practice

trials, the examiner emphasized the nature of the task by putting the pictures together while presenting the trial. There were 11 test trials that were presented verbally only. *Blending Syllables and Phonemes* required children to combine word elements to form a word. Children were presented with a puppet who “has a hard time saying words right--They come out funny.” The puppet spoke isolated word elements and children were asked to “Tell me what word the puppet is trying to say” (e.g., “What do you get when you say ‘sis’... ‘ter’ together?”). There were 2 practice trials and 10 test trials. *Blending Multiple Choice* also required children to combine word elements to form a word. On this task, however, children were shown three pictures that were labeled by the examiner prior to the puppet’s presentation of the auditory stimuli and children either said or pointed to the picture of the blended word. There were 2 practice items and 10 test trials.

Three measures required children to delete parts of a word to form a new word. *Elision Words* required children to delete a single-syllable word from a compound word. Two practice items were presented both verbally and with pictures. For example, the examiner showed the child two pictures and named them (e.g., “This is a bat, and this is a man.”); the examiner asked the child to say the compound (e.g., “Say, ‘batman’”) and then asked the child to say the word with part of it deleted (e.g., “Say ‘batman’ without saying ‘man.’”). During practice trials, the examiner emphasized the nature of the task by removing the picture of the word to be deleted. The 11 test trials were presented verbally only. *Elision Syllables and Phonemes* required children to say a word minus a specific sound. During the 3 practice trials and 10 test trials, a puppet, who “liked to talk funny” asked children to say a word (e.g., “Say, ‘cookie.’”) and then to say the word with either a syllable or phoneme missing (e.g., “Now say ‘cookie’ without saying ‘eee.’”). *Elision Multiple Choice* also required children to say a word minus a syllable or phoneme. On this task, children were shown three pictures that were labeled by the examiner prior to the puppet’s presentation of the stimuli, and children could say or point to the picture of the elided word. There were 2 practice trials and 10 test trials.

Phonological memory measures—Children completed two tasks designed to assess children's short-term memory for speech sounds. A *Nonword Repetition* task was constructed from phonology that was within the developmental level of the majority of preschool children. These nonwords followed conventional English phonology combination rules and items were made progressively more difficult by increasing numbers of syllables in the nonsense word. There were three items at each level of difficulty. A *Working Memory* task required children to hold phonological information in memory while performing another task. Children had to answer one, two, or three yes/no questions and then state the last word in each question (e.g., Can dogs fly? Are pigs red? Child had to answer yes/no to the questions and then say “fly” and “red”). There were three items at each level of difficulty.

Lexical access measures—Although lexical access tasks typically involve rapid naming of letters or numbers (e.g., McBride-Chang & Manis, 1996), many pre-readers are unable to name letters or numbers. Other tasks sometimes used to assess lexical access in younger children involve rapid naming of colors or shapes; however, these tasks are often too difficult for preschool children. For instance, in their sample of 2,220 English-speaking preschoolers, Anthony, Assel, and Williams (2007) found that nearly 80% of 3-year-olds, 43% of 4-year-olds, and 31% of 5-year-olds could not complete the Rapid Color Naming subtest of the DIAL-3. Consequently, the rapid naming tasks used in this study involved naming serial arrays of common objects with names that do not rhyme (i.e., dog, hat, bird, ball), names that do rhyme (i.e., hat, bat, cat, rat), and small and large circles or squares (child required to say “big” or “little”). For each of these three tasks, the child was shown an array of six rows that had four pictures in each row and were instructed to name the

objects (or size of object) sequentially across the rows as quickly as possible without errors. Time from start to completion was measured and two trials on each stimulus array were administered.

Evidence of validity of measures of phonological processing abilities—

Whereas the measures of phonological processing abilities used in this study have face validity for the construct they are intended to assess, use of these or similar measures with other preschool samples provides evidence for their convergent and discriminant validity. In a sample of 150 preschoolers (M age = 54.5 months, SD = 8.49) who completed phonological awareness, phonological memory, and lexical access measures similar to those used in this study and subtests from the *Comprehensive Test of Phonological Processing* (CTOPP; Wagner, Torgesen, & Rashotte, 1999) as part of a validity study for the *Test of Preschool Early Literacy* (Lonigan, Wagner, Torgesen, & Rashotte, 2007), concurrent correlations for measures of blending (r = .53) and elision (r = .52) with blending and elision subtests from the CTOPP, nonword repetition (r = .24) with the Auditory Memory subtest of the Woodcock-Johnson III (Woodcock, McGrew, & Mather, 2001), and rapid naming of objects (r s = .52 and .56) with two rapid naming subtests of the CTOPP were statistically significant and higher than correlations with other constructs.

In a sample of 100 preschool and kindergarten children (M age = 68.0 months, SD = 11.12) who completed the measures of phonological processing abilities used in this study and the CTOPP 18 to 24 months later, partial correlations (controlling for age at preschool testing) between composite phonological awareness (r = .31), phonological memory (r = .28), and lexical access (r = .31) measures with CTOPP phonological awareness, phonological memory, and lexical access subtest standard scores, respectively, were statistically significant for within construct longitudinal correlations and not significant for between construct longitudinal correlations (average r = .08), and in all but one case (for lexical access with phonological memory), the longitudinal correlations within construct were significantly higher than the longitudinal correlations across constructs.

Oral language and cognitive ability measures—Children completed two standardized tests of oral language. Receptive vocabulary was assessed using the *Peabody Picture Vocabulary Tests--Revised* (PPVT; Dunn & Dunn, 1981). Expressive vocabulary was assessed using the *Expressive One-Word Picture Vocabulary Test--Revised* (EOWPVT-R; Gardner, 1990). Children also completed the Bead Memory, Pattern Analysis, and Copying subtests of the *Stanford-Binet* (4th Ed.; Thorndike, Hagen, & Sattler, 1986) as indices of non-language cognitive abilities.

Print knowledge measures—A *letter-name knowledge* task required children to name 25 upper-case letters that were presented individually on 3 by 5 in. index cards (Due to a clerical error, “W” was not included in the stimulus materials used to test children’s letter-name knowledge.). The letters were presented to all children in the same random order. Testing was discontinued after 5 consecutive errors. A *letter-sound knowledge* task required children to provide the sound made by eight letters (M, B, D, A, C, O, P, S) when they appear in words. The eight letters were printed in uppercase on separate 3 by 5 in. index cards. These stimuli were presented to all children in the same order. If children responded with the letter name or a word that started with the letter (e.g., “dog” for D), then they were prompted to provide the letter sound. Long-vowel sounds were accepted as correct answers for A and O. All children completed the Word Identification subtest of the *Woodcock Reading Mastery Test--Revised* (WRMT-R; Woodcock, 1987). In addition, children were asked to read 25 high frequency words (e.g., “the,” “he,” “cat”). Administration of the Word Identification subtest of the WRMT-R followed standard procedure (i.e., discontinuation

following 6 consecutive errors), whereas all 25 high frequency words were presented to the children.

Results

Descriptive Statistics and Comparison of Younger and Older Samples

Descriptive statistics for the younger and older children on the oral language, cognitive ability, and print knowledge measures are shown in Table 1. For both groups, mean standard scores on the oral language and cognitive ability measures were within the average to low-average range. The younger children received somewhat higher standard scores on the two vocabulary measures and the three subtests of the Stanford-Binet than did the older children. The majority of children in the younger group of children had very limited print knowledge. Almost half (47%) of these children knew no letter names, 92% knew no letter sounds, and 94% could read no words on either the WRMT-R Word Identification or the frequent word reading tests. In contrast, children in the older group of children demonstrated significantly higher levels of print knowledge. Only 16% of these children knew no letter names, and only 63% knew no letter sounds. However, the majority of these children (85%) were nonreaders as evidenced by a score of zero on both the WRMT-R Word Identification (91% with a score of zero) and the frequent word reading tests (87% with a score of zero).

Descriptive statistics for raw scores on the 13 phonological processing measures for younger and older children are shown in Table 2. As indicated in the table, indices of reliability for the phonological processing measures were generally moderate to high. Tasks with a chance component (i.e., rhyme oddity, rhyme matching, multiple-choice blending, multiple-choice elision) had lower reliabilities than the other tasks. There was significant within group variability on all phonological processing variables for both groups of children. As noted in the table, the older children scored significantly higher on all of the phonological awareness, lexical access, and phonological memory measures than did the younger children.

Evaluation of Measurement Models

Theoretically plausible alternative models of children's performance on the phonological processing variables were evaluated using confirmatory factor analysis (CFA) in EQS (Bentler, 1995). We evaluated the fit of models consisting of the possible one-, two-, and three-factor combinations of the phonological awareness, phonological memory, and lexical access groupings of variables. All models included correlated residuals between specific phonological awareness variables to allow for common measurement variance due to the manipulations required by the tasks. These model parameters included correlations between residuals for the two rhyme tasks and correlations between the two multiple-choice tasks. Whereas inclusion of these parameters improved model fits because they accounted for systematic method covariance, they did not alter the structure of the models (i.e., structural results were the same with or without the correlated residuals).

Before conducting the CFAs, all variables were age-standardized within age group by regressing each subtest score onto chronological age to remove variance due to age statistically. CFAs were conducted with these age-corrected raw data using maximum likelihood estimation with the Satorra-Bentler scaled chi-square ($S-B\chi^2$) and adjustments to the standard errors to account for nonnormality in model fit statistics and significance testing (Bentler & Dudgeon, 1996). Inspection of the distributional properties of the different phonological processing variables revealed mild to moderate departures from normality in both younger and older samples on some variables. Because of concerns that even the $S-B\chi^2$ may not yield unbiased tests of model misspecification with non-normal distributions and smaller samples (Curran, West, & Finch, 1996), data points that were significant outliers

were set equal to the highest value of non-outlier cases (Tabachnick & Fidell, 2006). This transformation substantially improved the distribution of the variables (i.e., reducing skew and kurtosis to nonsignificant levels). Although the results of CFA with these transformed data were nearly identical to the results of CFA with untransformed data, indicating that the mild to moderate departures in normality in the untransformed data would have limited impact on the results and conclusions, analyses using the transformed data are reported.

Younger children—Fit indices for the different models for the younger children are shown in the upper panel of Table 3. Both the three-factor model and the two-factor model in which phonological awareness and phonological memory tasks were combined into a single-factor provided good fits to the younger children's data. Chi-square difference tests revealed that the two-factor model with the combined Phonological Awareness/Memory factor did not yield a significantly worse fit to the data than the three-factor model. This result indicates that the correlation between the Phonological Awareness factor and the Phonological Memory factor was not significantly different than 1.0 (i.e., the 2-factor model). In contrast, both other two-factor models and the one-factor model provided significantly worse fits to the data (see upper panel of Table 3). Consequently, the two-factor model in which phonological awareness and phonological memory were combined into a single-factor provided the best fitting and most parsimonious model for the younger children's data. Parameter values for this two-factor model for the younger sample of children are shown in Figure 1. With the exception of the two rhyme measures, all paths between the Phonological Awareness/Memory factor, the Lexical Access factor, and the indicators were significant and accounted for nontrivial amounts of the variance in children's scores on the different phonological processing variables.

Older children—Fit indices for the different models for the older children are shown in the lower panel of Table 3. As with the younger children, both the three-factor model and the two-factor model with a combined Phonological Awareness/Memory factor provided very good fits to the older children's data. Chi-square difference tests revealed that the two-factor model with the combined Phonological Awareness/Memory factor did not yield a significantly worse fit to the data than the three-factor model. This result indicates that the correlation between the Phonological Awareness factor and the Phonological Memory factor was not significantly different than 1.0 (i.e., the 2-factor model). Both remaining two-factor models and the one-factor model provided significantly worse fits to the data (see lower panel of Table 3). Therefore, the two-factor model in which phonological awareness and phonological memory tasks were combined into a single-factor provided the best fitting and most parsimonious model for the older children's data. Parameter values for the best fitting two-factor model for the older children are shown in Figure 2. All paths between the Phonological Awareness/Memory factor, the Lexical Access factor, and the indicators were significant and accounted for nontrivial amounts of the variance in children's scores on the different phonological processing variables.

Model comparison across samples—Because the same two-factor model of phonological processing abilities provided the most parsimonious fit to the data for both younger and older children, multi-sample CFAs were used to examine further the structural equivalence of this model of phonological processing abilities. A multi-sample model with none of the parameters constrained to equality across groups served as the basis for comparing the effects of constraining parameters across groups to equality. A summary of these analyses is shown in Table 4. The unconstrained multi-sample model provided a good fit to the data, confirming that the two-factor model worked well across both age groups. In the hierarchy of invariance constraints, neither constraining the correlation between factors to equality across groups nor constraining the correlations between residuals to equality

across groups resulted in a significant reduction in the fit of the model, χ^2 difference (3, $N = 433$) = 3.16, $p > .10$. However, constraining the factor loadings to equality across groups, χ^2 difference (16, $N = 433$) = 49.14, $p < .001$, and constraining the residuals to equality across groups, χ^2 difference (29, $N = 433$) = 57.27, $p < .001$, resulted in significant reductions in the fit of the model. Releasing the invariance constraints involving the factor loadings for the rhyme oddity and syllable/phoneme elision variables resulted in a model that fit the data as well as the fully unconstrained model, χ^2 difference (27, $N = 433$) = 37.96, $p > .10$. Therefore, whereas the same two-factor model provided a good fit to the structure of the data for both younger and older children, the degree to which performance on the rhyme oddity and syllable/phoneme elision tasks were accounted for by the Phonological Awareness/Memory factor varied between younger and older children.

Relations of Phonological Processing Factors to Vocabulary, Print Knowledge, and Nonverbal Cognitive Ability

Younger children—Correlations between the two phonological processing ability latent variables, measures of vocabulary, measures of print knowledge, and measures of cognitive abilities for the younger children are shown in Table 5. Correlations are based on tabled standard scores or age-regressed standardized scores for observed variables. Because of the near zero variance on the two reading measures, they were not included in these analyses.

As can be noted in the table, there were significant relations between most of the variables. The Phonological Awareness/Memory factor was related at least moderately to oral language, print knowledge, and nonverbal cognitive ability. Overall, the Lexical Access factor was less strongly related to the oral language, print knowledge, and nonverbal cognitive ability measures than was the Phonological Awareness/Memory factor. Differences between correlations for the factors were statistically significant ($p < .01$) for all variables except the EOWPVT and the letter-sound knowledge measure.

Older children—Correlations between the two phonological processing ability latent variables, measures of vocabulary, measures of print knowledge, and measures of cognitive abilities for the older children are shown in Table 6. Correlations are based on tabled standard scores or age-regressed standardized scores for observed variables. As with the younger sample, there were significant relations between most of the variables. The Phonological Awareness/Memory factor was moderately related to print knowledge and nonverbal cognitive ability and strongly related to oral language. The Lexical Access factor was significantly less strongly related to both oral language measures ($p < .001$) and the bead memory subtest of the Stanford-Binet ($p < .01$).

Because of the significant overlap between the Phonological Awareness/Memory factor and the oral language measures, a series of structural models were analyzed to determine the degree of independent reading-related variance in the Phonological Awareness/Memory factor. By itself, the Phonological Awareness/Memory factor accounted for 6% of the variance in WRMT-R word identification scores and 11% of the variance in the frequent word-reading task. Neither PPVT-R scores nor EOWPVT-R scores provided additional variance to the prediction of either reading measure, and both language measures were not significant in either model. Structural models also were used to test the degree of independent reading-related variance in the Phonological Awareness/Memory and Lexical Access factors using the WRMT-R word identification and frequent word reading tasks as dependant variables. The Lexical Access factor did not provide additional variance to either reading measure above that provided by the Phonological Awareness/Memory factor and it was not a significant predictor in either model. Of course, these results are tempered by the fact that only a small percentage of children had non-zero scores on the reading measures.

Discussion

The results of this study indicate that phonological processing abilities in preschool children are best represented as two correlated, yet distinct, factors. One factor includes tasks intended to measure phonological awareness and tasks intended to measure phonological memory, and the second factor includes tasks intended to measure phonological access to lexical store. This two-factor model is consistent with the results reported by Wagner et al. (1987) for 4- and 5-year-old preschool children and by Wagner et al. (1993) for kindergarten children. Our results expand on these earlier findings in at least four ways. First, they show that the same model of phonological processing abilities accounts for children's performance across the entire preschool period (i.e., 2- to 5-year-old children). Second, these results support lexical access as a unique factor for preschoolers. Third, these results confirm the two-factor model of phonological processing skills with a sizable sample, using measures that span the developmental continuum of phonological awareness, which included both synthesis (blending) and analysis (elision) tasks, and using measures of phonological memory that are unlikely to be confounded with other cognitive or knowledge components. Fourth, these results provide evidence for the common and unique correlates of these phonological processing abilities throughout the preschool period.

The extension of the two-factor model of reading-related phonological processing abilities to and across the preschool period, from very young children (2- and 3-year-olds) to older children (4- and 5-year-olds), fills an important gap in current understanding of the development of reading-related skills. Although there have been a number of studies of phonological awareness with preschool populations (e.g., Anthony et al., 2002; Chaney, 1992; Lonigan et al., 1998, 2000; MacLean et al., 1987), there has been only one prior study of English-speaking preschool children that investigated the interrelationship of these reading-related phonological processing abilities in preschool populations, and that study (Wagner et al., 1987) did not include measures of lexical access. This study demonstrated that all three domains of reading-related phonological processing abilities can be measured in preschoolers and have similar connections to each other and to other skills as found with older children (see Anthony et al., 2006, for similar results with Spanish-speaking preschoolers). These results also extend previous work by showing that despite significant development of phonological processing abilities across the preschool years and into kindergarten (i.e., significantly higher scores were found for the older group of children than for the younger group of children), the structure of these skills remains invariant. Given the potentially significant roles of these phonological processing abilities in predicting reading development and in identifying children at risk for reading difficulties, these findings indicate that efforts at understanding the causes and correlates of reading success and failure should be extended to younger children where the developmental origins of these skills can be found.

With a few exceptions, the two-factor model of preschool phonological processing abilities was invariant across younger and older groups of preschool children. The exceptions to model invariance involved the rhyme oddity measure and the syllable/phoneme elision measure. In other studies, we have shown that rhyme measures are among the weakest indicators of phonological processing skills (Anthony & Lonigan, 2004) and, in younger groups, display relatively poor reliabilities (Lonigan et al., 1998). Within a hierarchical model of phonological awareness development across linguistic complexity (Anthony et al., 2003; Fowler, 1991; Lonigan, 2006; Stanovich, 1992), rhyme awareness is a later developing skill and is dependent on the ability to segment the syllable into smaller parts (i.e., the onset and rime). Most tasks designed to assess children's rhyme awareness involve oddity or matching tasks on which the chance element is between .25 and .33. Because of younger children's relatively low levels of phonological awareness skills, this high level of

chance correct responding often masks younger children's true abilities. Consequently, the tasks are often unreliable. This lower reliability likely explains why the models differed between younger and older children for this variable. A possible explanation for differences in models between younger and older children for the syllable/phoneme elision variable is that this was the one phonological processing ability variable on which younger children scored at near floor levels.

The relations between the phonological processing abilities factors and measures of other skills provide evidence both for the co-occurring development of other important reading-related skills during the preschool years and for the specificity of phonological processing abilities to reading. For both younger and older children, the Phonological Awareness/Memory factor was associated with children's oral language skills, print knowledge, and cognitive abilities. The relationship between the Phonological Awareness/Memory factor and oral language skills was particularly strong in the older sample, suggesting common developmental origins of these skills. Despite the interrelations between these skills, however, analyses indicated that the Phonological Awareness/Memory factor was more related to early reading skills than was the Lexical Access factor, and the Phonological Awareness/Memory factor was uniquely associated with early reading skills. That is, despite high correlations between the Phonological Awareness/Memory factor and oral language skills, oral language skills did not contribute unique variance to the prediction of early reading skills but the Phonological Awareness/Memory factor did. Whereas these findings should be interpreted cautiously, given that only about 15% of the older sample of children could read any words, they do imply that what is measured by the Phonological Awareness/Memory factor is a specific reading-related skill. Similar to other studies (e.g., Anthony et al., 2006; Bryant et al., 1990; Lonigan et al., 2000; Storch & Whitehurst, 2002), these results highlight the early importance of phonological processing abilities for the development of reading skills.

Prior studies of younger children's phonological processing abilities have used some measures that have questionable content for the construct they were intended to measure. The use of letter recall, articulation rate, and picture recall tasks by Wagner et al. (1987) opens their results to alternative interpretations. For example, a letter recall task may confound phonological memory and letter-name knowledge. Because letter-name knowledge is a significant concurrent and longitudinal correlate of phonological awareness in general (Burgess & Lonigan, 1998; Lonigan et al., 2000) and higher levels of phonological awareness specifically (Johnston, Anderson, & Holligan, 1996; Stahl & Murray, 1994), this confound makes it more likely that such a measure would be associated with measures of phonological awareness. The results of this study rule out this explanation for the overlap between phonological memory and phonological awareness in younger children. In this study, only more typical measures of phonological memory were used (Chiappe, Glasner, & Ferko, 2007; McBride-Chang, 1995; Swanson & Jerman, 2007). Consequently, the fact that a single factor accounted for measures of phonological memory and measures of phonological awareness was unlikely to be the result of confounding of the constructs or their correlates in the measures.

There are at least three possible explanations for the fact that phonological awareness and phonological memory do not emerge as distinct underlying reading-related abilities in younger children. The first explanation would be that something about becoming a skilled reader results in a differentiation of phonological memory and phonological awareness. That is, given the bi-directional influences between phonological awareness and reading (e.g., Wagner et al., 1997), becoming a skilled reader significantly potentiates phonemic awareness and perhaps it is only phonemic awareness that is distinct from phonological memory. This explanation appears unlikely because (a) the majority of the phonological

awareness tasks used by Wagner et al. (1993) were phoneme-level tasks, (b) the phonological awareness tasks in this study included phoneme-level items, (c) most analyses show that phoneme-level and subphoneme-level tasks reflect the same underlying dimension (e.g., Anthony & Lonigan, 2004; Lonigan, 2006), and (d) both phoneme- and subphoneme-level tasks are predictive of later reading (e.g., Lonigan et al., 2000).

The second explanation is that phonological awareness tasks are actually auditory memory measures. Although there are undoubtedly memory demands on phonological awareness tasks (e.g., children must maintain an active representation of an orally presented stimulus while performing an operation on it), such auditory memory demands were lessened, albeit not eliminated, in this study by including tasks where some or all of the stimulus elements were represented by pictures. Particularly for the older children, there were not remarkable differences in task relations with the factor for measures that used pictures and measures that did not. As noted by Wagner et al. (1993), their finding that phonological memory was distinguishable from phonological awareness synthesis tasks (i.e., blending) weakens, but does not rule out, the memory argument. However, further investigation of this possibility is needed.

The final possible explanation for the lack of distinction between measures of phonological awareness and measures of phonological memory in younger children is that both types of tasks are dependent on the quality of underlying phonological representations. That is, incomplete, inaccurate, or degraded lexical or phonological representations of language-related units will impair the ability to maintain accurate phonological representations in short-term memory and limit children's ability to develop linguistic knowledge about words, which is required to perform the operations required by phonological awareness tasks (e.g., Elbro, 1996). A related but alternative account was proposed by Metsala and Walley (1998) in their Lexical Restructuring Model (LRM). In this model, it is hypothesized that a move from holistic to segmental lexical structure and a sharpening of these lexical representations is based on vocabulary growth. In this explanation, neither phonological awareness nor phonological memory tasks can be completed if a robust representation cannot be accessed (awareness) or created (memory).

In this study, the strong concurrent association between measures of oral language and the Phonological Awareness/Memory factor was consistent with the LRM. Similarly, vocabulary size has been associated with phonological short-term memory (Gathercole, Hitch, Service, & Martin, 1997), and Metsala (1997) reported that vocabulary, phonological awareness, and nonword repetition were moderately interrelated in samples of preschool children. Another domain that may reflect underlying phonological representations concerns the quality of children's speech output. Studies that have examined quality of speech output have indicated that children with speech-sound inaccuracies performed poorly on measures of word-level reading tasks (e.g., Larrivee & Catts, 1999; Rvachew, Ohberb, Grawburg, & Heyding, 2003) and that severity of speech sound inaccuracies played a role in predicting reading skills (e.g., Larrivee & Catts, 1999; Nathan, Stackhouse, Goulondris, & Snowling, 2004). In a recent study examining the phonological distinctness versus LRM hypotheses, McDowell, Lonigan, and Goldstein (2007) found that scores on a measure of speech-sound accuracy (i.e., expressive phonology) were related to scores both on measures of phonological awareness ($r = .65$) and measures of vocabulary ($r = .63$), and scores on vocabulary measures were related to scores on measures of phonological awareness ($r = .80$). Longitudinal and experimental studies are required to distinguish between the causal pathways between lexical representations and the development of or performance on phonological awareness, phonological memory, and vocabulary tasks.

One potential limitation to this study is that the evidence of invariance of the nature of phonological processing abilities was obtained using cross-sectional data. Although longitudinal data on the same group of children as they transitioned from the early to the late preschool period and beyond would strengthen these conclusions, it is unlikely that there was something unique to the samples studied (e.g., scores on measures, SES, preschool settings from which the children were drawn) or to the measures used that generated these findings, given that results were largely invariant across the younger and older groups and the same measures were used with both groups. Indeed, invariance across the samples in this study, despite some differences between the samples, suggests that the invariance is robust. A second limitation of the results of this study concerns the small number of children who were able to read any of the words on the two reading measures. Whereas the results do speak to the development of phonological processing abilities in nonreaders, they do not allow investigation of the relations between these skills and the full-range of word reading ability. Regardless, the finding that scores on the Phonological Awareness/Memory factor was correlated uniquely with scores on the reading measures suggest that phonological awareness/memory is a specific reading-related skill. Given that the development of reading is an age-linked developmental and educational phenomenon and not a population-linked phenomenon, however, longitudinal studies (e.g., Lonigan et al., 2000) will be required to address fully this question. Finally, as noted previously, children in the older sample were more likely to be drawn from sites serving lower income families than were the children in the younger sample. Although we did not collect more precise data about the socioeconomic status of each child's family in this study, the results indicate that the nature of phonological processing abilities were invariant to this factor. However, future studies that gather more extensive family background information are needed to explore fully possible interactions between age, family characteristics, and type of preschool experience with respect to the development of phonological processing abilities.

In summary, the results of this study extend previous work that has investigated the structure of phonological processing abilities in young children by demonstrating that the phonological processing abilities of English-speaking preschoolers are best characterized as two sets of interrelated abilities: phonological awareness/memory and lexical access. These findings were consistent across the range of ages of children included in this study, 2- to 5-year-old children. Both of these abilities were associated with abilities in other language and reading-related skills, particularly vocabulary size; however, there was also evidence that phonological awareness/memory was uniquely related to early reading. These results demonstrate the early developmental importance of phonological processing abilities for reading and imply that there may be a substantial role for early screening and intervention. Whereas the origins of these reading-related phonological processing abilities are not well understood, connections between phonological awareness/memory and vocabulary development offer an intriguing possibility for at least one potential condition necessary for the establishment of phonological awareness/memory. Ultimately, longitudinal studies and, where possible, intervention studies will be needed to explicate fully the causal links between these two early emerging abilities and later reading skills.

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Figure 1.

Two-factor model of the structure of phonological processing abilities in younger preschool children (2- and 3-year-olds). Circles represent latent variables and rectangles represent observed variables. All values represent standardized coefficients. All factor loadings shown as solid lines are significant at $p < .001$ unless otherwise noted. $N = 129$. * $p < .05$.

Figure 2.

Two-factor model of the structure of phonological processing abilities in older preschool children (4- and 5-year-olds). Circles represent latent variables and rectangles represent observed variables. All values represent standardized coefficients. All factor loadings shown as solid lines are significant at $p < .001$ unless otherwise noted. $N = 304$. ** $p < .01$.

Table 1

Descriptive Statistics for Younger (2- and 3-year-olds) and Older (4- and 5-year-olds) Samples of Preschool Children on Measures of Oral Language, Cognitive Abilities, and Print Knowledge

Measure	Sample				F for Group Contrast
	Younger Children		Older Children		
	Mean	(SD)	Mean	(SD)	
Oral Language					
PPVT-R Standard Score	91.16	(18.53)	84.54	(20.76)	9.83**
EOWPVT-R Standard Score	94.84	(15.54)	90.69	(18.54)	4.99*
Cognitive Ability					
Binet Copying Standard Score	46.16	(6.32)	41.54	(6.77)	43.96***
Binet Bead Memory Standard Score	49.09	(6.36)	44.98	(6.81)	34.34***
Binet Pattern Analysis Standard Score	48.16	(5.86)	43.90	(6.66)	39.80***
Print Knowledge					
Letter-name Knowledge	4.31	(7.00)	11.79	(9.93)	60.37***
Letter-Sound Knowledge	0.19	(0.84)	1.43	(2.42)	31.80***
Word Reading (WRMT-R)	0.00	(0.00)	0.74	(4.02)	4.36*
Word Reading (Frequent Words)	0.07	(0.28)	0.41	(1.63)	5.71*

Note. $n = 129$ for younger group; $n = 304$ for older group. PPVT-R = *Peabody Picture Vocabulary Test - Revised*; EOWPVT-R = *Expressive One-Word Picture Vocabulary Test - Revised*; Binet = *Stanford-Binet IV*; WRMT-R = *Woodcock Reading Mastery Test - Revised*. F for group contrast with 1, 431 df.

* $p < .05$;

** $p < .01$;

*** $p < .001$.

Table 2

Descriptive Statistics for Younger (2- and 3-year-olds) and Older (4- and 5-year-olds) Samples of Preschool Children on Measures of Phonological Processing Abilities

Measure	Sample					F for Group Contrast
	Younger Children		Older Children			
	Mean	(SD)	Mean	(SD)		
Phonological Awareness Tasks						
Rhyme Oddity	.54	4.22	(1.60)	5.13	(2.49)	14.53***
Rhyme Matching	.64	5.67	(1.95)	7.17	(2.53)	36.08***
Word Blending	.93	2.30	(2.86)	5.06	(4.16)	47.12***
Syllable & Phoneme Blending	.81	1.30	(1.63)	2.75	(2.32)	42.55***
Multiple-Choice Blending	.73	6.32	(2.33)	8.27	(1.94)	80.67***
Word Elision	.94	1.14	(2.33)	3.86	(4.16)	48.56***
Syllable & Phoneme Elision	.86	0.42	(1.15)	1.70	(2.39)	33.86***
Multiple-Choice Elision	.45	4.67	(2.07)	5.44	(1.81)	15.15***
Lexical Access Tasks						
RON NonRhyming Words	.85	68.41	(31.52)	48.07	(15.47)	80.85***
RON Rhyming Words	.82	85.05	(35.51)	57.24	(24.95)	86.22***
RON Size Naming	.84	64.53	(28.28)	41.48	(16.44)	112.60***
Phonological Memory Tasks						
Working Memory	.87 ^a	5.36	(4.52)	10.70	(6.86)	66.05***
NonWord Repetition	.88 ^a	11.02	(5.09)	14.77	(6.22)	36.53***

Note. *n* = 129 for younger sample; *n* = 304 for older sample. *F* for group contrast with 1, 431 *df*.

^a A ceiling criterion was used on these tasks; reliability was computed assuming that items above the ceiling were answered incorrectly. Reliabilities for RON (Rapid Object Naming) tasks are immediate test-retest correlations.

p < .001

Table 3

Robust Fit Indices for Models of the Structure of Phonological Processing Abilities in Younger and Older Preschool Children

Model	S-B χ^2	df	RCFI	TLI	RMSEA	AIC	χ^2 Difference ¹
<i>Younger Children (2- and 3-year-olds)</i>							
3-Factor	78.83	60	.89	.85	.05	-41.17	----
2-Factor (PS + MEM, RON)	79.71	62	.89	.87	.05	-44.29	0.85 ^{ns}
2-Factor (PS, MEM + RON)	85.64 [*]	62	.86	.82	.06	-38.37	6.40 [*]
2-Factor (PS + RON, MEM)	108.53 ^{***}	62	.72	.65	.08	-15.47	23.00 ^{***}
1-Factor	109.15 ^{***}	63	.72	.65	.08	-18.85	25.17 ^{***}
<i>Older Children (4- and 5 year olds)</i>							
3-Factor	96.07 ^{**}	60	.96	.95	.05	-23.93	----
2-Factor (PS + MEM, RON)	101.27 ^{**}	62	.96	.95	.05	-22.73	5.26 ^{ns}
2-Factor (PS, MEM + RON)	135.31 ^{***}	62	.92	.90	.06	11.31	32.67 ^{***}
2-Factor (PS + RON, MEM)	197.73 ^{***}	62	.85	.81	.09	73.73	52.49 ^{***}
1-Factor	200.91 ^{***}	63	.85	.81	.09	74.90	65.75 ^{***}

Note. $n = 129$ for younger children; $n = 304$ for older children. RCFI = Robust Comparative Fit Index; TLI = Tucker-Lewis Index; RMSEA = Root Mean Square Error of Approximation; AIC = Akaike Information Criterion.

¹ χ^2 difference tests involve comparisons to three-factor model and were computed using the procedure outlined by Satorra and Bentler (2001). PS = Phonological Awareness; MEM = Phonological Memory; RON = Rapid Object Naming.

^{ns} $p > .05$;

^{*} $p < .05$;

^{***} $p < .001$.

Table 4

Robust Fit Indexes for Multisample Tests of Structural Equivalence for Two-Factor Model of Phonological Processing Abilities in Younger (2- and 3-year-old) and Older (4- and 5-year-old) Preschool Children

Constraints	S-B χ^2	df	RCFI	TLI	RMSEA	AIC	χ^2 difference ¹
None	180.42 ***	124	.95	.93	.05	-67.58	----
Factor Intercorrelation	180.97 ***	125	.95	.93	.05	-69.03	0.24 ^{ns} , df = 1
Factor Intercorrelation & Residual Correlations	183.32 ***	127	.95	.93	.05	-70.68	2.52 ^{ns} , df = 2
Factor Intercorrelation, Residual Correlations, & Factor Loadings	230.45 ***	140	.91	.90	.06	-49.55	47.39 *** , df = 13
Factor Intercorrelation, Residual Correlations, Factor Loadings, & Residuals	242.53 ***	153	.92	.91	.05	-63.47	16.11 ^{ns} , df = 13

Note. $n = 129$ for younger children; $n = 304$ for older children. CFI = Comparative Fit Index; TLI = Tucker-Lewis Index; RMSEA = Root Mean Square Error of Approximation; AIC = Akaike Information Criterion.

¹ χ^2 difference test represents comparison to previous model and were computed using the procedure outlined by Satorra and Bentler (2001).

ns $p > .05$;
 * $p < .05$;
 *** $p < .001$.

Table 5

Correlations between Phonological Processing Factors and Measures of Oral Language, Print Knowledge, and Cognitive Abilities for Younger Sample of Preschool Children

Factor/Variable	Factor/Variable								
	1	2	3	4	5	6	7	8	9
1. Phonological Awareness/Memory	---								
2. Lexical Access	-.49***	---							
3. PPVT-R	.59***	-.39***	---						
4. EOWPVT-R	.44***	-.36***	.72***	---					
5. Letter-Name Knowledge	.58***	-.36***	.32***	.33***	---				
6. Letter-Sound Knowledge	.34***	-.07	.16	.14	.44***	---			
7. Binet Bead Memory	.44***	-.15	.44***	.37***	.17	.09	---		
8. Binet Copying	.54***	-.35***	.37***	.37***	.27**	.11	.26**	---	
9. Binet Pattern Analysis	.26 ^a	-.23*	.39***	.43***	.27**	.05	.33***	.26**	---

Note. $N = 129$. Correlations between the Lexical Access factor and other measures are negative because the score on the measure is the time to complete the naming tasks. PPVT-R = *Peabody Picture Vocabulary Test - Revised*; EOWPVT-R = *Expressive One-Word Picture Vocabulary Test - Revised*; Binet = *Stanford-Binet 4th Ed.*

**
 $p < .01$;

 $p < .001$.

Table 6

Correlations between Phonological Processing Factors and Measures of Oral Language, Print Knowledge, and Cognitive Abilities for Older Sample of Preschool Children

Factor or Variable	Factor/Variable										
	1	2	3	4	5	6	7	8	9	10	11
1. Phonological Awareness/Memory	---										
2. Lexical Access	-.55***	---									
3. PPVT-R	.74***	-.41***	---								
4. EOWPVT-R	.73***	-.40***	.74***	---							
5. Letter Name Knowledge	.49***	-.54***	.36***	.30***	---						
6. Letter-Sound Knowledge	.53***	-.38***	.38***	.33***	.55***	---					
7. WRM-R Word ID	.24***	-.20**	.17**	.17**	.20***	.36***	---				
8. Frequent Words	.31***	-.26***	.21***	.20***	.28***	.41***	.93***	---			
9. Binet Bead Memory	.31***	-.31*	.33***	.21***	.25**	.22**	.16**	.20***	---		
10. Binet Copying	.36	-.25	.37***	.34***	.21***	.19**	.17**	.20***	.22***	---	
11. Binet Pattern Analysis	.31*	-.34*	.36***	.27***	.21***	.18**	.21***	.19***	.32***	.32***	---

Note. $N = 304$. Correlations between the Lexical Access factor and other measures are negative because the score on the measure is the time to complete the naming tasks. PPVT-R = *Peabody Picture Vocabulary Test - Revised*; EOWPVT-R = *Expressive One-Word Picture Vocabulary Test - Revised*; WRM-R = *Woodcock Reading Mastery Test - Revised*; Word Identification subtest; Binet = Stanford-Binet 4th Ed.

* $p < .05$;

** $p < .01$;

*** $p < .001$.