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Modeling Phonological Processing for Children with Mild Intellectual Disabilities: The Relationship between Underlying Phonological Abilities and Associated Language Variables

Robert Michael Barker
Georgia State University

MODELING PHONOLOGICAL PROCESSING FOR CHILDREN WITH MILD INTELLECTUAL DISABILITIES: THE RELATIONSHIP BETWEEN UNDERLYING PHONOLOGICAL ABILITIES AND ASSOCIATED LANGUAGE VARIABLES

by

R. MICHAEL BARKER

Under the Direction of Rose A. Sevcik

ABSTRACT

The structure of phonological processing for typically developing children has been debated over the past two decades. Recent research has indicated that phonological processing is best explained by a single underlying phonological ability (e.g., Anthony and Lonigan, 2004). The current study had two goals. The first goal was to determine the structure of phonological processing for school-age children with mild intellectual disabilities (MID). The second goal was to determine the relationship between the components of phonological processing and expressive and receptive language ability. The participants were 222 school-age children identified by their schools as having MID. Confirmatory factor analysis was utilized to determine the structure of phonological processing. The results indicated that a model with one phonological awareness factor and one naming speed factor explained the data better than competing models with a single latent factor or more than two latent factors. There was a

negative significant relationship between phonological processing and naming speed. There were positive bivariate relationships between phonological processing and expressive and receptive language. There were negative bivariate relationships between naming speed and expressive and receptive language. These results are consistent with other research findings with typically developing children, indicating a similarity in the relationships between phonological process and language for children with MID. Theoretical and instructional implications are discussed.

INDEX WORDS: Phonological processing, Phonological awareness, Naming speed, Expressive language, Receptive language, Mild intellectual disability

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R. MICHAEL BARKER

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by

R. MICHAEL BARKER

Committee Chair: Rose A. Sevcik

Committee: MaryAnn Romski

Robin D. Morris

Christopher C. Henrich

Electronic Version Approved:

Office of Graduate Studies

College of Arts and Sciences

Georgia State University

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DEDICATION

I would like to dedicate this document to my family. Each and every one of you has impacted my life in different and important ways. Without your influences, I certainly would not be in the position I am in today. Thank you to you all!

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Introduction

Importance of Reading

The importance of adequate literacy skills in modern day society cannot be understated. For many, having minimum literacy proficiency is an important factor in determining job placement, medical health, and overall quality of life. This is true both for typically developing individuals (Baer, Kutner, & Sabatini, 2009) and for individuals with intellectual disabilities (Erickson, 2005). The 2003 National Assessment of Adult Literacy (NAAL; Baer et al., 2009; Kutner et al., 2007) demonstrated that at least 50% of individuals with below basic literacy skills were unemployed or not in the labor force. Conversely, approximately two thirds of individuals with proficient literacy were employed full time. Furthermore, those with the highest literacy scores (measured as prose, document, and quantitative literacy skills) were more likely to be in professional jobs compared to those with the lowest literacy skills. Other studies have demonstrated that poor literacy skills are related to difficulty interpreting written and spoken medical information (Erickson, 2005; Gazmararian et al., 1999). In another report from the NAAL, of those who reported having poor health, approximately 42% had below basic health literacy; only 3% had proficient health literacy. Conversely, of those who reported having excellent health, approximately 8% of individuals demonstrated below basic health literacy and 76% had intermediate or proficient health literacy (Kutner, Greenberg, Jin, & Paulsen, 2006). Furthermore, literacy skills have been linked to better social relationships (Erickson, 2005) and perceptions of higher competency by peers (Erickson, Koppenhaver, & Yoder, 1994) for individuals with intellectual disabilities.

For individuals with intellectual disabilities, however, even the most basic levels of literacy are often difficult to achieve. The reading abilities of children with intellectual

disabilities often lag behind their peers (Gronna, Jenkins, & Chin-Chance, 1998). In a school based study of children's performance on standardized assessments, results indicated that students with mild intellectual disabilities consistently scored lower than their typically developing counterparts (Gronna et al., 1998). Additionally, the performance gap between the typically developing students and students with mild intellectual disabilities closed more slowly as children got older. In other words, the study demonstrated that as students aged, their academic performance gains slowed considerably compared to typically developing students (Gronna et al., 1998). Other research has demonstrated that the reading achievement of individuals with intellectual disability often lags behind their own mental ages (Cawley & Parmar, 1995). Furthermore, emerging evidence indicates that the reading difficulties experienced by individuals with intellectual disabilities may be due, in part, to deficits in phonological processing and awareness (Cawley & Parmar, 1995; Conners, Atwell, Rosenquist, & Sligh, 2001; Conners, Rosenquist, Sligh, Atwell, & Kiser, 2006; Cossu, Rossini, & Marshall, 1993; Cupples & Iacono, 2000, 2002; Peeters, Verhoeven, van Balkom, & de Moor, 2008; Saunders & DeFulio, 2007; Verhoeven & Vermeer, 2006; Verucci, Menghini, & Vicari, 2006). Phonological processing is believed to be one of the core deficits for individuals with typical intelligence who have difficulty learning to read (Wagner & Torgesen, 1987).

The purpose of the current investigation is to construct a model of phonological processing for children with mild intellectual disabilities. This model will demonstrate two important aspects of phonological processing. First, it will determine the structure of phonological processing for children with intellectual disabilities by testing nested models of its structure. Second, the model will determine the relationship between important language variables and the components of phonological processing.

How Do Children Learn to Read?

Reading is a set of skills that allows individuals to extract linguistic meaning from orthographic representations of speech (Adams, 1990; Perfetti, 1985; Whitehurst & Lonigan, 1998). Consequently, successful reading is contingent on the integration of many different linguistic skills, and is thus largely a linguistic process (Liberman & Shankweiler, 1991). Investigations into the characteristics of individuals who have difficulty reading and those who are skilled readers have yielded a number of variables that are associated with successful reading (Adams, 1990). Unskilled readers (e.g., those with a developmental reading disability, "garden variety" poor readers, or beginning readers) may have significant difficulty with phonological awareness (Adams, 1990), may demonstrate slow naming speeds, or may have a combination of both (Wolf, 1991). Furthermore, additional problems with restricted vocabulary may contribute to problems with fluency and comprehension (Perfetti, 1985, 2007). Conversely, skilled readers have been described has being able to quickly and easily identify letters from their constituent parts, have strong connections between the letters and the sounds they represent, quickly identify the meaning of unfamiliar words in connected text, and make sophisticated guesses as to the meaning of words that may be presented as a degraded visual stimulus (Adams, 1990; Stanovich, 1991; Wagner, Torgesen, & Rashotte, 1994).

Broadly, children proceed through two stages when learning to read (Adams, 1990; Byrne, 1992; Gough, Juel, & Griffith, 1992). In the first stage, beginning readers learn to pair written words with the meanings of those words using the physical characteristics of the written word as a cue. For example, children may pair the written word "cat" with its spoken form based on the curved form of the initial letter or the tall letter at the end. This strategy works well for the first few words learned, but quickly becomes insufficient to discriminate all of the words a child

must learn to become a proficient reader. This strategy for reading must ultimately be discarded because it is not generative in nature (i.e., it cannot be used to recognize new and unfamiliar words; Chall, 1996; Stanovich, 1991). Because this strategy becomes untenable as they begin to learn greater numbers of words, children must learn a new strategy for reading words.

Beginning readers employ this new strategy by exploiting the alphabetic principle to exhaustively decode printed words. The alphabetic principle describes the fact that speech sounds are encoded by the orthography of alphabetic languages. Children learn the relationships between letters and the sounds they represent and use this knowledge as a powerful tool to decode a wide array of new and unique words (Adams, 1990; Byrne, 1992; Gough et al., 1992; Hulme, Snowling, Caravolas, & Carroll, 2005; Stanovich, 1991). When decoding a word, printed text activates phonological representations for the reader (Perfetti, 1985, 2007). The reader combines these phonological representations to form a spoken word, whether reading aloud, or silently (Perfetti, 1985). It is from the spoken word that the reader derives meaning from the text. Consequently, for the beginning reader, spoken language is a mediating variable in the extraction of meaning from text (Gough et al., 1992; Liberman & Shankweiler, 1991; Perfetti, 1991).

Learning to decode, however, is much more complex than the previous description may suggest. In fact, it has been described as an “unnatural act” that requires significant intervention on the part of teachers and parents for children to learn the process (Adams, 1990; Gillion, 2004; Gough & Hillinger, 1980; Stanovich, 1991). For instance, in order to begin decoding, a child must have certain understandings about text, speech, and the relationship between the two. First, the child must have the explicit understanding that the printed word is a representation of a spoken word. This understanding is one that must be taught explicitly through early literacy

experiences (Byrne, 1992; Gillion, 2004; Gough & Hillinger, 1980; Hulme et al., 2005; Whitehurst & Lonigan, 1998). Second, the child must have knowledge of letters. The child must have explicit knowledge of the shape and form of letters, their names, and the sounds they represent. Furthermore, he or she must take note of the orientation of letters on a page (e.g., to discriminate b from d; Gough & Hillinger, 1980; Hulme et al., 2005). Third, the child must develop an explicit understanding that spoken words are composed of phonemes (i.e., phonological awareness; Adams, 1990; Byrne, 1992; Gough et al., 1992; Stanovich, 1991; Wagner & Torgesen, 1987). This metalinguistic understanding has been described as one of the strongest predictors of learning to read (Morris et al., 1998; Verucci et al., 2006; Wagner & Torgesen, 1987; Wagner et al., 1994). And fourth, the beginning reader must have sufficient experience with attempting to decode; without sufficient opportunities, learning the meaning from printed text may be an impossible task (Adams, 1990; Gough et al., 1992; Whitehurst & Lonigan, 1998). Furthermore, the more experience a child has with decoding, the better he or she learns the rules underlying the decoding process, thus facilitating more efficient decoding.

Additional research has identified and described later stages in the development of reading. Specifically, as children become more proficient decoders, they can begin to use the context of a sentence to predict the meaning of a word (Perfetti, 1985, 1991; Stanovich, 1991; Whitehurst & Lonigan, 1998). Stanovich (1991) referred to this stage or process as top-down reading. Top-down reading strategies utilize information about the context of a sentence to infer the meaning of the word being read. Similarly, Perfetti (1985, 1991) states that using context to predict word meaning is central to the restrictive component of his Restricted-Interactive Model. Perfetti elaborates on this restricted component by stating that although the context of a sentence can confirm the meaning of a word, the meaning of a word can only come from the decoding

process. In other words, when a skilled reader encounters a word that may have an ambiguous meaning (e.g., bug = insect or bug = electronic listening device) both meanings of the word are simultaneously activated when the reader decodes the word (Adams, 1990). It is the context of the other words in the sentence that serve to restrict the meaning of the ambiguous word to one of its possible meanings.

Characteristics Common to Successful Beginning Readers

Phonological Processing

Phonological processing, as mentioned previously, is the ability to reflect on and manipulate the phonemic segments of speech (Gillion, 2004; Saunders & DeFulio, 2007; Tunmer, 1991; Wagner & Torgesen, 1987). It involves conscious access to the phonemic level of the speech stream and the ability to cognitively manipulate speech sounds (Gillion, 2004; Stanovich, 1986). Children's awareness of phonemes may be indicated by many different tasks, including manipulation tasks, segmentation tasks, and blending tasks (Adams, 1990; Gillion, 2004). Furthermore, different tasks have different loadings on working memory. For example, a deletion task, such as elision, determines a child's ability to delete a phoneme or set of phonemes from a word, recombine the remaining phonemes, and speak the new word (Gillion, 2004). Segmentation tasks determine a child's ability to individually speak the phonemes that form a target word while blending tasks determine a child's ability to take individual phonemes presented in sequence and combine them to form a word.

Many studies have indicated that successful beginning readers have strong phonological awareness. This is true for typically developing children (Adams, 1990; Catts, Gillispie, Leonard, Kail, & Miller, 2002; Muter, Hulme, Snowling, & Stevenson, 2004; Perfetti, Beck, Ball, & Hughes, 1987; Tunmer, 1991; Wagner & Torgesen, 1987; Wagner et al., 1994;

Whitehurst & Lonigan, 1998) and children with disabilities (Bird, Bishop, & Freeman, 1995; Blischak, Shah, Lombardino, & Chiarella, 2004; Morris et al., 1998; Saunders & DeFulio, 2007). For instance, in a longitudinal study of 244 students followed from kindergarten through second grade, Wagner, Torgesen, and Rashotte (1994) concluded that broader phonological processing abilities in kindergarten had a causal influence on decoding abilities in second grade. Additionally, in a study of 279 children assessed from kindergarten through fourth grade, Catts and colleagues (2002) obtained similar results. They demonstrated that students determined to be poor readers (i.e., children who scored at least 1 standard deviation below the mean on a measure of reading comprehension in second and fourth grade) scored significantly lower on measures of phonological awareness than children who were typical readers (i.e., children who were ± 1 standard deviation from the mean) and children who were good readers (i.e, children who scored greater than 1 standard deviation above the mean for reading comprehension). Likewise, children who were good readers had significantly higher scores on measures of phonological awareness than children who were typical readers.

Naming Speed

Another characteristic of successful beginning readers is the ability to rapidly name items presented serially. Naming speed describes an individual's ability to rapidly name serially presented visual symbols and stimuli (e.g., letters, numbers, colors, and simple objects; Wolf, Bowers, & Biddle, 2000). Naming speed tasks are generally simpler than phonological awareness tasks (Wolf, Bowers et al., 2000). They take only a few minutes to administer and require the participant to name a list of items in an array. For example, the Comprehensive Test of Phonological Processing (CTOPP; Wagner, Torgesen, & Rashotte, 1999) contains four subscales that measure naming speed: rapid letter naming, rapid color naming, rapid digit

naming, and rapid object naming. The stimuli for rapid letter naming consists of a 9 x 4 character array containing the letters a, t, s, k, c, and n. The participant is asked to verbalize the name of each of the letters in the array from left to right and top to bottom, in a manner consistent with English reading. The participant's time to speak the names of all of the letters in the array is the outcome measure for the task.

A growing literature investigating the relationship between naming speed and reading has indicated a strong relationship between the two (e.g., Denckla & Rudel, 1976; Katzir et al., 2006; Lovett, Steinbach, & Frijters, 2000; Manis, Doi, & Bhadha, 2000). For example, in one of the earliest demonstrations of this relationship, Denckla and Rudel (1976) determined that individuals diagnosed with dyslexia scored significantly higher on the four different types of naming speed tasks mentioned previously. Specifically, they compared the naming speed of 120 participants who were typical readers to that of 128 readers with dyslexia. Readers with dyslexia demonstrated higher naming speeds, compared to typical readers, regardless of age. Furthermore, this difference could not be explained by signs of brain damage or from IQ differences (Denckla & Rudel, 1976).

More recent research has confirmed and extended these findings (Katzir et al., 2006; Lovett et al., 2000; Manis et al., 2000; Morris et al., 1998). For example, in a study investigating the relationship between naming speed, orthographic knowledge and phonological awareness on reading outcomes for 85 second graders, Manis and colleagues (2000) concluded that naming speed tasks accounted for between 5% and 28% of unique variance in a variety of reading measures (e.g., word attack, word identification, comprehension, orthographic choice). Furthermore, Lovett and colleagues (2000) demonstrated that individuals with higher naming speed latencies and difficulties in the phonological awareness domain were more globally

impaired in terms of reading outcomes than individuals with difficulties in only one area. This phenomenon is a demonstration of the double deficit hypotheses of dyslexia and is reviewed extensively in Wolf, Bowers, and Biddle (2000).

Naming speed tasks are related to reading because of their similarity to the reading process (Wolf & Bowers, 2000; Wolf, Bowers et al., 2000). Naming speed tasks involve attentional, perceptual, conceptual, memory, lexical and articulatory processes that are also involved in reading. For example, when a participant approaches an array in a rapid letter naming task, he or she must attend to the stimuli, perceive the letter, associate the printed letter with a conceptual category for the letter, recall the lexical entity associated with the category (i.e., the name of the letter), and articulate the name of the letter. Furthermore, the participant must do this for each of the items in the array. Consequently, for individuals who do not have difficulties with visual perception or articulation, naming speed tasks may indicate the strength and quality of mental representations associated with the stimuli (Wolf & Bowers, 2000). Thus, slower speeds on naming speed tasks may indicate that the connections between orthographic representations, phonological representations, and lexical representations, or the representations themselves, are of diminished quality (Wolf, Bowers et al., 2000), the quality of which is important for successful reading (Adams, 1990; Perfetti, 1985, 1991).

Orthographic and Letter Knowledge

Successful beginning readers also have been found to possess high levels of knowledge about print, generally, and letters, specifically (Adams, 1990; Perfetti, 1991; Stanovich, 1991; Whitehurst & Lonigan, 1998). Research has indicated that knowledge of print conventions is important for beginning readers (Whitehurst & Lonigan, 1998). Print conventions, in English, include understanding that print differs from images in a book, that print is read from left to right

and top to bottom, that words are constructed of letters, and that sentences are constructed of words.

Additionally, letter knowledge can be particularly important for beginning readers (Adams, 1990; Gillion, 2004; Perfetti, 1985, 1991; Whitehurst & Lonigan, 1998). In order for children to begin to decode words, they must first have knowledge of the sounds that each letter represents (Gillion, 2004; Gough & Hillinger, 1980; Hulme et al., 2005). Children may learn about the sounds that each letter represents by knowing the name of the letters, as many letter names contain that information (Whitehurst & Lonigan, 1998). For example, the name of the letter *b* contains the phoneme /*b*/, which the letter represents. Although it is true that children with stronger letter knowledge tend to be better readers, interventions teaching children letter names do not seem to impact reading acquisition (Adams, 1990; Hulme et al., 2005). This may be because children with higher letter knowledge may have a greater understanding of print or other literacy-related processes such as phonological awareness (Adams, 1990; Whitehurst & Lonigan, 1998).

Vocabulary Knowledge

Another characteristic common to successful beginning readers is vocabulary knowledge. Vocabulary knowledge may be important to beginning readers in two ways. First, vocabulary knowledge may be associated with the development of phonological awareness (Metsala & Walley, 1998; Walley, Metsala, & Garlock, 2003). Specifically, as a child's vocabulary grows, the size of his or her vocabulary has an impact on his or her understanding that words are constructed of smaller segments including syllables and phonemes. This process, known as lexical restructuring, is thought to occur on a word by word basis as a function of lexical neighborhood density, age of acquisition, and frequency of exposure (Walley et al., 2003).

Recent research has supported this assertion (Garlock, Walley, & Metsala, 2001; McBride-Chang, Wagner, & Chang, 1997; Ouellette, 2006; Rvachew & Grawburg, 2006; Wise, Sevcik, Morris, Lovett, & Wolf, 2007a, 2007b). For instance, in a study comparing the spoken word recognition abilities of 64 preschoolers, 64 first and second graders, and 64 adults, Garlock, Walley, and Metsala (2001) demonstrated that all three groups required significantly more input in a gating task in order to recognize a spoken word with a late age of acquisition, compared to an early age of acquisition. For the gating task, the researchers provided participants with the first 100ms of a word for the first presentation, then increased the time of presentation of the word by 50ms for each subsequent presentation. Participants were asked to guess what word was being presented. Words with an earlier age of acquisition, such as *foot*, were guessed with less phonological information compared to words with later onset of acquisition, such as *badge*. They concluded words that were acquired earlier had a stronger phonological representation compared to words that were acquired later. Furthermore, they demonstrated that first and second graders scored higher on a phoneme deletion task for early onset words compared to late onset words, which in turn, was related to word reading performance.

This work has been extended by more recent research. In a school-based study of 279 second and third grade students with reading disability, Wise and colleagues (Wise et al., 2007a) demonstrated that children with higher receptive vocabulary scores performed better at the beginning of a reading intervention compared to children with lower receptive vocabulary scores on a measure of word blending. In another study with the same sample, Wise and colleagues (2007b) demonstrated positive relationships between receptive and expressive vocabulary and pre-reading skills (i.e., blending skills, elision skills, and grapheme-phoneme correspondence knowledge; Wise et al., 2007b). Furthermore, pre-reading skills were positively associated with

word identification skills. Additional research with typically developing preschool and early elementary school children has demonstrated similar findings (McBride-Chang et al., 1997; Metsala, 1999).

The second way that vocabulary knowledge is related to successful beginning reading is through the extraction of meaning. Reading is motivated by the extraction of meaning from text (Adams, 1990; Whitehurst & Lonigan, 1998). Vocabulary, at its core, is a collection of all of the semantic representations that an individual has built up over his or her linguistic history. This includes both the internal lexical representations and the spoken symbols that represent them. Without vocabulary knowledge related to a word being decoded, a child may successfully decode and speak a word, based on its orthography, without actually knowing what the word means (see Whitehurst & Lonigan, 1998 for a description). In this case a child's attempt to understand the word will be met with failure because the child does not have a semantic representation upon which to map the phonological code.

There are a number of studies that provide evidence that vocabulary knowledge is related to word identification and reading comprehension (Nation & Snowling, 2004; Ouellette, 2006; Perfetti, 2007; Strain, Patterson, & Seidenberg, 1995; Wise et al., 2007b). For instance, in a longitudinal study of 72 typically developing children, Nation and Snowling (2004) tested whether vocabulary knowledge was predictive of reading comprehension both cross-sectionally and longitudinally. Children's reading and language skills were measured at approximately 8.5 years old and approximately 13 years old. They determined that vocabulary knowledge predicted a significant proportion of variance (25.2 %) in reading comprehension scores when children were 8.5 years old, above and beyond variance accounted for by age, nonverbal ability, nonword reading, and phonological skills. Furthermore, they determined that vocabulary

knowledge at 8.5 years old predicted an additional 5% of variance in reading comprehension at 13 years old when controlling for the same variables. Vocabulary knowledge at 8.5 years old was also a significant predictor of word identification skills at 8.5 years old and 13 years old, predicting 3.8% and 1.9% of variance, respectively. Additionally, in a cross-sectional study of 60 fourth graders, Ouellette (2006) demonstrated that receptive vocabulary predicted significant variance in word identification and reading comprehension performance after controlling for age and nonverbal IQ. Expressive vocabulary predicted variance in word identification (Ouellette, 2006). Finally, Wise and colleagues (2007b) demonstrated that vocabulary knowledge was significantly related both directly, and indirectly through phonological knowledge, to word identification skills. Taken together, these studies provide strong evidence of the role that vocabulary knowledge has directly and indirectly in beginning to read.

In summary, reading successfully requires the integration of multiple linguistic and cognitive domains. That is, children must understand that spoken words contain phonemes and that these phonemes are represented by the orthography of the language. Furthermore, they must have learned the relationships between the orthography and the sounds that they represent. Additionally, they must be able to match the string of phonetic representations with an existing lexical representation to discover the meaning of the printed text. They also must hold the string of words in mind to determine the meaning of the entire sentence. When children can perform these steps quickly and effortlessly, they are considered to be accomplished readers with the skills to determine the meaning of unfamiliar printed text. However, some children have considerable difficulty becoming accomplished readers.

Intellectual Disability and Reading

Children with an intellectual disability generally have an IQ below 70 and have limitations in adaptive skills such as communication or self care (American Association on Intellectual and Developmental Disabilities [AAIDD], 2009a; American Psychiatric Association, 2000). The onset of both of these characteristics must be before 18 years of age. According to the Metropolitan Atlanta Developmental Disabilities Surveillance Program, the prevalence of intellectual disability among 8-year-old children is approximately 12 per 1,000 children (Bhasin, Brocksen, Avchen, & Van Naarden Braun, 2006). As many as 1 in 10 families have a member with an intellectual disability (AAIDD, 2009c). Furthermore, according to recent estimates, the cause of intellectual disability is unknown in 40 to 50 percent of individuals (AAIDD, 2009b; Vloedgraven & Verhoeven, 2007). Frequently, children with intellectual disabilities encounter difficulty with oral language and ultimately literacy learning (e.g., Erickson, 2005).

Compared to investigations of reading with typical populations, a limited number of studies have investigated how children with intellectual disabilities learn to read. Of the studies that have focused on children with intellectual disabilities, many have focused on the role that phonological awareness and rapid naming, to a lesser extent, have in the reading process (Cawley & Parmar, 1995; Conners et al., 2001; Conners et al., 2006; Cupples & Iacono, 2000, 2002; Peeters et al., 2008; Saunders & DeFulio, 2007; Verhoeven & Vermeer, 2006; Verucci et al., 2006). In general, these studies have demonstrated that the relationship between phonological awareness and reading is the same for individuals who have intellectual disabilities as it is for children who are typically developing.

For example, Saunders and DeFulio (2007) demonstrated strong relationships between measures of phonological awareness and reading in a sample of 30 adults with mild intellectual

disabilities. Each participant was given a battery of assessments that measured phonological awareness (by assessing matching of onsets, medial sounds, and rimes), rapid naming (utilizing rapid object naming and letter naming tasks), word identification, and nonword decoding. Their results indicated that phonological awareness and rapid naming were significantly and strongly correlated with both word identification and word attack, even after controlling for the effects of IQ. Furthermore, they demonstrated significant correlations between receptive vocabulary and both measures of phonological awareness. The results of this study provide additional evidence that phonological awareness and rapid naming are related to reading for children with intellectual disabilities, just as they are for typically developing children (Tunmer, 1991; Wagner & Torgesen, 1987). Additionally, their finding that receptive vocabulary is related to phonological awareness replicates findings with typically developing children (Garlock et al., 2001; McBride-Chang et al., 1997; Wise et al., 2007b).

Another study, by Cupples and Iacono (2000), investigated the growth of phonological awareness over time and its relationship to reading in a sample of 22 school-age children (range 6 to 10 years old) with Down syndrome. Participants were assessed utilizing a range of language, phonological awareness, and reading measures approximately 7 to 12 months apart. At the Time 1 observation, phoneme segmentation and phoneme counting skills were positively correlated with word identification, even after controlling for age, receptive language, and working memory. Similar results were obtained at Time 2. Additionally, the authors conducted multiple regression analyses to determine the relationship between Time 1 phonological awareness and Time 2 reading outcomes. The results indicated that Time 1 phoneme segmentation skills predicted an additional 8% of the variance in Time 2 nonword reading after controlling for Time 1 nonword reading. Additionally, Time 1 word identification and nonword

reading did not predict significant variance in phoneme segmentation at Time 2. These findings indicate, much like findings with typically developing children, that phonological awareness is a significant predictor decoding skills.

The findings of the previously described studies suggest that a phonics-based approach to reading instruction may be appropriate for children with intellectual disabilities. Conners and colleagues (2006) recently investigated the impact that phonological skills instruction has on the reading ability of 40 school-age children with intellectual disabilities. None of the children could decode words successfully when they entered the study. Children were matched on age, IQ, nonword reading accuracy, phonemic awareness, and language comprehension. One member of each pair was randomly assigned to either a phonological reading instruction group or a control group that received no intervention. The phonological reading instruction was conducted with children in a one on one format. Instruction consisted of oral practice in sound blending (six lessons), letter-sound associations (seven lessons), and sounding out (nine lessons). The results indicated that children who received the phonological reading instruction performed better on tests of "sounding out" (i.e., speaking the individual phonemes in a printed word) and pronouncing a whole word compared to the control group for a set of instructed items and a set of transfer items. Furthermore, they determined that entering levels of phonological awareness were significant predictors of how well children performed on sounding out target words. The results of this study suggest that phonological instruction can be successful in building phonological awareness for children with intellectual disability and that children with stronger language skills may be served better by this type of intervention compared to children with weaker language skills, a pattern demonstrated in work with typically developing children (Stanovich, 1986).

Another study by Hedrick, Katims, and Carr (1999) obtained similar results. They implemented a multifaceted reading intervention with nine children with mild to moderate intellectual disabilities. The reading intervention included a basal block, a literature block, a word block, and a writing block. In the basal block, children read aloud together, they read in pairs (one aloud while the other followed along) and read individually. In the literature block, children read materials at his or her particular level and of his or her own interest. The word block focused on decoding skills. Finally, in the writing block, children used orthography expressively and productively. Each student made gains from pre- to post-testing in discriminating interrogative sentences, knowledge of print conventions, and in decoding of unfamiliar printed words. The results of this study, along with those of Conners and colleagues (2006) suggest that the reading instruction strategies used with typically developing children may be successful in addressing many of the reading problems commonly seen in children with intellectual disabilities.

In another example of how the relationships between phonological awareness and reading are similar in children with intellectual disabilities and typically developing children, Conners and colleagues (2001) demonstrated strong differences between two groups of children identified as being either strong decoders or weak decoders. In the study of 65 children with intellectual disabilities, they compared 21 strong decoders to 44 weak decoders on measurements of nonword and sight word reading, general language ability, phonemic awareness, and phonological processing. After controlling for the effect of age, the stronger decoders had significantly better phonological processing than the weak decoders. The two groups did not differ on IQ. These results indicate that phonological processing abilities may be a better

predictor of decoding success than IQ, as indicated by other research with typically developing children (Adams, 1990).

In perhaps one of the strongest demonstrations that the predictors of reading success are the same for children who are typically developing and those with intellectual disabilities, Cawley and Parmar (1995) showed that characteristics that distinguished “good” and “poor” readers were the same for children with average intelligence and children with intellectual disability. For their analysis, they recruited 160 children and split the sample based on two factors: intelligence (average, intellectual disability) and reading ability (good, poor). Ultimately, there were 40 children in each group. For each child they measured oral reading ability, word recognition skills, decoding skills, and letter sound knowledge. They demonstrated significant differences between good readers and poor readers, but no consistent pattern of differences as a function of intelligence. These results indicate that the relationships between various variables related to reading are the same, regardless of intellectual functioning. In other words, the results of this study provide evidence that the differences between good and poor readers are stronger than the differences between children with average intelligence and intellectual disability at least in terms of variables related to reading.

The role that speech may have in the development of phonological awareness for individuals with disabilities is becoming clearer. Research has indicated that individuals with impaired or no speech may have poorer phonological awareness compared to individuals with normal speech. For example, Vandervelden and Siegel (1999) demonstrated that a control group of participants with normal speech and no history of speech impairments scored significantly higher on measures of phonological awareness than individuals who had no speech, even though both groups were matched on reading ability. Additionally, they demonstrated that a different

group of individuals with impaired speech scored significantly lower than a control group with normal speech matched for reading level. Finally, when comparing children with no speech to those with impaired speech, Vandervelden and Siegel's (1999) results indicated medium to large effect sizes, with the group with speech impairments having higher scores on almost every measure of phonological processing. Their results indicate that individuals who have problems producing speech, or cannot produce speech, may have difficulty developing and retrieving phonological representations. This, in turn, may have an impact on reading outcomes.

The Structure of Phonological Processing

There has been some debate in the literature regarding the structure of phonological processing. This debate has focused on whether phonological processing is a single cognitive-linguistic ability or consists of several different abilities that are separate but correlated. Early accounts of the structure of phonological processing concluded that phonological processing consisted of distinct, but correlated abilities (Høien, Lundberg, Stanovich, & Bjaalid, 1995; Muter, Hulme, Snowling, & Taylor, 1997; Wagner, Torgesen, Laughon, Simmons, & Rashotte, 1993). In a study of 184 kindergarten and second grade students, Wagner and colleagues (1993) demonstrated that phonological processing consisted of four distinct but correlated abilities for kindergartners and five distinct but correlated abilities for second graders. For kindergarteners, and in no particular order, the four phonological processing abilities consisted of analysis/working memory, synthesis, isolated naming, and serial naming. For second graders, and in no particular order, the five phonological processing abilities consisted of analysis, synthesis, working memory, isolated naming, and serial naming. The fact that analysis and working memory represented a single latent ability for kindergartners and two separate latent abilities for second graders is in line with the assumption that as children mature, their

phonological abilities become more differentiated. Although strong methodologically because of the authors' use of confirmatory factor analysis to test the models, the authors estimated 40 and 45 parameters for the kindergarten and second grade models, respectively. According to the general rule of thumb that confirmatory factor analyses have 10 participants for every parameter estimated (Kline, 2005), the kindergarten and second grade samples should have had 400 and 450 participants, respectively. Having too few participants can result in unstable and unreliable results (Kline, 2005).

Høien and colleagues (1995) used principal components analysis to investigate the structure of phonological awareness in a study of 128 preschool children. Their results demonstrated that measures of phonological awareness were best categorized into three factors: a phoneme factor, a syllable factor, and a rhyme factor. The phoneme factor consisted of a measure of phoneme blending, phoneme deletion, initial phoneme matching, and phoneme counting. The syllable factor consisted of one measure of syllable counting. Likewise, the rhyme factor consisted of one measure of rhyme recognition. In the same paper, Høien and colleagues (1995) reported an identical factor structure in a sample of 1509 first graders. In addition, they determined that the three phonological awareness factors accounted for 58% of the variance in word reading scores for first grade students. Although this study clearly demonstrates that phonological awareness consists of distinguishable components, its results are not congruent with those of Wagner and colleagues (1993). More specifically, the single phoneme factor defined by Høien and colleagues, consisting of phoneme blending, counting, and identification, was described as two separate factors by Wagner and colleagues (1993).

Finally, Muter and colleagues (Muter, Hulme, Snowling et al., 1997) demonstrated that phonological awareness was best represented by two distinct and weakly associated abilities

(rhyming and segmentation) in a sample of 38 preschool children. Utilizing exploratory factor analysis with orthogonal varimax rotation, they demonstrated that a rhyming factor and segmenting factor accounted for 47% and 29% of the variance in phonological awareness measures, respectively. The rhyming factor consisted of measures of rhyme deletion and production. The segmenting factor consisted of measures of phoneme deletion and identification. Again, the analyses from this study indicated that phonological awareness was best explained by separate factors, however, the findings are not consistent with either the results of Wagner and colleagues (1993) or Høien and colleagues (1995).

More recent studies have demonstrated that phonological awareness is better explained by a single factor (Anthony & Lonigan, 2004; Anthony et al., 2002; Anthony, Lonigan, Driscoll, Phillips, & Burgess, 2003; Vloedgraven & Verhoeven, 2007). For example, Anthony and colleagues (2002) assessed phonological awareness in two groups of preschoolers: one group of 4 to 5 year olds (n = 149) and one group of 2 to 3 year olds (n = 109). Each child completed two measures of rhyme sensitivity, three measures of blending, and three measures of elision. For each group of children, they performed confirmatory factory analyses that compared the fit of increasingly parsimonious models of phonological awareness. Specifically, they determined the fit of a multiple factor solution and then compared increasingly parsimonious nested models with fewer factors to the previous model to determine if fit decreased significantly. With both groups, the multiple factor solution fit the data well, however, so did the subsequent simpler models. Importantly, the simpler models did not fit the data significantly worse and provided a more parsimonious explanation of the data. Consequently, the authors concluded that the single factor solution explained the data best. The results for the older children indicated that the two rhyming tasks (i.e., rhyme oddity and matching), the three blending tasks (i.e., word, syllable,

and phoneme blending), and the three elision tasks (i.e., word, syllable, and phoneme elision) were all strong indicators of phonological awareness with standardized loadings from .56 to .78. The results for the younger children were similar except that the rhyme oddity task did not load significantly on the phonological awareness factor. The loadings for the younger children ranged from .24 to .83. Lonigan and colleagues explain that rhyming did not strongly load on the phonological awareness factor for the younger children because of floor effects for these measures.

In a later study, Anthony and Lonigan (2004) found converging evidence of a single phonological awareness factor when reanalyzing data from four previously published reports (Lonigan, Burgess, Anthony, & Barker, 1998 [n = 202]; Muter, Hulme, & Snowling, 1997 [n = 826]; Muter, Hulme, Snowling et al., 1997 [n = 38]; Wagner et al., 1997 [n = 202]). Anthony and Lonigan reanalyzed the raw data for the Lonigan et al. (1998) and Wagner et al. (1997) studies. The Muter et al. (1997; 1997) studies were reanalyzed utilizing correlation matrices provided in the reports and served as a strong demonstration of how different methods can garner different results, as the original studies concluded that phonological awareness tasks measured independent skills. In one set of analyses, Anthony and Lonigan (2004) analyzed whether there was a distinction between phoneme level variables and sensitivity to onsets and rimes. The results of the reanalysis, utilizing confirmatory factor analysis, indicated that both a single factor model and a two factor model, where the factors were allowed to correlate, fit the data well. However, in the two factor model, the factors correlated at .90 or higher, indicating that the two factors were nearly identical. Furthermore, the single factor solution did not fit the data significantly worse than the two factor correlated solution. Consequently, the more parsimonious single factor model was determined to best represent the data for beginning

readers. Additional analyses assessing whether rhyme sensitivity and segmental awareness were distinguishable and rhyme sensitivity and phonological sensitivity were distinguishable indicated that a single factor solution was preferable for both comparisons. The results of this study indicate that the different measures described previously may indicate a single phonological ability, rather than distinct abilities.

Considering the evidence, Anthony and Lonigan (2004) conclude, "phonological sensitivity is a single ability that can be measured by a variety of tasks (e.g., detection, blending, and elision) that differ in linguistic complexity (e.g., syllables, rimes, onsets, and phonemes)" (p. 51). Furthermore, their research has demonstrated that different methodologies may contribute to the conflicting findings of multiple underlying and independent phonological awareness abilities. The reanalysis of data from Muter and colleagues (1997; 1997) indicated that strategies such as exploratory factor analysis with orthogonal rotation may have forced the factors to be uncorrelated, thus creating the appearance that the abilities were independent. However, the confirmatory factor analysis with a priori contrasts utilized by Anthony and Lonigan (2004; Anthony et al., 2002) systematically demonstrated that these independent abilities were indeed so highly correlated that they were better explained by a single ability. In addition, other studies have demonstrated that phonological awareness is best described by a single latent ability (Anthony & Francis, 2005; Stahl & Murray, 1994; Stanovich, Cunningham, & Cramer, 1984; Vloedgraven & Verhoeven, 2007)

The Developmental Perspective

An important guiding principle when developing questions about the development of any skill is the developmental perspective. Broadly, the developmental perspective can be summarized as an effort to construct principles or constructs that help researchers understand

observed growth and change and its apparent ordered and sequential nature (Zigler, 1963; Zigler & Hodapp, 1986). At the heart of the developmental perspective, particularly when applying it to the study of individuals with intellectual disabilities, is an understanding of typical development. When applied to the study of reading for children with intellectual disabilities, a researcher may use what is known about developmental trajectories in other populations of children (e.g., typically developing children or children with reading disabilities) to make predictions about the development of reading for children with intellectual disabilities.

The developmental perspective has three important applications for the study of individuals with intellectual disabilities. First is the similar sequence hypothesis. The similar sequence hypothesis states that children with and without intellectual disabilities progress through the same stages of cognitive development and differ only in their rate of achieving certain goals or skills (Zigler & Hodapp, 1986). When applied to reading, one might predict that a child with an intellectual disability would follow the same sequence of development of awareness and manipulation of phonemes. For example, a child with an intellectual disability may first show awareness of speech sounds on the word level, then the syllable level, and later the phoneme level, in the same way that typically developing children do (Anthony et al., 2003). The only difference a researcher would expect to find is the length of time it would take a child with an intellectual disability to transition through each level of awareness.

The second application of the developmental perspective to the study of individuals with intellectual disabilities is the similar structure hypothesis. The similar structure hypothesis states that individuals with intellectual disabilities and those without should have cognitive structures that have the same general components (Zigler & Hodapp, 1986). For example, in the case of working memory, an individual with an intellectual disability should have the same components

(i.e., phonological loop and visuospatial sketchpad) as a typically developing individual. Furthermore, in the case of phonological processing, the similar structure hypothesis predicts that individuals with intellectual disabilities should show evidence of two distinct but correlated abilities: phonological awareness and naming speed. This will be the central tenet of this dissertation.

The final application of the developmental perspective to the study of individuals with intellectual disabilities involves similar responses to environmental factors. Given the previous two hypotheses, the developmental perspective predicts that individuals with and without intellectual disabilities will respond to similar environmental factors similarly. However it is important to note that individuals with intellectual disabilities frequently have very different experiences compared to those without disabilities (Calculator, 1997; Fitzgerald, Roberts, Pierce, & Schuele, 1995; Zigler & Hodapp, 1986). In the case of learning to read, children may find themselves in classrooms where the skill is not emphasized, where rhyming games are not played, and where teachers and staff set expectations too low. Furthermore, a history of failure can have drastic impacts on future achievement (Zigler & Hodapp, 1986). That being said, the implication of the developmental perspective that indicates that all individuals should respond to the environment similarly provides justification for utilizing proven methods of reading instruction with children with intellectual disabilities.

Questions

To date, all of the research concerning the structure of phonological processing has been conducted with children who are typically developing. Consequently, there does not exist a model of phonological processing for children with mild intellectual disabilities. The description of a model of phonological processing for individuals with mild intellectual disabilities will help

inform recommended practices for supporting the development of this skill so vital to reading acquisition (Anthony & Francis, 2005; Anthony & Lonigan, 2004; Anthony et al., 2002).

Structure of Phonological Processing

The first goal of this dissertation is to determine the structure of phonological processing for individuals with mild intellectual disabilities utilizing a confirmatory factor analysis strategy. Specifically, this goal will test whether assessments of phonological processing that focus on analysis and synthesis of phonemes, phonological working memory, and naming speed measure either a single latent phonological awareness construct, thus representing a general phonological ability, or if each task represents a separate, but correlated component of phonological awareness. In order to determine the structure of phonological processing for children with mild intellectual disabilities three questions will be considered and tested.

Question 1. Is phonological processing best explained by a single overall phonological processing ability for children with mild intellectual disabilities? Based on the rationale of the similar structure hypothesis, it is hypothesized that phonological processing will *not* be best explained by a single phonological processing ability, consistent with the results of Anthony and Lonigan (2004; Anthony et al., 2002) and Wagner and colleagues (1993).

Question 2. Is phonological processing best explained by two latent abilities for children with mild intellectual disabilities? Again, based on the rationale of the similar structure hypothesis, it is hypothesized that phonological processing will consist of two distinct but correlated components, consistent with the results of Anthony and Lonigan (2004; Anthony et al., 2002) and Wagner and colleagues (1993). One component will consist of measures related to awareness and manipulation of phonemes, such as that described by Anthony and Lonigan (Anthony & Lonigan, 2004; Anthony et al., 2002) for preschool children. The other component

will consist of measures related to the rapid serial naming of items in an array such as that described by Wagner and colleagues (1993).

Question 3. Is phonological processing best explained by three or more latent abilities for children with mild intellectual disabilities? Although it is expected that phonological processing will be best explained by two latent abilities, other researchers have found that phonological processing consists of more than two latent abilities (e.g., Høien et al., 1995; Muter, Hulme, & Snowling, 1997; Muter, Hulme, Snowling et al., 1997). Therefore, an alternative model will be tested to eliminate the possibility that phonological processing is best explained by three or more latent abilities.

Correlates of Phonological Processing

The second goal of this dissertation is to determine the linguistic variables that are associated with phonological processing for children with mild intellectual disabilities. Specifically, after establishing the structure of phonological processing, analyses will be conducted to determine the strength of the relationships between phonological processing abilities and expressive and receptive language ability.

Question 4. What is the relationship between expressive language ability and phonological processing? It is hypothesized that there will be a positive relationship between general expressive language ability and phonological awareness such that students with stronger expressive language skills will demonstrate stronger phonological processing compared to those with weaker expressive language skills. Furthermore, it is hypothesized that there will be a negative relationship between expressive language skills and naming speed such that students with stronger expressive language skills will demonstrate shorter naming speed latencies compared to those with weaker expressive language skills.

Question 5. What is the relationship between receptive language ability and phonological processing? It is hypothesized that there will be a positive relationship between receptive language and phonological processing such that students with stronger receptive language skills will demonstrate stronger phonological processing compared to those with weaker receptive language skills. Additionally, it is hypothesized that there will be a negative relationship between receptive language skills and naming speed such that students with stronger receptive language skills will demonstrate shorter naming speed latencies compared to those with weaker receptive language skills.

Method

The data analyzed for this dissertation were collected as a part of a larger project investigating the impact of selected reading programs with a population of elementary school students diagnosed with mild intellectual disability (Sevcik, 2010). Data were collected over the course of four school years from August 2005 to May 2009. The data analyzed in this dissertation are from the Time 0 observation, prior to intervention.

Participants

Participants were screened with a set of exclusionary and inclusionary criteria to a) ensure good sampling strategies (Morris & Thompson, 1991) and b) to foster efforts to recruit a diverse sample of participants and at the same time require a priori, rigorous criteria that assure generalizability of results. Exclusionary criteria included English as a second language, a history of hearing impairment (<25dB at 500+ Hz bilaterally), a history of uncorrected visual impairment (>20/40), and serious emotional/psychiatric disturbance (e.g., major depression, psychosis). Inclusionary criteria included measured IQ from 50-69 and poor or no reading skills (below 10th percentile on standardized reading measures).

Data were available for 222 participants across years 1 through 4 of the study. All children were identified as having a mild intellectual disability by their school. IQ scores were obtained from each child's school when available. The mean IQ of the participants was 63.11 (*sd* = 9.52). The mean age of the sample was 114.04 months (*sd* = 17.27 months). Of the 222 participants, 81 (36.5%) were female. There were 67 second graders, 53 third graders, 52 fourth graders, and 50 fifth graders in the sample. Finally, the sample was very ethnically diverse. Table 1 shows the ethnic diversity of the sample.

Table 1

Sample Ethnicity

Ethnicity	*n*	%
African American	106	48
Caucasian	66	29
Latino	37	17
Asian	4	2
Multi-racial	9	4

Assessment Battery

The following assessments were administered as part of the reading assessment battery at baseline, prior to intervention. Raw scores, and not standard scores, were analyzed for two reasons. First, with the exception of the *Expressive Vocabulary Test* (EVT; Williams, 1997) and the *Peabody Picture Vocabulary Test – III* (PPVT-III; Dunn & Dunn, 1997), most of the assessments used in this study were not standardized on a population of children with intellectual disabilities. Therefore, using standard scores would likely underestimate participants performance and result in restricted variance of scores. Second, because the goal of this study

was not to compare participants' performance to other populations of children, it was unnecessary to use standard scores.

Measures of Phonological Processing

Students' ability to manipulate phonemes was measured using the *Comprehensive Test of Phonological Processing* (CTOPP; Wagner et al., 1999) elision, blending words, blending nonwords, segmenting words, segmenting nonwords, sound matching, rapid letter naming, and rapid color naming subscales.

Analysis Measures. The segmenting words and nonwords subscales measure an individual's ability to break down words or nonwords into their respective phonological components.

Synthesis Measures. The blending words and nonwords subscales measure an individual's ability to take individual phonemes or groups of phonemes presented in the auditory modality, and blend them into real words and nonwords, respectively.

Working Memory Loaded Measures. The elision subscale measures an individual's ability to analyze real words, break them down into their phonological parts, delete a phonological part or parts, and synthesize a new word. The sound matching subscale measures an individual's ability to match the onset or rime phoneme of a stimulus word with that of a target word. These measures were considered as working memory loaded because both require the student to hold a word or set of phonemes in working memory and to manipulate the word or phonemes or to compare a part of the word to another target.

Naming Speed Measures. Students' naming speed was assessed using the rapid color naming and rapid letter naming subscales of the CTOPP. Both subscales measure the time it takes a participant to rapidly name all the items in an array of colors (red, green, blue, yellow,

brown, and black) or letters (a, t, k, s, c, n). Each subscale contains two arrays with four rows of nine items each.

Measures of Expressive and Receptive Language

The *Expressive Vocabulary Test* (Williams, 1997) was administered to determine an estimate of students' expressive vocabulary skill.

Three subscales of the *Clinical Evaluation of Language Fundamentals – 4* (CELF-4; Semel, Wiig, & Secord, 2003) were administered to determine students' Expressive Language Index (ELI): Word Structure, Recalling Sentences, and Formulated Sentences. The Word Structure subscale assessed students' ability to apply morphology rules to mark inflections, derivations, and comparison; and select and use appropriate pronouns to refer to people, objects, and possessive relationships. The Formulated Sentences subscale assessed students' ability to formulate complete, semantically and grammatically correct spoken sentences of increasing length and complexity, using given words and contextual constraints imposed by illustrations.

The *Peabody Picture Vocabulary Test – III* (Dunn & Dunn, 1997) was administered to determine an estimate of students' receptive vocabulary skill.

Three subscales of the CELF-4 (Semel et al., 2003) were administered to determine students' Receptive Language Index (RLI): Concepts and Following Directions (C&FD), Sentence Structure, and Word Classes 1. The C&FD subscale assessed students' ability to interpret spoken directions of increasing length and complexity, containing concepts that require logical operators; remember the names, characteristics, and order of mention of objects; and identify from among several choices the pictured objects mentioned in the directions. The Sentence Structure subscale assessed students' ability to interpret spoken sentences of increasing length and complexity and select pictures that illustrate referential meaning of the sentence. The

Word Classes 1 subscale assessed students' ability to understand relationships between words that are related by semantic class features and to express those relationships by pointing to a visual array.

Procedure

Trained assessment administrators collected data during the baseline assessment at the school where the child was enrolled. Assessment administration occurred in a small quiet room in a one on one setting at the child's school. Each participant gave assent prior to data collection. Assessments were administered per the instructions of each assessment's published administration manual. The entire assessment battery, including assessments not analyzed here, took approximately three to five hours to administer. Assessment generally was broken up over the course of multiple visits.

Results

Descriptive Results – Phonological Processing Variables

Descriptive statistics of the raw scores for each CTOPP subscale are presented in Table 2. The means for each variable (with the exception of RCN and RLN) represent the average number of items correct. The means for RCN and RLN represent the average number of seconds participants took to name the stimuli presented. It became apparent by investigating the distributions of the CTOPP data that some of the subscales had non-normal distributions. For example, dividing the skewness statistic by its standard error resulted in a value greater than two for all CTOPP subscales except blending words, indicating significant skew. Furthermore, each of these variables had a significant positive skew, many of which were caused by a high proportion of scores that were a value of 0. Likewise, blending words, segmenting words, segmenting nonwords, RCN, and RLN all had significant kurtosis. Methods for addressing

issues related to distribution non-normality and floor effects will be discussed in the data analysis section for phonological processing.

Table 2

Descriptive Results for CTOPP subscales

Variable	N	M	SD	Mdn	Min	Max	#0's	Skew(SE)		Kurtosis(SE)	
Elision	222	1.83	2.27	1	0	9	98	1.20	(0.16)	0.48	(0.33)
SM	222	6.15	4.58	5	0	19	11	0.70	(0.16)	-0.33	(0.33)
BW	221	4.52	3.27	4	0	12	41	0.14	(0.16)	-1.01	(0.33)
BNW	198	2.26	2.26	2	0	8	72	0.63	(0.17)	-0.66	(0.34)
SW	221	1.41	2.50	0	0	11	145	1.86	(0.16)	2.63	(0.33)
SNW	197	1.03	1.89	0	0	8	139	1.94	(0.17)	3.03	(0.34)
RCN	217	112.75	51.22	99.95	43.34	386.00	0	2.35	(0.17)	8.36	(0.33)
RLN	206	92.80	57.78	77.94	26.81	433.20	0	2.73	(0.17)	10.44	(0.34)

Note. M = Mean, SD = Standard deviation, Mdn = Median, #0's = number of scores of 0. SM = Sound matching, BW = Blending words, BNW = Blending nonwords, SW = Segmenting words, SNW = Segmenting nonwords, RCN = Rapid color naming, RLN = Rapid letter naming.

Instances of missing data were investigated by hand and through the M*plus* program (Muthén & Muthén, 2007a). M*plus* indicated that there were nine distinct patterns of missing data for the CTOPP subscales. The first pattern was no missing data (n = 180). The second pattern of missing data represented participants who were missing data only for rapid letter naming (n = 11). These participants could not name the letters in the practice stimuli prior to administration, therefore they could not complete the assessment. The third pattern of missing data represented one participant who was missing data for rapid color naming (n = 1). This participant could not complete the practice items for the rapid color naming subscale. The fourth

pattern of missing data represented participants who were missing data for rapid letter naming and rapid color naming (n = 4). Three of these participants could not complete the practice items for either subscale. The fourth participant's data was randomly missing. The fifth pattern represented one participant who was only missing data for segmenting nonwords (n = 1). This participant's data was missing randomly. The sixth pattern of missing data represented participants who were missing scores on both segmenting nonwords and blending nonwords (n = 22). Each of these cases was from the first year of data collection; segmenting nonwords and blending nonwords were not administered to participants in the first year of the study. The seventh pattern of missing data represented one participant who was missing data for segmenting nonwords, blending nonwords, and rapid letter naming (n = 1). This participant also was from the first year of the study and was not administered the segmenting nonwords and blending nonwords subscales. In addition, he or she could not complete the practice for rapid letter naming. The eighth pattern of missing data represented one participant who was missing data for segmenting nonwords, blending nonwords, and segmenting words (n = 1). This participant was from the first year of the study and was not administered segmenting nonwords and blending nonwords. The data for segmenting words for this participant was missing randomly. Finally, the ninth pattern of missing data represented one participant who was missing data for blending words. This participant's blending words data also was missing randomly.

In summary, the largest source of missing data for the CTOPP was the result of segmenting nonwords and blending nonwords not being administered during the first year of the study. However, these participants were administered the other six scales of the CTOPP. The second largest source of missing data was the result of children not being able to name the practice items in the rapid color naming and rapid letter naming subscales. This notwithstanding,

81% of participants had complete data for all eight of the subscales administered. Finally, only three participants were missing data from three of the subscales; 219 participants had scores for at least 6 of the eight subscales administered. Strategies for addressing issues related to missing data will be discussed in the section titled *Data Preparation and Special Considerations* for the phonological processing analysis section.

Descriptive Results – Language Variables

Descriptive statistics of the raw scores for the expressive and receptive language measures are presented in Table 3. The means for each variable indicate the average number of items correct. Much like the CTOPP data, many of the language variables had significant non-

Table 3

Descriptive Results for Expressive and Receptive Language Measures

Variable	N	M	SD	Mdn	Min	Max	#0's	Skew		Kurtosis	
WS	222	11.08	6.72	11	0	30	9	0.35	(0.16)	-0.36	(0.33)
RS	222	17.48	14.88	16	0	74	21	1.04	(0.16)	1.11	(0.33)
FS	222	11.86	11.04	10	0	48	31	1.14	(0.16)	0.80	(0.33)
EVT	221	49.07	10.77	47	23	94	0	0.69	(0.16)	1.47	(0.33)
C&FD	222	12.91	9.27	11	0	44	10	0.87	(0.16)	0.38	(0.33)
SS	222	14.18	5.25	14	3	26	0	0.05	(0.16)	-0.75	(0.33)
WC	222	21.19	10.96	22	0	42	6	-0.19	(0.16)	-0.94	(0.33)
PPVT-III	222	67.55	22.52	68	4	139	0	0.10	(0.16)	0.34	(0.33)

Note. M = Mean, SD = Standard deviation, Mdn = Median, #0's = number of scores of 0. WS = Word structure, RS = Recalling sentences, FS = Formulated sentences, C&FD = Concepts and following directions, SS = Sentence structure, WC = Word classes.

normality. Word structure, recalling sentences, formulated sentences, EVT, and C&FD all had significant positive skew. However, unlike the CTOPP subscales, the positive skew for these variables were not caused by floor effects, as indicated by the low proportion of scores of 0. Recalling sentences, formulated sentences, EVT, sentence structure, and word classes all had significant kurtosis. In terms of missing data, only one score was missing for the EVT for one participant. This participant's EVT data was missing randomly. Methods for addressing issues related to distribution non-normality, floor effects, and missing data will be addressed in the section titled *Confirmatory Factor Analysis for Language*.

Confirmatory Factor Analysis (CFA) for Phonological Processing

The structure of phonological processing for students with mild intellectual disabilities was assessed utilizing confirmatory factory analysis (CFA) with M*plus* software (Muthén & Muthén, 2007a). CFA is a strategy that allows the researcher to a priori define the observed variables that measure a latent construct (Kline, 2005). CFA uses maximum likelihood estimation to iteratively determine parameter values that maximize the likelihood that the observed data were drawn from the population in question. Furthermore, maximum likelihood estimation is a full information method that calculates all parameters simultaneously. In other words, the parameter estimates take all available information into account. This is in contrast to least squares regression strategies that only take partial information into account when estimating parameters. Additionally, see Appendix A for a discussion of testing model fit when placing boundary constraints on estimates.

Data Preparation and Special Considerations

Certain steps were taken to prepare the data prior to conducting the CFA. First, in IBM SPSS Statistics 18.0 (2010), all of the scores for sound matching were divided by the constant 2

and the scores for rapid color naming and rapid letter naming were divided by the constant 10 so that each variable was on approximately the same scale (Kline, 2005). In addition, a special maximum likelihood estimation technique was chosen in order to address the non-normality of the distributions and non-independence of observations for the CTOPP subscales, both of which are core assumptions of maximum likelihood estimation. MLR estimation was chosen to address these concerns. MLR estimation provides parameter estimates with standard errors and chi-square statistics that are robust to non-normality and non-independence of observations (Muthén & Muthén, 2007b).

Although MLR estimation addressed many of the issues related to distribution non-normality, a visual investigation of the distributions indicated that additional steps should be taken to best characterize some of the variables because of potential floor effects. For example the elision, blending words, and blending nonwords subscales were characterized by a high number of scores of 0 (see Table 1) with an approximately normal distribution through scores 1 and higher. This type of distribution best approximates a zero-inflated poisson (ZIP) distribution. M*plus* analyzes ZIP distributions differently than continuous distributions in that it also estimates a binary latent variable that compares individuals with a score of 0 to individuals with a score greater than 0. Because of this advantage, elision, blending words, and blending nonwords subscales were characterized as ZIP distribution for the CFA analysis.

A visual investigation of the distributions for segmenting words and segmenting nonwords indicated that a large number of participants scored 0 on each of the subscales (see Table 2), with the remaining scores scattered throughout the range of scores. These variables also demonstrated evidence of floor effects. However, these variables were best characterized as binary variables where 0 indicated a score of 0 and 1 indicated a score of 1 or greater.

Segmenting words and segmenting nonwords were recoded accordingly and input into M*plus* as binary variables. Sound matching, rapid color naming, and rapid letter naming were entered into M*plus* as continuous variables.

Finally, full information maximum likelihood (FIML) fitting was used to address issues related to missing data (Muthén & Muthén, 2007b). FIML uses all available data points for each case to estimate parameters that have complete data and those that have incomplete data via the associations between parameters (Enders & Bandalos, 2001). This results in increased precision of parameters. Montecarlo studies have demonstrated that FIML fitting is superior to other post-hoc strategies for handling missing data because it results in unbiased parameter estimates (e.g., Enders & Bandalos, 2001).

Testing the Structure of Phonological Awareness

The CFA for this analysis consisted of nested models in order to test the fit of increasingly complex models of phonological awareness. In other words, each successive model estimated more parameters than the previous model, allowing for systematic assessment of fit relative to the previous model and overall parsimony of the model. Although an overall statistic of model fit is not available for models using ZIP and binary variables (Muthén & Muthén, 2007b), relative model fit was indicated by comparing model loglikelihood (LL) values, with the scaled Chi-square difference test (Satorra & Bentler, 2001), the Akaike Information Criterion (AIC), and the sample-size adjusted Bayesian Information Criterion (BIC) between nested models. Significant increases in the loglikelihood statistic (i.e., values closer to 0) indicate statistically significant better model fit and justify the less parsimonious model. Furthermore, the AIC and BIC are statistics that can be used to compare the relative fit of nested and non-nested models. Smaller values indicated better fitting models for both.

As a starting point to test Questions 1 through 3, a model was constructed with a single phonological processing latent ability. This first model was a generalized model in which all of the measurements of phonological awareness described previously were used as indicators of single latent phonological processing construct (see Figure 1). This model was the first step in creating more complex models that will address the questions related to the structure of phonological processing. All factor loadings were in the expected direction. For the generalized

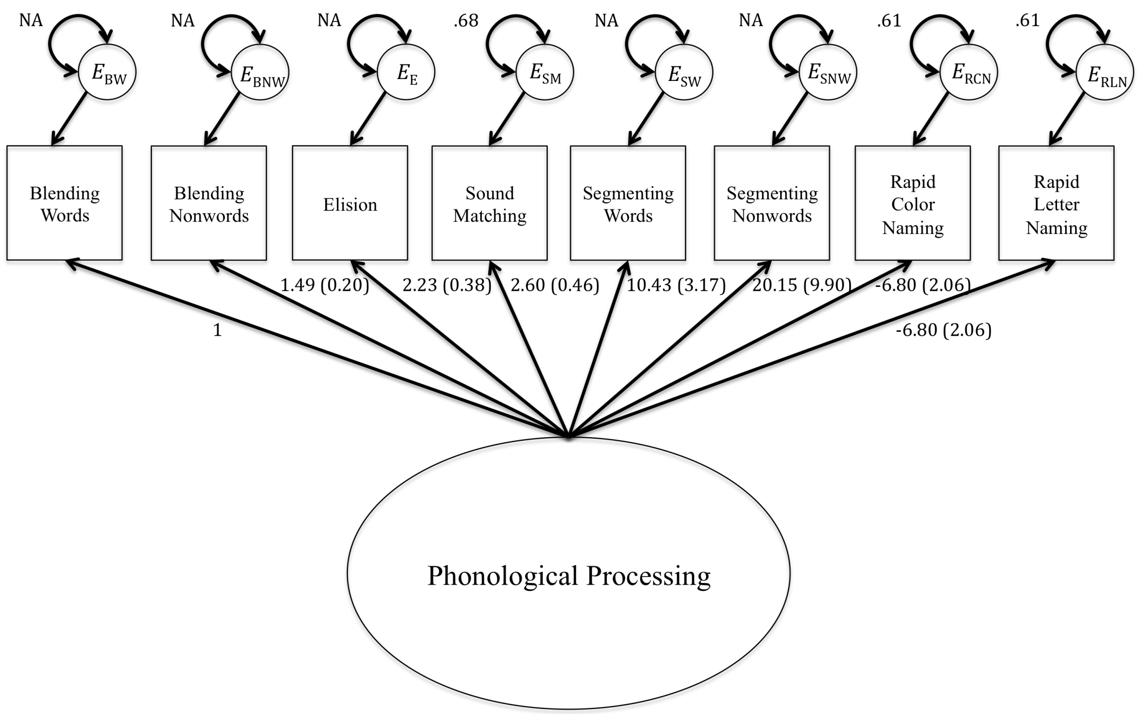

Figure 1. Model of phonological processing with one latent ability. Values on paths represent unstandardized factor loadings. Values in parentheses represent standard errors. Solid lines indicate significant loadings. No error variances are given for blending words, blending nonwords, elision, segmenting words, and segmenting nonwords because variances cannot be calculated for count variables.

model, LL = -3127.47, SCF = 1.56, Free Parameters = 21, AIC = 6296.93, BIC = 6301.84. An alternative solution to this model with all variables characterized as continuous variables is presented in Appendix B.

Question 1. In order to address Question 1, that is, determine if a single phonological processing latent ability explained the data best, it was necessary to compare the generalized model to a model with two latent variables. This second model tested whether a two factor solution with a phonological awareness latent variable and a naming speed latent variable (see Figure 2) fit the data significantly better than the generalized model. The two-factor model was created by using elision, sound matching, blending words, blending nonwords, segmenting words, and segmenting nonwords as indicators of a phonological awareness latent variable and rapid color naming and rapid letter naming as indicators of a naming speed latent variable. For the two-factor model, LL = -3075.86, SCF = 1.51, Free Parameters = 22, AIC = 6195.72, BIC = 6200.86. Comparing the general model to the two-factor solution, the scaled chi-square difference test (Satorra & Bentler, 2001), $\chi^2_D(1) = 247.51$, $p < .01$, indicated that the two-factor

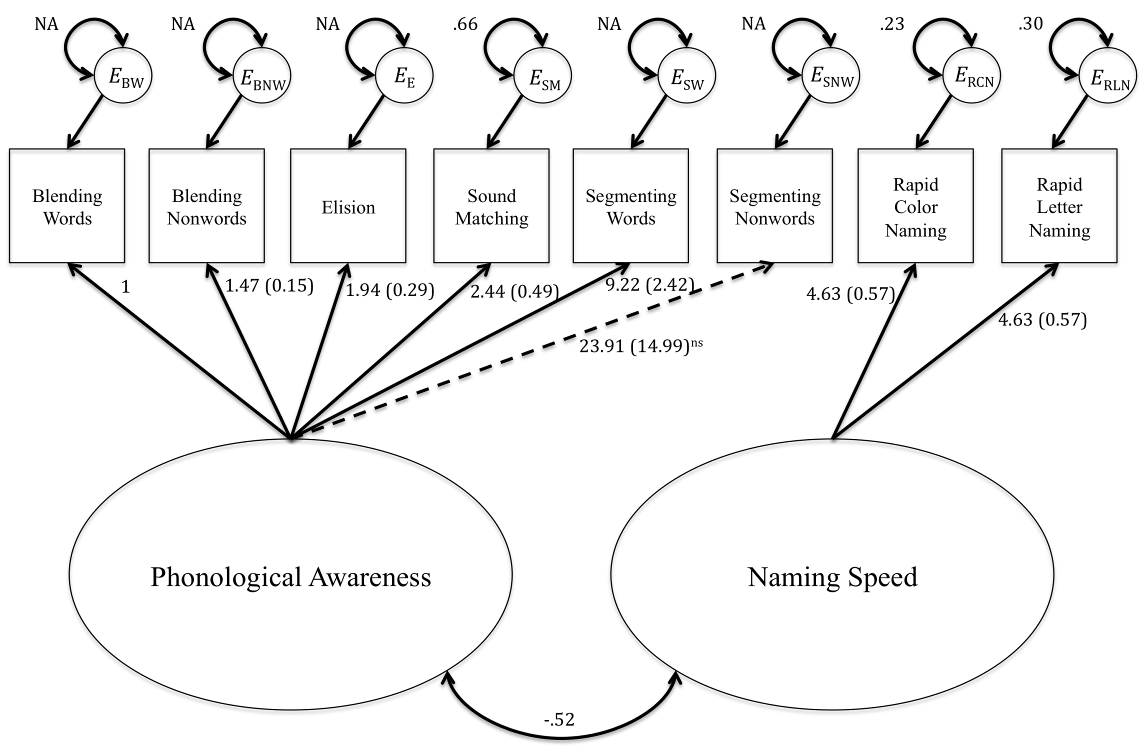

Figure 2. Model of phonological awareness with two latent abilities. Values on paths represent unstandardized factor loadings. Values in parentheses represent standard errors. Solid lines indicate $p < .01$. Dashed lines indicate $p > .05$. No error variances are given for blending words, blending nonwords, elision, segmenting words, and segmenting nonwords because variances cannot be calculated for count variables.

solution fit the data significantly better than the one factor solution. Furthermore, both the AIC and BIC decreased by approximately 100, providing additional evidence that a two-factor solution fit the data better. The results confirm the hypothesis concerning Question 1; phonological processing is not best explained by single phonological processing latent ability. An alternative solution to this model with all variables characterized as continuous is presented in Appendix B.

Questions 2 and 3. In order to address Questions 2 and 3, it was necessary to construct a three-factor model. If the three-factor model did not fit the data significantly better than the two-factor solution, then the hypotheses related to questions 2 and 3 would be confirmed. The three-factor solution consisted of a phonological awareness latent variable that used blending words, blending nonwords, segmenting words and segmenting nonwords as indicators, a naming speed latent variable that used rapid color naming and rapid letter naming as indicators, and a working memory related latent variable that used elision and sound matching as indicators. First attempts at running the model with all correlations between the latent variables freely estimated resulted in the model failing to converge. Using different starting values to estimate the correlation between the phonological awareness latent variable and the working memory related latent variable did not result in model convergence. However, the model did converge to a solution when the correlation between the phonological awareness latent variable and working memory related latent variable was constrained to .80. This value was chosen because it represents a reasonably low correlation that demonstrates that the phonological awareness latent variable and the working memory related latent variable were distinct from one another. This model fit the data slightly worse than the two-factor solution, LL = -3080.53, SCF = 1.50, Free Parameters = 23, AIC = 6207.06, BIC = 6212.43, as indicated by the lower loglikelihood value and the slightly

higher AIC and BIC values. This provided solid evidence that the two-factor solution was the best explanation of the data, considering both model fit and parsimony, thus confirming the hypotheses for Questions 2 and 3. That is, phonological processing is best explained by two latent phonological processing abilities: phonological awareness and naming speed. Phonological processing is not best explained by three or more latent abilities.

The Phonological Awareness and Naming Speed Model. As can be seen in Figure 2, blending words, blending nonwords, elision, sound matching, and segmenting words were all significant indicators of the phonological awareness, $p < .01$. Segmenting nonwords was not a significant indicator of phonological awareness, $p = .11$, probably due to the large number of participants who could not perform the task (see Table 2). Error variances were not available for the ZIP variables because variances are not calculated for count variables (Muthén & Muthén, 2007a, 2007b).

In addition, both rapid color naming and rapid letter naming were significant indicators of the naming speed latent variable (see Figure 2). Because of problems with negative error variances, the factor loadings for each of these indicators were constrained to be equal. The results indicated low standardized error variances for both rapid color naming and rapid letter naming (.23 and .30, respectively) with high standardized factor loadings (.88 and .83, respectively). The phonological awareness and naming speed latent abilities had a strong and negative correlation of -.52, indicating that as phonological awareness increased, the amount of time it took to name items in an array decreased. In other words, children who exhibited stronger phonological awareness also were faster at naming items in an array.

Confirmatory Factor Analysis for Language

In order to address Questions 4 and 5, latent variables were constructed using measures of expressive and receptive language. The CFA compared two nested models, one general language ability model, similar to the generalized phonological processing model, and a two-factor model with expressive and receptive language abilities. Considering the distributions for each of the language variables, more conventional modeling strategies could be used compared to the phonological processing model. MLR estimation was chosen because the distributions for many of the language variables had significant amounts of positive skew. Furthermore, because visual inspection of the distributions indicated that floor effects were not present for the language variables, it was clear that each could be accurately characterized as continuous variables (as opposed to ZIP or binary variables). Missing data also were not a concern as only one participant was missing one score on the EVT. Nonetheless, FIML estimation was used to handle this missing data point (Enders & Bandalos, 2001; Muthén & Muthén, 2007b). Consequently, it was possible to utilize more conventional statistics of overall model fit and change in model fit.

The overall fit of each model was indicated by estimates of model chi-square (χ^2_M), root mean square error of approximation (RMSEA), comparative fit index (CFI), and standardized root mean square residual (SRMR). Tests of χ^2_M determine whether the observed model is significantly different from the null hypothesis that the model fits perfectly. Therefore, non-statistically significant values of χ^2_M indicate that the null hypothesis cannot be rejected and that model fit is good (Kline, 2005). RMSEA is a fit statistic that favors parsimonious models; all things being equal, the RMSEA for a model that is less complex will have a RMSEA that indicates better fit. An RMSEA of .05 or less is indicative of good fit (Hu & Bentler, 1999).

Also, the upper limit of the 90% confidence interval for RMSEA should be less than .10 to indicate good fit (Kline, 2005). The CFI is an incremental fit index that compares the tested model to a model that assumes zero population covariances among the observed variables. Typically, CFI values that are greater than roughly .95 indicate reasonably good fit (Hu & Bentler, 1999). SRMR is a fit statistic that compares observed covariance to the covariances predicted by the model. Consequently, values close to zero indicate excellent model fit; values that are less than .08 are considered favorable (Hu & Bentler, 1999). The two-factor model was compared to the general language model utilizing the scaled chi-square difference test (Satorra & Bentler, 2001).

Word structure, recalling sentences, formulated sentences, concepts and following directions, sentence structure, and word classes from the CELF-4 and scores from the EVT and

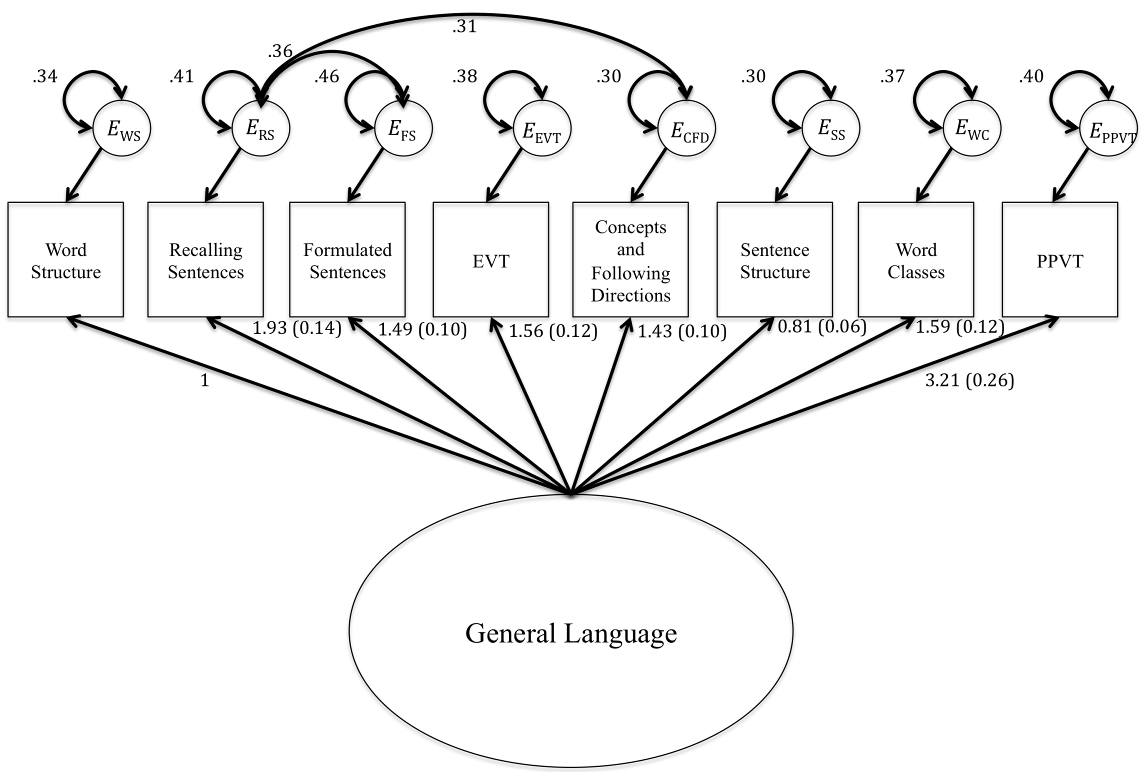

Figure 3. Model of language with one latent ability. Values on paths represent unstandardized factor loadings. Values in parentheses represent standard errors. Solid lines indicate $p < .01$.

PPVT-III were used as indicators for the general language model (see Figure 3). The error variance for recalling sentences was allowed to covary with formulated sentences and with concepts and following directions because of their strong working memory components. The general language model fit the data reasonably well, χ^2_M (18) = 45.21, $p < .01$, SCF = 1.12, RMSEA = .08 (90% CI: .05 - .11), CFI = .97, SRMR = .03. Each indicator was significantly related to the general language factor, $p < .01$ with standardized factor loadings from .70 to .84. The standardized error variances for each indicator were reasonably low (.28 to .43). However, the fact that χ^2_M was significant, RMSEA was greater than .05, and that the 90% confidence interval for RMSEA contained .10 indicated that it may have been possible to estimate a better fitting model.

For the two-factor model, word structure, recalling sentences, and formulated sentences from the CELF-4 and the EVT were used as indicators of an expressive language latent factor. Concepts and following directions, sentence structure, and word classes from the CELF-4 and the PPVT-III were used as indicators of a receptive language latent factor (see Figure 4). The two-factor model fit the data very well, χ^2_M (17) = 27.23, $p = .055$, SCF = 1.12, RMSEA = .05 (90% CI: .00 - .09), CFI = .99, SRMR = .02. Furthermore, the scaled chi-square difference test indicated that the two-factor model fit the data significantly better than the one factor model, χ^2_D (1) = 17.04, $p < .01$. Furthermore, each indicator of expressive and receptive language was significantly related to its corresponding latent variable, $p < .01$. The standardized factor loadings were high for each (.74 to .85 for expressive language and .78 to .85 for receptive language) and the error variances were low (.27 to .45 for expressive language and .27 to .39 for receptive language). Finally, expressive language ability and receptive language ability were highly and significantly correlated ($r = .92$, $p < .01$). These results indicate that the data best fit a

two-factor model that includes an expressive latent ability and a receptive latent language ability.

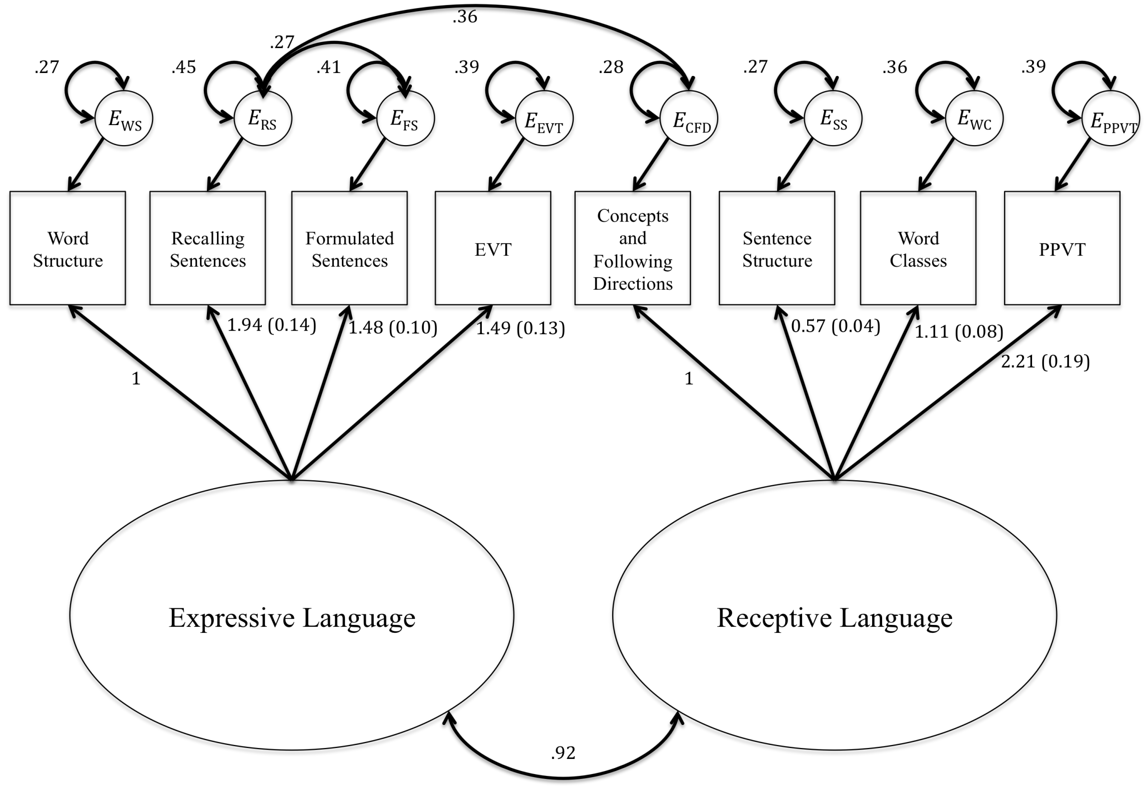

Figure 4. Model of language with two latent abilities. Values on paths represent unstandardized factor loadings. Values in parentheses represent standard errors. Solid lines indicate $p < .01$.

The Relationships Between Phonological Awareness, Naming Speed, and Receptive and Expressive Language

It is important to determine the relationship between phonological awareness, naming speed, and their correlates for two main reasons. First, it is important to determine the extent to which the phonological awareness and naming speed latent variables are associated with other variables differently. In other words, from a methodological perspective, it is important to demonstrate that other variables are related to the latent abilities identified by the CFA differently to ensure their discriminant validity. Second, it is important to identify potential mechanisms of influence on phonological awareness, naming speed, and ultimately reading, in order to identify potential mechanisms of support and change. To address both of these

concerns, a hybrid structural equation model was conducted that estimated the relationships between the four latent variables described previously: phonological awareness, naming speed, expressive language, and receptive language, LL = -9081.63, SCF = 1.35, Free Parameters = 53, AIC = 18269.26, BIC = 18281.64. The correlation coefficients between each of these variables are presented in Figure 5.

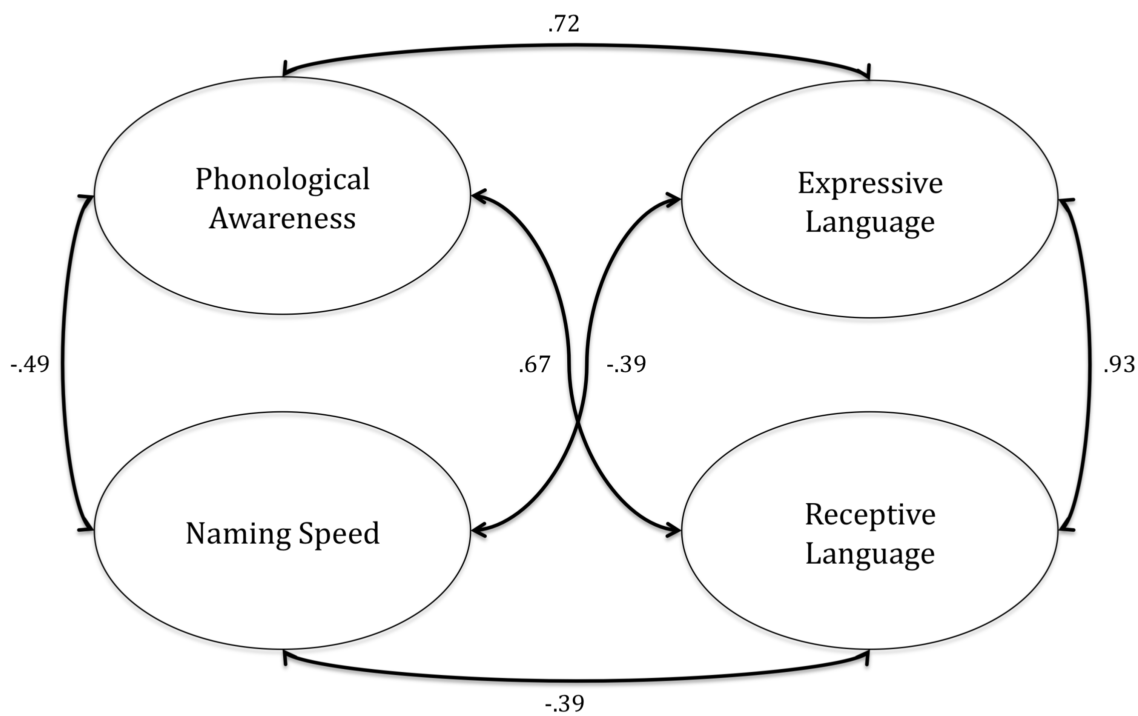

Figure 5. Model of correlations between phonological awareness, naming speed, expressive language, and receptive language. Values represent bivariate correlations between the latent variables. Solid lines indicate $p < .01$.

Discriminant Validity

Two sets of analyses were conducted to establish the discriminant validity of the phonological awareness latent variable and the naming speed latent variable. The first set of analyses involved establishing significant differences among the bivariate correlations for the four latent variables. First, the bivariate correlations between expressive language and phonological awareness and expressive language and naming speed were constrained to be equal. This resulted in a significant decrease in overall model fit, $\chi^2_D(2) = 96.85$, $p < .01$, and

indicated that the relationship between expressive language and phonological awareness was significantly different from the relationship between expressive language and naming speed. Additionally, a second analysis was conducted that constrained the bivariate correlations between receptive language and phonological awareness and receptive language and naming speed to be equal. This also resulted in a significant decrease in overall model fit, $\chi^2_D(2) = 119.70$, $p < .01$, and indicated that the relationship between receptive language and phonological awareness was significantly different from the relationship between receptive language and naming speed.

The second set of analyses involved establishing significant differences among the path coefficients between the four latent variables. This set of analyses was conducted only to parse variance in such a way to establish discriminant validity, and not to infer causality. In order to do so, a hybrid structure equation model was constructed that estimated path coefficients from phonological awareness to expressive language and receptive language, and from naming speed to expressive language and receptive language, LL = -9081.63, SCF = 1.35, Free Parameters = 53, AIC = 18269.27, BIC = 18281.65 (see Figure 6). As expected, constraining the path coefficient from phonological awareness to expressive language to be the same as the coefficient from naming speed to expressive language resulted in a significant decrease in model fit, $\chi^2_D(2) = 213.09$, $p < .01$. Likewise, constraining the path coefficient from phonological awareness to receptive language to be the same as the coefficient from naming speed to receptive language resulted in a significant decrease in model fit, $\chi^2_D(2) = 93.15$, $p < .01$. Taken together with the results of the bivariate correlations, these results provide strong evidence that phonological awareness has distinct relationships with expressive language and receptive language when compared to the same relationships between naming speed and expressive and receptive

language. Consequently, discriminant validity of the phonological processing latent constructs was established.

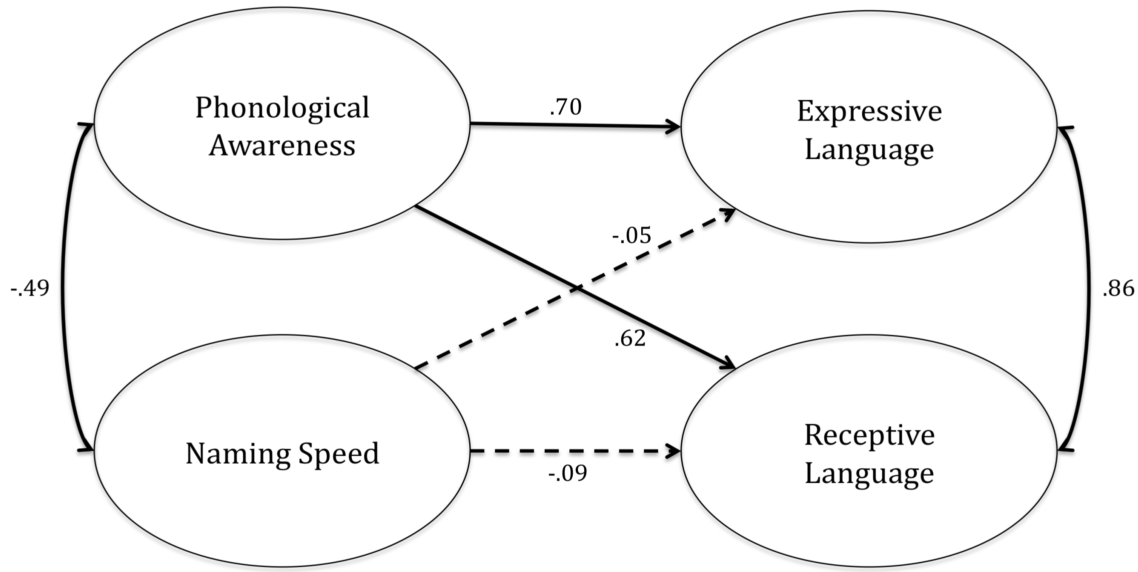

Figure 6. Model of phonological awareness and naming speed predicting expressive and receptive language. Values represent standardized path coefficients. Solid lines indicate $p < .01$. Dashed lines indicate $p > .05$.

Relationships Between the Latent Variables

The model presented in Figure 5 also was used to address the hypotheses presented in Questions 4 and 5. Question 4 sought to determine the relationship between expressive language and phonological processing. As demonstrated by Figure 5, there was a significant and positive bivariate relationship between expressive language and phonological awareness, $r = .72$, $p < .01$. This finding provides support for the hypothesis that there would be a positive relationship between these two variables. Also indicated in Figure 5, there was a significant and negative bivariate relationship between expressive language and naming speed, $r = -.39$, $p < .01$, thus providing support for the hypothesis that there would be a negative relationship between these two variables.

Question 5 sought to determine the relationship between receptive language and phonological processing. The first hypothesis stated that there would be a significant and

positive relationship between receptive language and phonological awareness. As demonstrated in Figure 5, there was a significant positive bivariate relationship between these two variables, $r = .67$, $p < .01$, supporting this hypothesis. The second hypothesis associated with Question 5 stated that there would be a significant and negative relationship between receptive language and naming speed. As shown in Figure 5, there was a significant and negative bivariate relationship between these two variables, $r = -.39$, $p < .01$, supporting this hypothesis. Consequently, the bivariate relationships between the four latent variables support the hypotheses for Questions 4 and 5.

In addition to bivariate correlations, it was important to investigate the unique relationships between the language variables and the phonological processing variables controlling for the other variables in the model to more precisely address Questions 4 and 5. In order to do so, a hybrid structural equation model was constructed that utilized phonological awareness and naming speed as criterion variables and expressive and receptive language as predictor variables (see Figure 7). According to this model, expressive language was a significant predictor of phonological awareness, $\beta = .74$, $p < .02$, while controlling for the effects of receptive language. Receptive language did not significantly predict phonological awareness, $\beta = -.02$, p = ns, while controlling for the effects of expressive language. This was likely due to the high degree of multicollinearity between the two language variables. Furthermore, naming speed was not significantly predicted by expressive language while controlling for the effects of receptive language, $\beta = -.21$, p = ns, or by receptive language while controlling for the effects of expressive language, $\beta = -.20$, p = ns. These results provide only partial support for the hypothesis related to Question 4 in that expressive language was a significant and positive predictor of phonological awareness. Possible explanations for these results will be elaborated in

the discussion section.

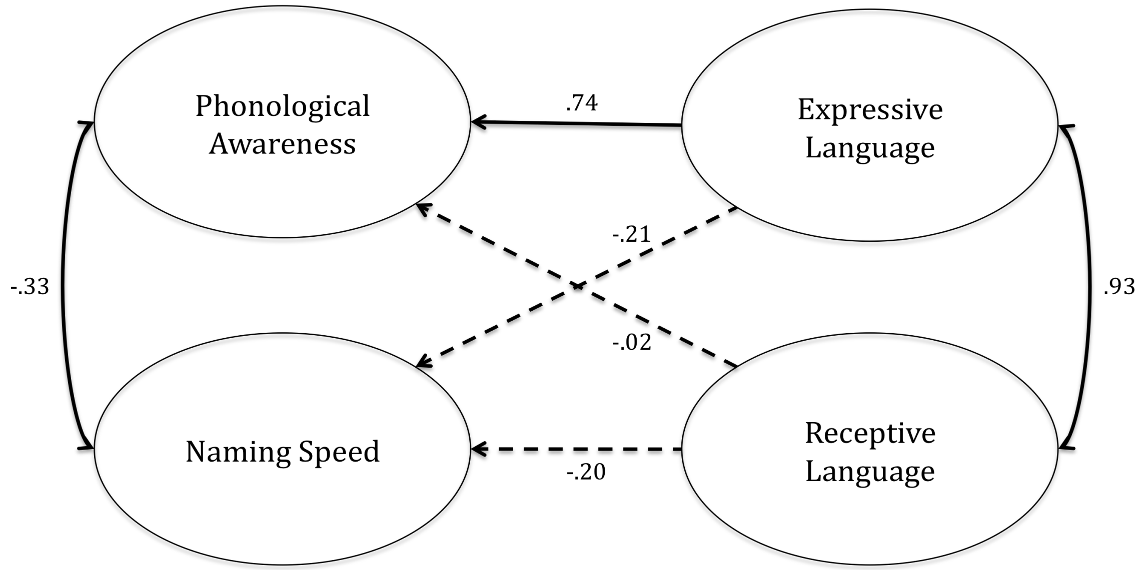

Figure 7. Model of expressive and receptive language predicting phonological awareness and naming speed. Values represent standardized path coefficients. Solid lines indicate $p < .02$. Dashed lines indicate $p > .05$.

Discussion

The overarching goal of this dissertation was to identify the underlying abilities that compose phonological processing for children with mild intellectual disabilities. Furthermore, this is the first study of its kind to use CFA strategies to identify the structure of phonological processing for children in this population. In doing so, it is possible to determine the linguistic correlates of the components of phonological processing, information that may be used to inform reading interventions for children who have mild intellectual disability.

Phonological Processing Measurement Model

The results from this study confirm the hypothesis that phonological processing is best explained by two correlated but distinct abilities: phonological awareness and naming speed. Although the general phonological processing model fit the data reasonably well, the two-factor solution fit the data significantly better than the general phonological processing model. Furthermore, the results suggested that more than two factors did not contribute to better model

fit. Subscales of the CTOPP that measured the awareness and manipulation of phonemes were used as indicators of the phonological awareness latent ability identified in this study. Specifically, these were, blending words, blending nonwords, segmenting words, segmenting nonwords, sound matching, and elision. Segmenting nonwords was the only indicator that was not a significant indicator of phonological awareness, probably due to the low number of students who could successfully perform the task (i.e., floor effects). These results were consistent with previous research that indicated a single phonological awareness latent ability (Anthony & Lonigan, 2004; Anthony et al., 2002). For example, one study of typically developing preschool-age children demonstrated that measures of rhyme sensitivity, blending skills, and elision skills were strong indicators of a single underlying phonological awareness ability (Anthony et al., 2002). The rhyme sensitivity measures were conceptually similar to the sound matching subscale used in the CTOPP for this study in that participants were asked to match or discriminate pictures that represented words based on the sounds at the end of the words. Likewise, the blending measures and elision measures used in Anthony, et al. (2002) were similar to the blending and elision measures used in this study. In another example using data from three previous studies (Anthony & Lonigan, 2004), researchers were unable to identify differences between onset and rime level tasks where participants were asked to manipulate and analyze the beginning and ending sounds of words, from phoneme level tasks, where participants were asked to manipulate and analyze single phonemes into words and nonwords, for typically developing young school-age children. In other words, these types of tasks measured the same underlying construct of phonological awareness. Taken together the results from this study and previous studies provide strong evidence for a single phonological awareness ability that can be

measured by a variety of different tasks that assess performance on a variety of different phonological awareness skills, which include analysis and synthesis.

The second latent variable identified in this study related to phonological processing was naming speed. Naming speed was indicated by two different rapid naming tasks from the CTOPP: rapid color naming and rapid letter naming. Naming speed has been shown to be reliably associated with reading difficulties for typically developing children (Katzir et al., 2006; Wolf, 1991; Wolf & Bowers, 1999), and thus was an important variable to model for this population of children with mild intellectual disabilities.

There is, however, some debate as to how naming speed, as a skill, should be categorized as it relates to phonological awareness. Specifically, some researchers have assumed that naming speed is subsumed within broader phonological awareness abilities (Wagner & Torgesen, 1987; Wagner et al., 1993). However, research investigating the double-deficit hypothesis, which states that phonological awareness and naming speed are two separate skills and that individuals with dyslexia have deficits in one or the other, or both, has provided strong evidence of the distinction between the sets of skills (Lovett et al., 2000; Wolf & Bowers, 1999). This study, although not designed to address this issue specifically, provides further evidence that naming speed may be separate from, but correlated with, phonological awareness, at least for children with mild intellectual disabilities.

As predicted by the developmental perspective (Zigler & Hodapp, 1986), the results of these analyses investigating the structure of phonological processing provide evidence that children with mild intellectual disabilities indeed show the same structure for phonological processing as children who are younger and typically developing. Although there are limitations to interpretation because of the cross-sectional nature of this study and the lack of a typically

developing comparison group, it seems that children with mild intellectual disabilities likely are developing phonological processing in the same manner, with the same structure, as their typically developing counterparts.

These findings highlight two aspects of the developmental perspective when considering similarities between children who are typically developing and children who have mild intellectual disabilities. The first is the similar structure hypothesis (Zigler & Hodapp, 1986). The similar structure hypothesis states that children with disabilities will have similar processes underlying their intellectual function when compared to younger children without disabilities (Zigler & Hodapp, 1986). Clearly, in this case, school-aged children with mild intellectual disabilities demonstrated the same underlying phonological processing structure as younger children have in other studies (e.g., Anthony & Lonigan, 2004; Anthony et al., 2002). The second aspect of the developmental perspective that these findings highlight is that related to similar responses to the environmental factors. This aspect of the developmental perspective emphasizes that all individuals, with or without disabilities, should respond to the environment similarly, albeit sometimes at different rates. The fact that the students in this study demonstrated similar phonological processing structure to typically developing children who are younger may be an indication that their home and/or school learning environments may be similar. It may be the case that the similarity in structure of phonological processing is due to similarities in environmental exposure to pre-reading materials and activities in the home and at school.

Language Measurement Model

Two distinct but highly correlated language variables were identified in this study: expressive language and receptive language. Although no specific hypotheses concerning the

structure of language ability were posited for this dissertation, it was important to create latent variables for both expressive and receptive language to address hypotheses concerning the linguistic correlates of the components of phonological processing. One of the most interesting outcomes of this analysis of linguistic variables was the very high correlation between the expressive and receptive language factors. A correlation of .92 between two latent variables in a CFA calls into question the extent to which the two latent variables are actually distinct from one another. In this case, however, there is a strong rationalization for differentiating expressive language from receptive language in that expressive language assessments measure what a child is able to produce, receptive language assessments measure what a child is able to understand. Furthermore, there is evidence from norming studies that indicate that the ELI and RLI of the CELF-4 are highly correlated, $r = .79$, (Semel et al., 2003), as are the EVT and the PPVT-III, *r's* = .68 to .83, (Williams, 1997). The same was reflected in the raw scores from the data for this study. The correlation between a composite expressive language variable (created by summing the raw scores for word structure, recalling sentences, formulated sentences, and the EVT) and a composite receptive language variable (created by summing concepts and following directions, sentence structure, word classes, and the PPVT-III) was .79. Considering these converging lines of evidence, and the fact that the two-factor model with an expressive language factor and a receptive language factor fit the data significantly better than the single factor model, it was justified to consider expressive and receptive language as distinct but highly correlated language skills.

Phonological Awareness and Language

Because of the high correlation between the expressive and receptive language and how it affected the path coefficients between the language latent variables and phonological processing

latent variables (see Figure 7), the bivariate correlations between all four latent variables were interpreted. In this case, bivariate correlations represent a better estimate of the relationship between the components of phonological processing and language.

The results of this study indicated strong and significant correlations between the two language latent variables and the phonological awareness latent variable (see Figure 5), consistent with the predictions of the study. In other words, children with mild intellectual disabilities who had stronger expressive language skills also had stronger phonological awareness skills, relative to other children in the sample. Likewise, children who had stronger receptive language skills demonstrated stronger phonological awareness skills relative to children with weaker receptive language skills.

These results are consistent with the results of previous studies with children and adults who are typically developing (Garlock et al., 2001; Metsala & Walley, 1998; Walley et al., 2003) and with children with reading disabilities (Wise et al., 2007a, 2007b). Consequently, the children with mild intellectual disabilities in this study demonstrated evidence of lexical restructuring (Walley et al., 2003) in the same way that typically developing children and children with reading disabilities have in past studies. This is the first demonstration of this relationship between phonological awareness and language variables for children with mild intellectual disabilities.

In addition, these findings highlight some important implications of the developmental perspective. First, these results show that, like the structure of phonological processing, the relationship between phonological awareness and language variables is similar for individuals with and without intellectual disabilities. Even though this study did not directly compare children with mild intellectual disabilities to typically developing children, it did demonstrate

that information from research with typically developing children can be used to accurately predict relationships among linguistic domains for individuals with mild intellectual disabilities. As a result, it seems reasonable that the similar structure hypothesis espoused by Zigler and Hodapp (1986) can be employed to aid in understanding of the relationships between linguistic domains and phonological awareness. Similarly, although not directly tested in this study, it seems likely that, because the relationships between phonological awareness and the language variables were similar to those of typically developing children, children with mild intellectual disabilities respond similarly to environmental influences. Although the process of lexical restructuring may be more protracted for children with mild intellectual disabilities, it may be the case that the environmental influences that facilitate it are the same, culminating in similar relationships between expressive and receptive language and phonological awareness.

Naming Speed and Language Variables

The results of this study indicated that there were medium and significant negative relationships between the two language latent variables and naming speed (see Figure 5). Children who demonstrated stronger expressive language skills had lower naming speed latencies relative to children with weaker expressive language skills. Likewise, children who had stronger receptive language skills had lower naming speed latencies relative to children with weaker receptive language skills. This means that children with stronger language skills were able to speak the names items in an array more quickly than children with weaker language skills.

These results were consistent with the assumption that naming speed tasks measure, among other things, the strength of lexical representations (Wolf, Bowers et al., 2000). In other words, one way that an individual can excel at a naming speed task is if they have well defined

concepts associated with each of the items in the array that he or she is attempting to name. It is likely that the individuals that have better expressive and receptive language skills also have better defined mental representations associated with their language skills. As a result, it took less time for them to name the items in an array during a naming speed task.

Furthermore, two of the tasks of the CELF-4 contained strong working memory components, a second aspect that is important when completing a naming speed task. In order to complete a naming speed task, a participant must recall the label for an item in the array into working memory and then hold it there long enough to speak the name of the item. The recalling sentences subscale of the CELF-4 heavily loaded onto the expressive language latent variable. This subscale required participants to orally repeat increasingly complex sentences to the administrator. Likewise, the concepts and following directions subscale of the CELF-4 heavily loaded onto the receptive language latent variable. This task required participants to listen to spoken directions, and then point to items in an array in a particular order, per the instructions. Consequently, both subscales had a strong working memory component in that they required participants to keep complex linguistic stimuli in working memory and either repeat it, or comply with the stimuli. In fact, the error variances for recalling sentences and concepts and following directions were correlated at .36 because of their shared working memory component (see Figure 4).

Much like the relationships between phonological awareness and the latent language variables, the relationships between naming speed and the latent language variables provide support for the similar structure and similar response to environment implications of the developmental perspective as it relates to individuals with mild intellectual disabilities. As stated previously, the significant relationships between naming speed and the language latent variables

were expected based on the nature of the naming speed task. Additionally, other research has indicated that individuals with intellectual disabilities do not demonstrate deficits in naming speed relative to mental age matched controls (Conners et al., 2006; Ypsilanti, Grouios, Zikouli, & Hatzinikolaou, 2006). Taken together, this suggests that individuals with mild intellectual disabilities do indeed have a similar structure and respond similarly to the environment, at least as it relates to naming speed and language, relative to reports of typically developing individuals in other studies.

Measurement Issues

Measuring phonological processing in populations of children that have a high incidence of speech and language difficulties, which are commonly associated with intellectual disability, is a difficult task. This is because many published assessments of phonological processing rely on expressive oral responses from students in order to gauge the respondents' competence on a particular task (Iacono & Cupples, 2004). With the exception of the sound matching task of the CTOPP, all of the measurements of phonological processing used in this study heavily relied on spoken responses from the participants. The concern of how this might affect the validity of the measurements for the children in this study, however, was assuaged by the fact that the CFA models produced a well fitting latent factor structure that was congruent with prevailing theory about the structure of phonological processing for typically developing children (e.g., Anthony & Lonigan, 2004; Wagner et al., 1993). The results of this study suggest that, taken as a group (with the exception of segmenting nonwords), the subscales of the CTOPP used in this study may provide a valid measurement of phonological processing for individuals with mild intellectual disabilities.

Instructional Implications

Skills related to both phonological awareness and naming speed are important areas to consider when developing a reading intervention for school-aged children. The separateness of these skills implies that supporting one of them may not necessarily support the other. Furthermore, these findings provide a rationale for utilizing conventional reading instructional strategies that focus on supporting phonological processing that are commonly used with typically developing children or with children with reading disabilities. It stands to reason that if children with mild intellectual disabilities demonstrate phonological processing abilities with the same structure as typically developing children then they should respond to the same types of instruction.

Evidence is beginning to emerge that demonstrates that reading instruction strategies designed for typically developing children and children with reading disabilities also are effective for children with intellectual disabilities. For example, Hedrick and colleagues (1999) demonstrated that a multimethod approach to literacy instruction that emphasized decoding, comprehension, vocabulary, and writing resulted in significant reading gains for individuals with mild to moderate mental retardation. Likewise, Conners and colleagues (2006) demonstrated that a phonological skills instruction program could help children with intellectual disabilities learn skills related to phonological awareness. In fact, the data used in this dissertation are baseline measurements for children with mild intellectual disabilities who participated in a project with the goal of assessing the effectiveness of different interventions designed specifically for children reading disabilities. One intervention, Phonological Analysis and Blending/Direct Instruction (PHAB/DI; Lovett et al., 2000), focuses specifically on teaching skills related to the analysis and blending of phonemes. The second intervention, which

combines PHAB instruction with Rate, Automaticity, Vocabulary Elaboration, and Orthography instruction (RAVE-O; Wolf, Miller, & Donnelly, 2000) focuses on teaching phonological awareness skills and skills that affect results on naming speed measures. Preliminary data from this project suggests that these interventions are successful in teaching reading skills to children with mild intellectual disabilities (Sevcik, Wise, Morris, & Romski, 2010).

Limitations and Future Directions

Although the design of this study answered questions about the structure of phonological processing and language for individuals with mild intellectual disabilities, and facilitated speculation about the role that environmental influences may have had in determining the structure of phonological processing and language, it did not address questions related the sequence of development for this population. In fact, because of this study's cross-sectional design and a focus on only one baseline observation, it is difficult to make any assumptions about the sequence of development for participants before or after the data was collected. Additional research should be conducted to determine the antecedents to the structural state of phonological processing and language described in this study. Additionally, the larger study from which the data for this dissertation was drawn has three additional time-points of data that will enable questions regarding the sequence of development following the initial observation described here. In the future, it is vitally important to extend the information presented in this dissertation to include additional observations to answer important questions related to the sequence of the development of phonological processing for children with mild intellectual disabilities.

Commensurate with the limitation regarding inferences about sequence of development, it is important to note that the design of this study was completely correlational in nature. As a

result, it is only with caution that any causal inferences should be made regarding these analyses. In fact, the path coefficients estimated for this study were only done so in order to answer different questions about the nature of the data. Specifically, using expressive and receptive language as criterion variables and phonological awareness and naming speed as predictor variables (see Figure 6) demonstrated that phonological awareness and naming speed were indeed measuring two different aspects of phonological processing. Turning the analyses around and using phonological awareness and naming speed as criterion variables and expressive and receptive language as predictor variables (see Figure 7) was supposed to reveal the relationships between the criterion and predictor variables while controlling for the other predictor variable in the model. However, this revealed that the high degree of multicollinearity between expressive and receptive language made these results difficult to interpret. Considering the correlational nature of the study and the fact that all of the measures were collected at the same baseline time point, it was most appropriate to interpret the bivariate correlations between the latent variables.

Additionally, there are many factors that are related to reading success that were not taken into account for this dissertation. One, for example, is working memory. Working memory generally, and the phonological loop (Baddeley, 1986), specifically, allows individuals to hold phonemes in conscious awareness and manipulate them. Researchers have found children with intellectual disabilities who were strong decoders had significantly better rehearsal in phonological memory than children with intellectual disabilities who were poor decoders (Conners et al., 2001). Others have reported that, for school-aged children with intellectual disabilities and severe speech impairments, poor phonological rehearsal may be responsible for poor reading skills, in spite of adequate phonological knowledge (Dahlgren Sandberg, 2001). Although phonological awareness and naming speed are very important skills that predict

successful reading in children, it may be important to consider other skills and abilities, such as working memory, when developing an intervention strategy for children with intellectual disabilities.

Finally, it is important to expand the scope of this work in the future to involve reading outcome variables. Although this study was successful in describing the structure of phonological processing for children with mild intellectual disabilities, an important next step is to include measures of decoding and reading achievement to ensure that phonological awareness and naming speed, for children in this sample, are associated with reading outcomes in the same way that they are for children who are typically developing. On a related note, it is important to determine whether language variables and phonological awareness and naming speed interact to predict reading outcomes. This will enable researchers and clinicians to identify profiles of phonological processing and language that can be used to inform the best strategies for intervening in and remediating reading difficulties for children with mild intellectual disabilities.

Conclusions

In conclusion, this dissertation represents an important first step in understanding the development of phonological processing for children with mild intellectual disabilities. It established that the structure of phonological processing for children with intellectual disabilities resembles that of typically developing children. Furthermore, it demonstrated that the components of phonological processing (i.e., phonological awareness and naming speed) are related to linguistic factors (i.e., expressive and receptive language) in predictable ways, much like typically developing children. These results support the assumption that individuals with mild intellectual disabilities move through many of the same steps as typically developing children on the road to becoming literate adults. Furthermore, they highlight that it may be very

important to support the development of phonological processing and language in order to help these children, who are at high risk for not learning to read, achieve appropriate levels of literacy.

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Appendix A

Boundary Constraints

One issue that must be addressed when conducting a CFA and testing increasingly complex models where the indicators are used to define different latent constructs is that of bias introduced because of boundary constraints (Stoel, Garre, Dolan, & van den Wittenboer, 2006). For example, in the case of the phonological processing CFA described in this study, the single phonological processing model was essentially the two-factor solution with the correlation between phonological awareness and naming speed constrained to 1.00. Constraining that correlation to 1.00 may have resulted in an underpowered χ^2_D test. In order to correct for this, Stoel and colleagues (2006) suggest utilizing the actual parameters estimated from the sample generate a χ^2 distribution for the null hypothesis. According to Stoel and colleagues (2006) the general χ^2 distribution with 1 degree of freedom typically used to compare change in fit from the two-factor solution to the one-factor solution may overestimate the χ^2 value necessary to reject the null hypothesis. This systematically increases the likelihood that the null hypothesis will not be rejected. In other words, it influences the likelihood that the model with fewer latent abilities will not fit significantly worse than the previous model.

Stoel and colleagues (2006) explain that in order to correct underpowered significance tests that result from testing parameter boundaries, one must utilize a boundary corrected χ^2 distribution. The strategy for doing so is outlined in the article. Of primary application for this set of analyses is an adjustment of the critical value of χ^2 with $df = 1$. In a standard χ^2 distribution with $\alpha = .05$, the critical value of χ^2 is 3.84. In the boundary adjusted χ^2 distribution with $\alpha = .05$, however, the critical value of χ^2 is 2.71. See Stoel and colleagues (2006) for a complete explanation.

In order for bias introduced from boundary constraints to have affected the results of this study, the χ^2_D for each analysis must have fallen between 3.84 and 2.71, and thus must have been not statistically significant with $df = 1$ and $p < .05$. Each χ^2_D in this study was much larger than 3.84; for the phonological processing CFA, the χ^2_D with $df = 1$ was 245.51 and for the language CFA, the χ^2_D with $df = 1$ was 17.04, both of which are statistically significant. Consequently, it appears that issues related to boundary constraints were not of concern for this particular study.

Appendix B

Analyzing Count Data as Continuous

This appendix contains figures for CFA's that parallel the phonological processing model, but with all variables characterized as continuous variables instead of a mix between ZIP, binary, and continuous variables. The results of these analyses indicated that fit was poor for each model, as seen in Figures B1 and B2. Furthermore, the AIC and BIC for the continuous models were considerably higher than the corresponding values for the analyses that characterized the data as ZIP and binary. Consequently, characterizing blending words, blending nonwords, and elision as ZIP variables and segmenting words and segmenting nonwords as binary variables was the appropriate strategy for analyzing the data presented here.

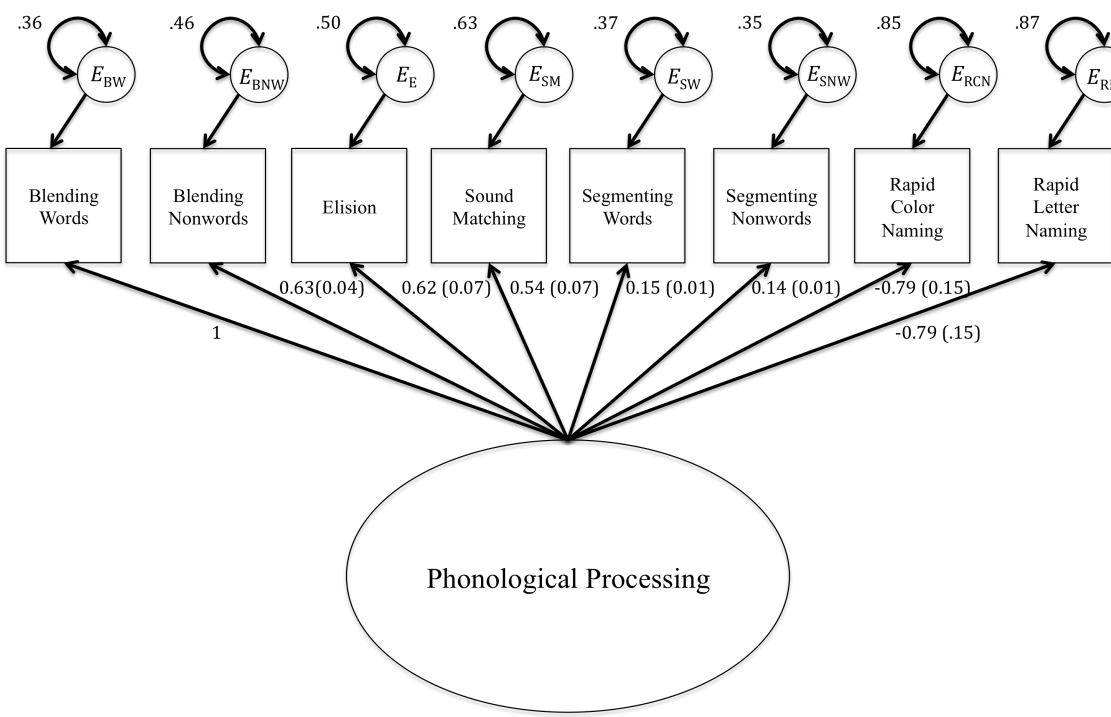

Figure B1. Model of phonological processing with one latent ability and all variables characterized as continuous. Values on paths represent unstandardized factor loading. Values in parentheses represent standard errors. Solid lines indicate significant loadings. The fit statistics for this model are: $\chi^2(21) = 186.77$, $p = .00$, SCF = 1.26, RMSEA = .19 (90% CI: .16 - .21), CFI = .74, SRMR = .11, AIC = 6603.45, BIC = 6608.83.

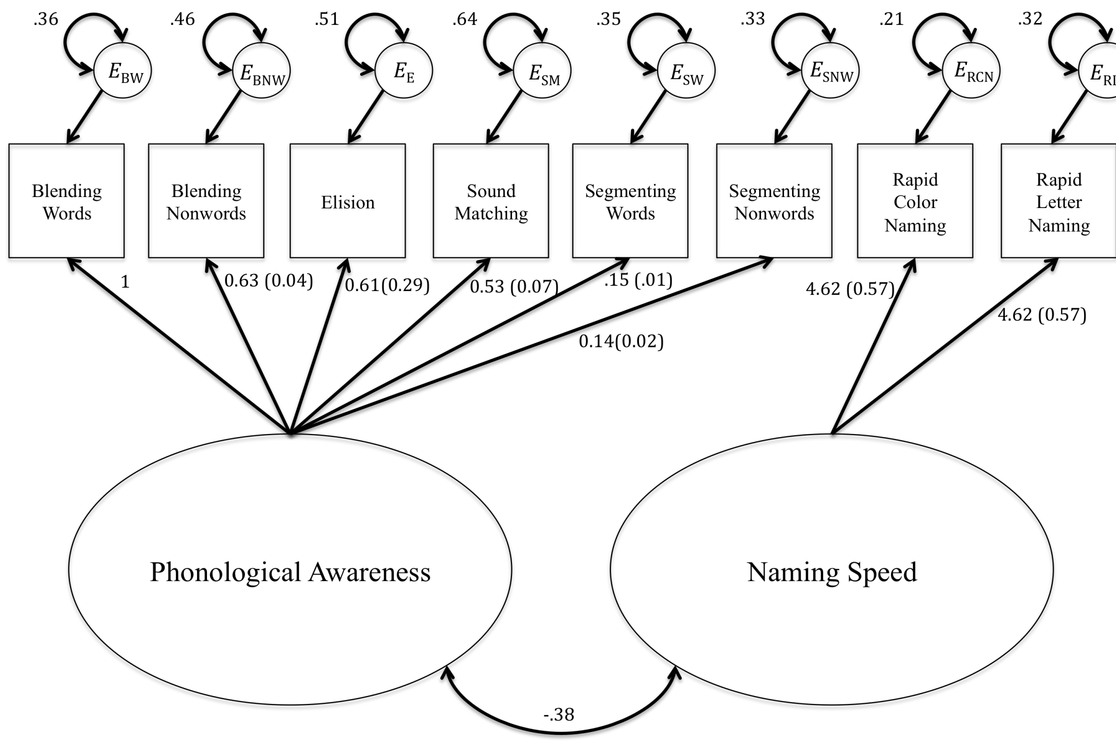

Figure B2. Model of phonological processing with two latent abilities and all variables characterized as continuous. Values on paths represent unstandardized factor loading. Values in parentheses represent standard errors. Solid lines indicate significant loadings. The fit statistics for this model are: $\chi^2(20) = 82.71$, $p = .00$, SCF = 1.18, RMSEA = .12 (90% CI: .09 - .15), CFI = .90, SRMR = .06, AIC = 6467.91, BIC = 6473.52.