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A Model of Phonological Processing, Language, and Reading for Students with Mild Intellectual Disability

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Abstract

Little is known about the relationships between phonological processing, language, and reading in children with intellectual disability (ID). We examined the structure of phonological processing in 294 school-aged children with mild ID and the relationships between its components and expressive and receptive language and reading skills using structural equation modeling. Phonological processing consisted of two distinct but correlated latent abilities: phonological awareness and naming speed. Phonological awareness had strong relationships with expressive and receptive language and reading skills. Naming speed had moderate relationships with these variables. Results suggest that children with ID bring the same skills to the task of learning to read as children with typical development, highlighting that phonologically based reading instruction should be considered a viable approach.

Keywords

phonological processing; phonological awareness; naming speed; intellectual disability

For students with intellectual disability, even the most basic levels of literacy are often difficult to achieve. The reading skills of students with intellectual disability often lag behind their peers, and as students age, their academic performance gains slow considerably compared to typically developing students (Gronna, Jenkins, & Chin-Chance, 1998). Additionally, the reading achievement of individuals with intellectual disability often lags behind their own mental ages (Cawley & Parmar, 1995). Models of phonological processing in children with typical development have demonstrated that phonological awareness and naming speed are core components that contribute to reading success. Evidence is emerging that indicates difficulties with these components may be responsible, in part, for the reading

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difficulties of students with intellectual disability. To date, however, a comprehensive model of the components of phonological processing does not exist for students with mild intellectual disability (MID). The purpose of the current investigation was to construct such a model using confirmatory factor analysis (CFA), and to determine the relationship between the components of phonological processing, language, and reading skills.

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) and is largely a linguistic process (Liberman & Shankweiler, 1991). Phonological processing, and its components, have been consistently linked to successful reading in children with typical development (Adams, 1990; Rieben & Perfetti, 1991). Phonological processing refers to the metalinguistic skill of using the sound structure of oral language when processing both written and oral information (Anthony et al., 2006; Anthony, Williams, McDonald, & Francis, 2007).

Recent studies, using confirmatory factor analysis (CFA), have demonstrated phonological processing consists of three distinct but correlated abilities in children with typical development: phonological awareness, phonological memory, and naming speed (Anthony et al., 2006; Anthony et al., 2007). We focused on two of these components, phonological awareness and naming speed, for the current study. Phonological awareness is the ability to focus on and manipulate segments of speech, including words, syllables, and phonemes (Gillion, 2004; National Institute of Child Health and Human Development, 2000; 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). Phonological awareness has been consistently defined by measures of elision and blending (Anthony et al., 2006; Anthony et al., 2007), as well as rhyme sensitivity, segmental awareness, and phonological sensitivity (Anthony & Lonigan, 2004; Anthony et al., 2002) for children who were in preschool through first-grade. Naming speed describes an individual's ability to rapidly name visual stimuli (e.g., letters, numbers, colors, and simple objects) presented in a list from left-to-right and top-to-bottom in a manner consistent with English reading. Results are an indicator of the efficiency that one can retrieve phonological and lexical codes from memory (Wolf, Bowers, & Biddle, 2000). Naming speed has been defined by variables that measure rapid serial naming of objects and sizes (Anthony et al., 2006; Anthony et al., 2007) and letters and digits (Wagner, Torgesen, Laughon, Simmons, & Rashotte, 1993) in CFA studies. The current study focused on these two components of phonological processing in children with mild intellectual disability. We did not investigate phonological memory in this study because indicators of this variable were not available from the larger project from which this data were drawn.

Phonological Awareness and Reading

Phonological awareness, and its connection to reading, has been the focus of considerable research. Many studies have indicated that successful beginning readers have strong phonological awareness. This is true for children with typical development (Adams, 1990; Catts, Gillispie, Leonard, Kail, & Miller, 2002; Muter, Hulme, Snowling, & Stevenson, 2004; Perfetti, Beck, Ball, & Hughes, 1987; Tunmer, 1991; Wagner & Torgesen, 1987; Wagner, Torgesen, & Rashotte, 1994; Whitehurst & Lonigan, 1998) and children with disabilities (Bird, Bishop, & Freeman, 1995; Blischak, Shah, Lombardino, & Chiarella, 2004; Morris et al., 1998). 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 comparison of 183 students assessed from kindergarten through fourth grade, Catts et al. (2002) demonstrated that students who

were poor readers (i.e., students who scored at least 1 standard deviation below the mean on a measure of reading comprehension in second and fourth grade, $n = 66$) scored significantly lower on measures of phonological awareness in fourth grade than students who were typical readers (i.e., students who scored higher than -1 standard deviation on reading comprehension in second and fourth grade, $n = 117$).

Considerably less research has investigated the role phonological awareness plays in reading success for individuals with intellectual disability. Of this limited research, however, patterns have emerged that are similar to those of children with typical development (Cawley & Parmar, 1995; Conners, Atwell, Rosenquist, & Sligh, 2001; Cupples & Iacono, 2000; Lemons & Fuchs, 2010; Saunders & DeFulio, 2007; Wise, Sevcik, Ronski, & Morris, 2010). Saunders and DeFulio (2007) demonstrated that phonological awareness had strong positive correlations with both word identification and word attack, even after controlling for the effect of IQ, in a sample of 30 adults. 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. Their results indicated that Time 1 phoneme segmentation skills accounted for a significant proportion of variance in Time 2 nonword reading, after controlling for Time 1 nonword reading. Conners et al. (2001) demonstrated strong differences on measures of phonological awareness between two groups of children with intellectual disability who were either strong decoders or weak decoders. This difference, however, was no longer present when the authors controlled for participants' age. Wise and colleagues (2010) demonstrated large proportions of variance accounted for by measures of blending, elision, and letter-sound knowledge in word and nonword identification skills in a group of elementary school children with mild intellectual disability. Finally, in a review of reading studies on children with Down syndrome, Lemons and Fuchs (2010) concluded that phonological awareness skills were important predictors of reading skills in this population.

Evidence is also mounting for the success of phonics-based instruction for children with intellectual disability. For example, Conners, Rosenquist, Sligh, Atwell, and Kiser (2006) 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 into pairs based 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 instruction. 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. A 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. Instruction contained a component that focused on decoding skills. Each student made gains from pre- to post-testing in decoding of unfamiliar printed words. Lemons and Fuchs (2010) also concluded that phonological awareness instruction was an important for children with Down syndrome in their review. The results of these studies 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 spite of this evidence, much of the research base for teaching children with developmental disabilities to read has focused on sight word instruction. In a comprehensive review of 128 studies on teaching reading to children with significant disabilities, approximately 75% focused on teaching sight words (Browder, Wakeman, Spooner, Ahlgrim-Dezell, &

Algozzine, 2006). Only 10% focused on phonics instruction; moreover, according to the evaluation criteria established by the authors, only one study was of high quality. Of the research reviewed, however, the studies that used phonics-based approaches had the largest effect sizes.

Naming Speed and Reading

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; Wagner et al., 1993; Wagner et al., 1994; Wagner et al., 1997). For example, research has demonstrated that individuals diagnosed with dyslexia have significantly longer naming speed latencies than typical readers, regardless of IQ (Denckla & Rudel, 1976). Others have demonstrated that naming speed latency accounted for up to 28% of unique variance in reading performance in second graders (Manis et al., 2000). In elementary students with typical development, Wagner and colleagues have demonstrated strong correlations between naming speed and word reading within a single time point (Wagner et al., 1993) and strong correlations between naming speed and word reading one year later (Wagner et al., 1994; Wagner et al., 1997). To date, however, very few studies have investigated the relationship between naming speed and reading for individuals with intellectual disability. One, by Saunders and DeFulio (2007), demonstrated strong correlations between naming speed and reading measures, after controlling for IQ.

Hypotheses

To date, research concerning the structure of phonological processing has been conducted only with young children with typical development. Considering the data demonstrating similar relationships between reading and its correlate skills for children with and without MID, it stands to reason that phonological awareness will have the same structure for both groups of children. This assertion, however, has not been tested empirically. Consequently, research has not described a model of phonological processing for children with MID. The description of such a model for children with MID will help inform recommended practices for supporting the development of this skill so vital to reading acquisition.

The first goal of this paper was to determine the structure of phonological processing for students with MID using a confirmatory factor analysis (CFA) strategy. Specifically, we tested whether assessments of phonological processing that focus on segmenting, blending, manipulation, and matching of phonemes, and naming speed measure either a single latent phonological processing construct, thus representing a general phonological ability, or if these measures represent two separate but correlated components of phonological processing. Based on previous research and the fact that we did not include measures of phonological memory, we hypothesized phonological processing would consist of two distinct but correlated abilities: phonological awareness and naming speed.

Second, staying within the structural equation model framework, we determined the linguistic and reading correlates of the components of phonological processing for students with MID. Consistent with the results of research with individuals with typical development and intellectual disability described previously, we hypothesized that phonological awareness would be positively correlated with expressive and receptive language and reading variables, such that students with stronger phonological awareness would demonstrate relatively stronger language and reading skills. We also hypothesized that naming speed would be negatively correlated with expressive and receptive language and reading, such that students who had faster (i.e., shorter) naming speeds would also demonstrate relatively stronger language and reading skills.

Method

The data analyzed for this paper were collected as a part of a larger project investigating the impact of selected reading programs with a sample of elementary school students diagnosed with MID (Sevcik, Wise, Morris, & Ronski, in preparation). Data were collected over five school years. The data analyzed here are from the baseline observation, prior to intervention.

Participants

Participants were screened with a set of inclusion and exclusion criteria. All inclusion and exclusion information was obtained by a combination of parent report and school records, unless otherwise noted. Inclusion criteria were second to fifth grade, identification by the child's school as having mild intellectual disability, and reading skills below the 10th percentile on the *Woodcock Reading Mastery Test-Revised* (WRMT-R; Woodcock, 1998) word identification and word attack subscales. Exclusion criteria were 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).

We recruited participants from 11 public elementary schools in a large metropolitan area of the Southeastern United States. Classroom teachers, who were informed of our selection criteria, referred children for participation. After obtaining consent from parents, 307 students were given the pre-intervention assessment battery for the larger study. Participants for the present study were selected from this pool of participants. Thirteen of these participants were not included in the final sample because they were missing data on two or more of the measures evaluated for this study. Thus, the final sample for this study was 294 students with MID.

All participants were enrolled in special education services. Demographic information, broken down by grade, is presented in Table 1. IQ scores were obtained from each child's school when available. IQ did not differ between grades, $F(3,198) = 0.39$, $p = ns$, partial $\eta^2 = .01$. The mean IQ of the participants was 63.11 ($sd = 9.76$, $n = 202$). Age differed significantly between grades (see Table 1), $F(3,290) = 266.30$, $p < .01$, partial $\eta^2 = .73$. The mean age of the sample was 110.92 months ($sd = 15.85$). One hundred and six (36%) participants were female. There were 92, 66, 79, and 57, second-, third-, fourth-, and fifth-graders, respectively. Finally, the sample was ethnically diverse; there were 163 African American students, 64 Caucasian students, 45 Latino students, 9 Asian students, 12 multi-racial students, and 1 student's parent or guardian selected "other."

Assessment Battery

The following assessments were administered as part of the assessment battery for the larger study prior to intervention. All assessments were administered according to published instructions.

Phonological processing—Students' phonological processing was measured using the *Comprehensive Test of Phonological Processing* (CTOPP; Wagner, Torgesen, & Rashotte, 1999) elision, blending words, blending nonwords, segmenting words, segmenting nonwords, sound matching, rapid letter naming, and rapid color naming subscales. The alpha coefficients for these measures were .89, .84, .81, .89, .90, .93, .82, and .82, respectively, per the CTOPP examiner's manual.

Phonological awareness measures: The segmenting words and nonwords subscales measured an individual's ability to divide words or nonwords into their respective

phonological components. Initial items required awareness at the phoneme level (e.g., “Say *no* one sound at a time”).

The blending words and nonwords subscales measured an individual’s ability to take individual phonemes or groups of phonemes presented in the auditory modality, and coarticulate them into real words and nonwords, respectively. Initial items required awareness at the syllable level (e.g., “What word do these sounds make? *Num – ber*”).

The elision subscale measured an individual’s ability to break real words into parts, delete a piece, and coarticulate the remaining pieces into a new word. Initial items required awareness at the word level (e.g., “Say *popcorn*. Now say *popcorn* without saying *corn*”).

The sound matching subscale measured an individual’s ability to match the onset or rime phoneme of a stimulus word with that of a target word. All sound matching items required awareness at the phoneme level (e.g., “Which word starts with the same sound as *par*. *pig*, *hat*, or *cone*?”).

Naming speed measures: Students’ naming speed was assessed using the rapid color naming (RCN) and rapid letter naming (RLN) subscales of the CTOPP. Both subscales measured the time it took a participant to 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 contained two arrays with four rows of nine items each. Times were summed across the two arrays.

Language—Students’ language was measured using the *Expressive Vocabulary Test* (EVT; Williams, 1997), the *Peabody Picture Vocabulary Test – III* (PPVT-III; Dunn & Dunn, 1997), and subscales of the *Clinical Evaluation of Language Fundamentals – 4* (CELF-4; Semel, Wiig, & Secord, 2003).

Expressive language: The EVT (Williams, 1997) was administered to measure students’ expressive vocabulary. In the first section of the EVT, children are asked to speak the names of pictures or body parts pointed to by the administrator. In the second section, children speak a synonym of a word spoken by the administrator and represented by a picture. The EVT examiner’s manual reports internal consistency coefficients that range from .90 to .98. Test–retest reliabilities range from .77 to .90.

Three additional measures of expressive language were given from the CELF-4 (Semel et al., 2003): word structure, recalling sentences, and formulated sentences. Word structure assessed the 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. Recalling sentences measured the ability to repeat a sentence exactly the way it was presented. Formulated sentences assessed the ability to create complete, semantically and grammatically correct spoken sentences of increasing length and complexity, using given words and contextual constraints imposed by illustrations. The CELF-4 examiner’s manual reports alpha coefficients of .83, .91, and .81 for word structure, recalling sentences, and formulated sentences, respectively.

Receptive language: The PPVT-III (Dunn & Dunn, 1997) was administered to measure students’ receptive vocabulary. Children are shown an easel page with four line-drawn pictures. They are asked to point to or say the number of the picture that goes with the name spoken by the administrator. The PPVT-III examiner’s manual reports internal consistency coefficients that range from .89 to .97 for Form A and .86 to .96 for Form B. Test–retest reliabilities range from .91 to .94.

Three additional measures of receptive language were given from the CELF-4 (Semel et al., 2003): concepts and following directions (C&FD), sentence structure, and word classes 1. C&FD assessed the 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. Sentence structure assessed the ability to interpret spoken sentences of increasing length and complexity and select pictures that illustrate referential meaning of the sentence. Word classes 1 assessed the ability to understand relationships between words that are related by semantic class features and to express those relationships by pointing to a visual array. The CELF-4 examiner's manual reports alpha coefficients of .87, .70, and .90 for C&FD, sentence structure, and word classes 1, respectively.

Reading measures—Reading skills were assessed using the word identification and word attack subscales of the WRMT-R (Woodcock, 1998). The word identification subscale measured real word reading. The word attack subscale measured the ability to decode nonwords. The WRMT-R examiner's manual reports the split-half reliabilities for word identification and word attack to be .98 and .94, respectively.

Procedure

Trained administrators collected data during the baseline assessment at each child's school. Assessment administration occurred in a small quiet room in a one-on-one setting. Assessments were administered per the instructions of each assessment's published administration manual. Students were redirected to the assessments when distracted and given breaks as needed to ensure that scores were representative of student skill level. Students received a score of 0 on any assessment only when the ceiling rule for the assessment had been reached and the student had gotten no answers correct. The entire assessment battery, including assessments not analyzed here, took approximately three to five hours to administer. Assessment occurred over the course of multiple visits.

Results

Descriptive statistics of the raw scores for each variable are presented in Table 2. The means for each variable (except RCN and RLN) represent the average number of items correct. The means for RCN and RLN represent the average number of seconds it took for participants to name the stimuli. Fourteen of 18 variables demonstrated significant skew and 12 of 18 demonstrated significant kurtosis, as evidenced by skew or kurtosis statistic to standard error ratios greater than two (see Table 2). No more than 16% data was missing for any one variable (see Table 2). Missing data were generally the result of absenteeism, scheduling conflicts, students transferring to other schools, or administrator error. Some students were missing RCN ($n = 7$) and RLN ($n = 21$) data because they could not name the practice stimuli and, per the published instructions, could not take the assessment. In addition, 36 students were missing blending nonwords and segmenting nonwords data because these subscales were added to the assessment battery after the beginning of the study. Missing data were addressed using full information maximum likelihood (FIML) fitting in the CFA analyses.

Phonological Processing CFA

The structure of phonological processing for students with MID was determined utilizing CFA with *Mplus* Version 5.21 (Muthén & Muthén, 2007a). CFA is an analysis strategy that allows the researcher to a priori define the observed variables that measure a latent construct and then determine whether the hypothesized model fits the observed data. CFA uses

maximum likelihood estimation, which iteratively estimates parameter values that maximize the likelihood that the observed data were drawn from the population in question (Kline, 2005). Furthermore, maximum likelihood estimation is a full information method that calculates all parameters simultaneously and takes all available information into account.

Data preparation—Steps were taken to prepare the data for 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, rapid letter naming, PPVT-III and EVT were divided by the constant 10 so that each variable was on approximately the same scale (Kline, 2005). In addition, maximum likelihood estimation with robust estimates (MLR) was used 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 provides parameter estimates with standard errors and chi-square statistics that are robust to non-normality and non-independence of observations (Muthén & Muthén, 2007b). Elision, blending words, blending nonwords, segmenting words, and segmenting nonwords all exhibited significant positive skew (see Table 2), a violation of the normality assumption for maximum likelihood estimation. An investigation of the distributions revealed that elision, blending words and blending nonwords subscales were characterized by a high number of scores of 0 (see Table 2) with an approximately normal distribution through scores 1 and higher. This type of distribution best approximates a zero-inflated poisson (ZIP) distribution. Because normality is not assumed for ZIP variables, elision, blending words, and blending nonwords subscales were characterized as ZIP distributions in the CFA analyses. Likewise, the segmenting words and segmenting nonwords subscales had a large proportion of 0s with the remaining scores scattered throughout the range of scores. To address this violation of normality, these variables were entered into the CFA as binary variables where a score of 0 indicated the student did not get any items correct and 1 indicated they got one or more items correct on the subscale.

FIML fitting was used to estimate 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. Monte Carlo 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).

Structure of phonological processing—The CFA consisted of nested models that tested whether the two-factor model of phonological processing fit better than the one-factor model. Because we used the MLR estimator and included ZIP and binary variables, relative model fit was indicated by comparing model loglikelihood (LL) values with the scaled χ^2 difference test (χ^2_D ; Satorra & Bentler, 2001) and the Akaike Information Criterion (AIC) between the models. A significant increase in the loglikelihood statistic (i.e., values closer to 0) would indicate statistically significant better model fit and justify the less parsimonious two-factor model. Age was included as a covariate in each model.

First we estimated a general model where all of the CTOPP subscales were used as indicators of a single phonological processing latent construct, $LL = -4139.22$, parameters = 22, scaling correction factor (SCF) = 1.47, $AIC = 8322.44$. Next, we estimated a two-factor model of phonological processing using elision, sound matching, blending words, blending nonwords, segmenting words, and segmenting nonwords as indicators of a phonological awareness latent variable and RCN and RLN as indicators of a naming speed latent variable, $LL = -4070.38$, parameters = 24, $SCF = 1.44$, $AIC = 8188.76$. The scaled χ^2 difference test indicated that the two-factor solution fit the data significantly better than the one-factor

solution, $\chi^2_D(2)=126.66, p < .001$. Thus, the two-factor model of phonological processing explained the data best.

The factor loadings and error variances (when available) for each indicator and latent variable are presented in Figure 1. Standardized factor loadings (and standard errors) are presented unless otherwise indicated. Blending words, blending nonwords, elision, sound matching, segment words, and segmenting nonwords were significant indicators of phonological awareness, $p < .01$. Likewise, RCN and RLN were significant indicators of naming speed, $p < .01$. Because of problems with negative error variances, the factor loadings for naming speed were constrained to be equal. Error variances were not available for the ZIP and binary variables because variances cannot be calculated for count variables (Muthén & Muthén, 2007a, 2007b). The results indicated low residual variances for the continuously distributed indicators. Finally, phonological awareness and naming speed were strongly correlated, $r = -.47, p < .01$.

Correlates of Phonological Processing

Prior to determining the correlates of phonological processing, expressive and receptive language latent variables were created using the language measures described previously, controlling for age. Results indicated that the model fit well overall, $\chi^2(22) = 31.90, p = .08, RMSEA = .04, CFI = .99, SRMR = .02$, (see Figure 2), and that it fit better than a one-factor language model, $\chi^2_D(2)=11.41, p < .01$. Next, we used structural equation modeling to combine the CFAs for phonological processing and language to estimate the correlations between the latent constructs and the two reading variables. Specifically, we constructed a model that estimated correlations between each of the phonological processing (i.e., phonological awareness and naming speed) and language (i.e., expressive and receptive language) latent variables and the reading (i.e., word identification and word attack) observed variables, controlling for students' age. The results of this model are presented in Table 3. Results indicated that phonological awareness had strong positive associations with the language and reading variables, $r_s = .51$ to $.73, p_s < .01$. Naming speed demonstrated the moderate correlations with language and reading, $r_s = -.29$ to $-.25, p_s < .01$.

Discriminant Validity of Phonological Processing Components

We conducted an additional set of analyses to determine the discriminant validity of the phonological awareness and naming speed latent variables. To do so, we recoded RCN and RLN by subtracting each score from the maximum score for the variable. In doing so, the phonological awareness indicators and the naming speed indicators were on the same scale. In other words, after recoding, low scores on all variables indicated low skill and high scores indicated high skill. Recoding RCN and RLN did not change any of the results previously described except for the sign of the correlations between naming speed and all other variables. As a result, we could make meaningful statistical comparisons of the associations for phonological awareness and naming speed.

Starting with the final model presented previously, we estimated path coefficients from phonological awareness and naming speed to the same third variable. This is the same as regressing a dependent variable onto two predictors (i.e. phonological awareness and naming speed). We did this using expressive language, receptive language, word identification, and word attack as dependent variables. For each dependent variable, we freely estimated each path coefficient, and then constrained them to be equal in a subsequent model. We compared model fit to determine if the equality constraint resulted in significantly decreased model fit, thus indicating phonological awareness and naming speed were significantly different from one another as predictors of the dependent variable. The

model with the constrained path coefficients resulted in significantly worse model fit for each dependent variable; $\chi^2(2) = 821.38, 128.99, 10.44, \text{ and } 213.47, p < .01$, for expressive language, receptive language, word identification, and word attack, respectively. These results provide strong evidence that phonological awareness had distinct relationships with other variables in the overall model, compared to the same relationships for naming speed. Thus, discriminant validity was established for the components of phonological processing.

Discussion

The results of this study confirmed our hypothesis that phonological processing consisted of two latent abilities instead of one general phonological processing skill; these were phonological awareness and naming speed. In addition, our hypotheses concerning the relationships between the components of phonological processing and language and reading were confirmed. Phonological awareness demonstrated strong positive correlations with language and reading. Naming speed demonstrated relatively weaker but significant negative correlations with the same language and reading variables.

Six 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: blending words, blending nonwords, sound matching, elision, segmenting words, and segmenting nonwords. These results were consistent with previous research with preschool children who were typically developing (Anthony & Lonigan, 2004; Anthony et al., 2002; Anthony et al., 2006; Anthony et al., 2007). The blending and elision assessments used in these studies were conceptually similar to those in the current study in respect to instructions and linguistic complexity of initial items. Anthony and colleagues used initial items that required awareness at the word level for both blending and elision. This is important because, from a developmental perspective, items that are less linguistically complex may be easier, and thus more appropriate for students with MID. Furthermore, sound matching was conceptually similar to rhyme sensitivity measures found to load onto phonological awareness in other studies (Anthony et al., 2002). In both cases, these assessments measured awareness at the phoneme level, but used pictures to make the task easier. Finally, segmenting words and nonwords have not been included in previous research. Regardless, these variables also loaded strongly onto the phonological awareness latent variable. Taken together, these results indicate that students with MID demonstrate a phonological awareness ability that can be measured by a variety of different tasks that assess performance on a variety of different phonological awareness skills, much like children with typical development.

The strong, positive relationships between phonological awareness and language suggest that students may have been undergoing the process of lexical restructuring. Lexical restructuring refers to the process by which, as a child's vocabulary grows, the size of his or her vocabulary impacts his or her understanding that words are constructed of smaller segments including syllables and phonemes (Walley, Metsala, & Garlock, 2003). This process 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). Studies with children and adults with typical development (Garlock, Walley, & Metsala, 2001), children with reading disability (Wise, Sevcik, Morris, Lovett, & Wolf, 2007a, 2007b), and adults with mild intellectual disability (Saunders & DeFulio, 2007) have demonstrated these relationships between language and phonological awareness. This is one of the first demonstrations of the relationship between phonological awareness and language variables for school-aged children with MID.

Naming speed was indicated by two rapid naming tasks from the CTOPP: rapid color naming and rapid letter naming. This is consistent with the results of other studies that have investigated naming speed as a component of phonological processing (Anthony et al., 2006; Anthony et al., 2007; Wagner et al., 1993). Furthermore, the negative associations with language and reading are consistent with the results of other studies with children with typical development (Katzir et al., 2006; Wolf, 1991; Wolf & Bowers, 1999). To date, however, naming speed as a predictor of reading in individuals with intellectual disability has been understudied; we could find only two studies that investigated this relationship in English speaking individuals. Saunders and DeFulio (2007) demonstrated significant relationships between naming speed, language measures, and reading measures for adults with MID. Levy, Smith, and Tager-Flusberg (2003) demonstrated no significant correlations between naming speed and real word and nonword decoding in a group of 20 youth with Williams syndrome, although the effect sizes for the correlations were of moderate size (i.e., r^2 s = .15 and .30 respectively). Our results represent the first demonstration of the relationships between naming speed, language, and reading in school-aged children with MID.

Implications for Instruction

Skills related to both phonological awareness and naming speed are important areas to consider when developing reading instruction and intervention for all school-aged children. These findings provide further rationale for utilizing conventional reading instructional strategies that focus on supporting phonological processing that are commonly used with children with typical development or children with reading disability. If students with MID demonstrate phonological processing abilities with a similar structure as children with typical development then they should respond to the same types of instruction.

It should be noted that much of the research on the relationship between phonological awareness and reading, and reading instruction in children with intellectual disabilities was conducted with children with Down syndrome. There has been considerable debate about the importance of phonological awareness for developing reading skills in this population. Early reading instruction focused almost exclusively on sight word instruction, due in large part to the low language skills and IQ scores exhibited by children with Down syndrome. This approach to instruction was supported by a study by Cossu, Rossini, and Marshall (1993) that demonstrated Italian speaking children with Down syndrome scored very poorly on measures of phonological awareness (i.e., segmentation, deletion, and synthesis) compared to typically developing children who were matched on both sight word and word attack reading skills. The results of this study have been questioned, however, because of the relative difficulty of the phonological awareness tasks used compared to participants' cognitive abilities (Cupples & Iacono, 2000, 2002; Wise et al., 2010). In a comprehensive review of 20 studies conducted since 1970, Lemons and Fuchs (2010) concluded that, contrary to these findings, children with Down syndrome use phonological awareness skills when reading and that phonics-based approaches to instruction should be beneficial. The results of the current study—with its very large sample size—provides further evidence for the relationship between phonological processing and reading, and the use of phonics-based approaches to instruction for children with and without Down syndrome.

Other studies have demonstrated similar effects in samples of children with intellectual disabilities of mixed etiologies. 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 intellectual disability. Likewise, Connors and colleagues (2006) demonstrated that a phonological skills instruction program helps children with intellectual disability learn skills related to phonological awareness. Furthermore, the data used in this

paper are baseline measurements for students with MID who participated in a project with the goal of assessing the effectiveness of different interventions designed specifically for children reading disability. Preliminary data from this project suggests that these interventions are successful in teaching reading skills to children with MID (Sevcik et al., in preparation).

Much research is needed to determine the characteristics of reading instruction that are most effective for children with MID. For example, what are the relative contributions of blending, letter–sound, and vocabulary instruction to overall word reading and decoding outcomes? A recent meta-analysis of encoding instruction for children with typical development indicated large effects for instruction that used letter manipulatives, such as tiles or plastic letters, for teaching and writing phoneme–grapheme relationships on a range of reading-related measures (Weiser & Mathes, 2011). Hedrick et al. (1999) used a similar teaching strategy in the Making Words component of their intervention, although given the design of the study, it was impossible to isolate the effects of this encoding instruction. It also remains unclear whether metacognitive skills training, such as those described in the PHAST program (Lovett, Lacerenza, & Borden, 2000), would be helpful for children with MID.

Limitations

Because of this study's focus on one baseline observation, it is not possible to make assumptions about how the structure of phonological processes for students with MID may change over time. Moreover, as a result of its correlational design, it is not possible to make causal inferences about the role phonological processing or language plays in predicting future reading in students with MID. Consequently, questions remain about how the relative importance of the components of phonological processing to reading may change as a function of both instruction and maturation in this population of children.

Another limitation of the current study is the lack of phonological memory measures in order to test for the third component described by Anthony et al. (2006; 2007) in previous studies with typically developing children. They described a phonological memory latent variable indicated by tasks measuring children's recall of words, nonwords, and sentences. Phonological memory was correlated with phonological awareness at .59 and naming speed at $-.30$, controlling for age, in English-speaking children (Anthony et al., 2007) and $.78$ and $-.50$, not controlling for age, in Spanish-speaking children (Anthony et al., 2006). We collected one related measure, the recalling sentences subscale of the CELF-4, which is conceptually similar to the measures described by Anthony et al. in that students were asked to recall sentences of increasing length and complexity. We conducted a follow-up analysis to determine if recalling sentences was related to phonological awareness and naming speed in our sample similar to that described by Anthony et al. After removing recalling sentences from the expressive language latent variable, the correlations between recalling sentences and the other variables in the model (i.e., phonological awareness, naming speed, word identification, and word attack) were small and non-significant, $r_s = -.11$ to $.07$, $p_s = .25$ to $.78$. Even though this follow-up analysis did not show evidence for the strong relationships described by Anthony et al., it does not rule out the potential importance of phonological memory in this population of children with MID. Consequently, the relationship between phonological memory and the components of phonological processing and reading remains a question for future research with children in this population.

In addition, we did not have sufficient IQ data to use IQ as a covariate in this study. Because we relied on students' schools for IQ scores, we only had scores for 202 participants from many different assessments, including the *Kauffman Brief Intelligence Test* (Kaufman & Kaufman, 2004), *Wechsler Intelligence Scale for Children* (Wechsler, 2003), and the

Stanford-Binet Intelligence Scales (Roid, 2003). In some cases the assessment given could not be determined. We ran an exploratory analysis on those 202 students, however, controlling for IQ, to ensure that our findings were not related to differences in IQ among our participants. The results indicated that our pattern of results remained the same controlling for IQ; all correlations between phonological awareness, naming speed, expressive and receptive language, word identification and word attack either stayed the same or slightly increased. Consequently, controlling for IQ did not fundamentally change the findings of this study.

Another potential limitation is our focus on children with MID who had limited reading skills. It seems most likely that excluding children with MID who were proficient readers reduced the variability within each of our measures which may have biased our estimates. However, considering that our estimates were very close in magnitude to those of Anthony et al. (Anthony et al., 2006; Anthony et al., 2007)—they reported correlations between phonological awareness and naming speed of $-.50$ and $-.48$ compared to our estimate of $-.47$ —it suggests that the impact was minimal.

Finally, our relatively small numbers of students within the each grade—there were less than 100 students in each grade, and 3rd and 5th grades had 66 and 57 students, respectively—did not allow us to build grouped models of phonological processing to investigate whether relationships between phonological processing, language, and reading differed by grade. Of interest, however, is that, in spite of older preschool students with typical development having higher mean levels of phonological awareness and lower mean naming speed latencies compared to younger preschool students, Anthony et al. (2007) found that the relative associations between the components phonological processing were the same for both groups. The same patterns may hold true for our students, particularly considering that all of our students were not yet reading. Consequently, future research should investigate these relationships longitudinally to determine if the associations between the components of phonological processing remain the same, as shown by Anthony et al., or change as children with MID begin to read.

Conclusions

In conclusion, this study represents an important first step in understanding the development of phonological processing for students with MID. It established that the structure of phonological processing for school-aged children with MID resembles that of children with typical development. These results are consistent with the assumption that children with MID develop similarly to children with typical development in regards to phonological processing, language, and reading, albeit at what is likely a slower rate. Furthermore, these results highlight the importance of supporting the development of phonological processing in order to assist these students, who are at high risk for not learning to read, achieve appropriate levels of literacy.

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Figure 1.

Best fitting model of phonological processing with two latent abilities, controlling for age. Values represent factor loadings and (standard errors). * indicates unstandardized factor loadings; standardized factor loadings for ZIP variables are always 1. The remaining coefficients are standardized. All factor loadings and correlations are significant at $p < .01$. No error variances are given for blending words, blending nonwords, elision, segmenting words, and segmenting nonwords because variances cannot be calculated for count variables.

Figure 2.

Best fitting model of language with two latent abilities, controlling for age. Values represent standardized factor loadings and (standard errors). All factor loadings and correlations are significant at $p < .01$.

Table 1

Demographic Information by Grade

Grade	<i>n</i>	Girls	Age	IQ
2nd	92	33	94.80 (8.81)	64.14 (10.49)
3rd	66	22	105.83 (6.67)	62.47 (9.87)
4th	79	32	119.63 (8.93)	62.60 (9.29)
5th	57	19	130.75 (7.83)	62.66 (9.04)
Total	294	106	110.92 (15.85)	63.11 (9.76)

Note. *n* for IQ means were 69, 45, 53, and 35, for 2nd, 3rd, 4th, and 5th grades, respectively.

Table 2

Descriptive Statistics

Variable	N	M	SD	Mdn	Min	Max	%0	Skew	Kurtosis
Elision	293	1.79	2.32	1	0	12	45	1.42 (0.14)	1.52 (0.28)
SM	293	6.33	4.80	5	0	20	6	0.74 (0.14)	-0.26 (0.28)
BW	293	4.76	3.31	5	0	13	18	0.09 (0.14)	-0.89 (0.28)
BNW	248	2.37	2.34	2	0	12	34	0.77 (0.15)	0.12 (0.31)
SW	292	1.45	2.52	0	0	11	65	1.77 (0.14)	2.12 (0.28)
SNW	247	1.00	1.88	0	0	8	70	2.01 (0.15)	3.30 (0.31)
RCN	286	116.23	56.37	101.85	24.00	410.00	0	2.40 (0.14)	8.22 (0.29)
RLN	272	94.59	57.60	79.12	26.81	433.20	0	2.48 (0.15)	8.57 (0.29)
WS	285	10.75	6.64	10	0	30	5	0.39 (0.14)	-0.39 (0.29)
RS	285	17.66	14.99	16	0	74	10	1.00 (0.14)	0.88 (0.29)
FS	285	11.41	10.46	9	0	46	14	1.04 (0.14)	0.59 (0.29)
EVT	290	49.17	10.71	47	16	94	0	0.51 (0.14)	1.19 (0.29)
C&FD	286	12.80	9.22	11	0	44	4	0.81 (0.14)	0.17 (0.29)
SS	285	14.15	5.20	14	3	26	0	0.02 (0.14)	-0.74 (0.29)
WC	286	20.73	10.98	22	0	42	3	-0.12 (0.14)	-0.96 (0.29)
PPVT	294	67.06	22.43	68	4	139	0	0.03 (0.14)	0.11 (0.28)
WID	294	19.21	17.13	15.5	0	106	11	0.95 (0.14)	1.26 (0.28)
WA	294	3.26	5.56	0	0	30	50	2.30 (0.14)	5.45 (0.28)

Note. M = mean, SD = standard deviation, Mdn = median, %0 = % of participants who scored 0. SM = sound matching, BW = blending words, BNW = blending nonwords, SW = segmenting words, SNW = segmenting nonwords, RCN = rapid color naming, RLN = rapid letter naming, WS = word structure, RS = recalling sentences, FS = formulated sentences, SS = sentence structure, WC = word classes 1, WID = word identification, WA = word attack.

Table 3

Correlations Controlling for Age

	1	2	3	4	5	6
1. PA	—					
2. NS	-.44	—				
3. EXP	.73	-.28	—			
4. REC	.65	-.27	.93	—		
5. WID	.54	-.29	.37	.24	—	
6. WA	.51	-.25	.37	.22	.68	—

Note. All correlations are significant at $p < .01$. PA = phonological awareness, NS = naming speed, EXP = expressive language, REC = receptive language, WID = word identification, WA = word attack.