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A Structural Equation Model Using Fluency-Based Early Literacy Measures to Predict Emerging Reading Ability in Kindergarten

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The reauthorization of the Individuals with Disabilities Education Act has initiated changes that are affecting early literacy assessment, and it has prompted the growing use of measures that incorporate phonological and alphabetic fluency. However, the question of how phonological and alphabetic fluency can inhibit (or promote) reading acquisition in kindergarten has received sparse attention. This study investigated phonological and alphabetic fluency as a predictor of emerging reading ability in kindergarten. Results indicated that a three-construct structural equation model could be developed. Moreover, an alphabetic construct, as formed from sublexical fluency measures administered at the middle of kindergarten, fully mediated the relationship between phonological fluency and end-of-year emerging reading ability. Implications are discussed in the context of reading acquisition.

Keywords: *early intervention; reading; assessment; phonological assessment; elementary*

The field of special education has a long-standing tradition of research related to the area of reading disabilities (Becker & Gersten, 1982; Deno, 1985; Engelmann, Becker, Carnine, & Gersten, 1988). When children do not acquire the fundamental skills related to reading acquisition, reading disability is almost sure to occur (Juel, 1988; Juel, Griffith, & Gough, 1986; Speece & Ritchey, 2005; Stanovich, 1986). Acquiring fluent reading skills is a risk factor associated with a host of poor school and societal outcomes, including reading failure or disability, poor academic achievement, adult illiteracy, increased rates of problem behavior; and high school dropout (Nelson, Benner, Lane, & Smith, 2004; Trout, Nordness, Pierce, & Epstein, 2003; Walker & Shinn, 2002).

The fiscal and human cost associated with remediating entrenched reading disabilities has prompted educators to move toward prevention and early intervention (Torgesen, 2002; Walker & Shinn, 2002), as emphasized in No Child Left Behind (2002) and the Individuals with Disabilities Education Improvement Act of 2004 (2004). As an outgrowth of these efforts, the role of fluency in reading acquisition has received renewed attention (Bradley, Danielson, & Doolittle, 2005; Good, Simmons, & Kame'enui, 2001). Particularly salient is the premise that phonological and alphabetic fluency is central to reading acquisition (Kame'enui & Simmons, 2001). Three constructs germane to phonological and alphabetic fluency, as implicated in the research literature for promoting reading acquisition, are phonological awareness, alphabetic knowledge, and sublexical fluency (National Reading Panel, 2000; National Research Council, 1998; Rayner, Foorman, Perfettii, Pesetsky, & Seidenberg, 2001; Ritchey & Speece, 2006). We review each here.

Phonological Awareness

The research literature has identified phonological awareness as a fundamental construct for promoting reading acquisition (Smith, Simmons, & Kame'enui, 1998),

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by helping children move beyond the initial stages of reading acquisition (Ehri, 1998; Ehri, Nunes, Willows, et al., 2001; Schatschneider & Torgesen, 2004). Although researchers have defined phonological awareness in several ways, they generally focus on "one's awareness and access to the phonology of one's language . . . demonstrated by performance on tasks such as counting, segmenting, blending, and reversing syllables and phonemes" (Wagner, 1986, p. 623). Phonological awareness does not involve orthography (i.e., written language, spelling); it often revolves around phonemic analysis and synthesis (Stanovich, Cunningham, & Cramer, 1984; Wagner, Torgesen, & Rashotte, 1999). *Phonological awareness* refers to the broad awareness that spoken words are composed of sounds, and it includes phonemic awareness, which focuses on sound units at the phoneme level (e.g., *wait* is made up of thee phonemes; Wagner, 1986). Researchers have argued that phonological awareness is causally related to word reading and alphabetic mastery (Wagner & Torgesen, 1987), reporting correlations from .40 to .60 between phonological awareness skills in kindergarten and word reading at the end of first grade (Torgesen, Wagner, & Rashotte, 1994).

Alphabetic Knowledge

Alphabetic knowledge is the second construct identified in the research literature as promoting reading acquisition (Ehri, 1998; Ehri, Nunes, Stahl, & Willows, 2001). It generally consists of letter sounds and names and their application to unknown words. The research literature has in several ways referenced the print-related skills that cluster around the construct of alphabetic knowledge. Terms include *phoneme decoding* (Torgesen et al., 1999), *phonological recoding* (Herrmann, Matyas, & Pratt, 2006), and *cipher knowledge* (Juel et al., 1986). Knowledge of letter sounds in particular provides the basis of what Juel et al. (1986) referred to as cipher knowledge, or the rules that govern the spelling–sound correspondences of a language. For example, children apply alphabetic knowledge when they use common spelling–sound relationships to phonologically recode words (Herrmann et al., 2006; Juel et al., 1986; Torgesen et al., 1999).

The application of alphabetic knowledge is typically assessed through letter naming, letter sound identification, and nonword reading tasks (e.g., Herrmann et al., 2006; Juel et al., 1988; Torgesen et al., 1999). Children who know their letter names usually understand that letters underlie reading, not contextual and environmental cues (Ehri, 1998). Identification of letter sounds and their grapheme–phoneme relationships provides the basis of understanding the structure of words. Letter sound identification is essential for phoneme decoding, as reflected with nonword, or pseudoword, reading tasks (e.g., *rad*, *jag*, *mog*, *fum*). Researchers repeatedly observe children with reading disabilities as being deficient in nonword reading (Rack, Snowling, & Olson, 1992), an indication that they are unable to apply their alphabetic skills to words. Other types of alphabetic knowledge are required for fluent word reading (e.g., graphophonemic awareness and spelling), particularly for the reading of irregular and low-frequency words (Ehri, 1995). However, letter names and sounds and their application to words are essential prerequisites for reading acquisition.

Sublexical Fluency

The third construct important to promoting reading acquisition is sublexical fluency (Torgesen, Rashotte, & Alexander, 2001; Wolf & Bowers, 1999; Wolf & Katzir-Cohen, 2001), which refers to automaticity in phonological and alphabetic subskills and processes (Coyne, Kame'enui, & Simmons, 2001; Good, Gruba, & Kaminski, 2001; Ritchey & Speece, 2006). Sublexical fluency combines phonological and alphabetic knowledge with automaticity. Speece and Ritchey (2005) observed that "fluent reading of connected text requires knowledge of and fluency with sublexical phonological units and their orthographic counterparts" (p. 388). Fluent readers must be able to automatically retrieve phonological codes and their corresponding orthographies from long-term memory (Wagner & Torgesen, 1987).

Researchers often measure fluency indirectly, through naming speed of letters, objects, and digits (Cutting & Denckla, 2001; Denckla & Rudel, 1974; Wagner et al., 1999). Children who experience phonological processing and naming speed difficulties have a *double deficit* (Wolf & Bowers, 1999; Wolf, Bowers, & Biddle 2000). An alternative approach focuses on assessing the rapid retrieval of phonological and grapheme–phoneme relationships through direct measurement (Kaminski & Good, 1996; Ritchey & Speece, 2006). The phonological and alphabetic predictors of the present study reflect this direct measurement approach, focusing on fluency in retrieving phonological codes, naming letters, identifying letter sounds, and reading nonsense words. Next, we review the research on the measures that we used in this study that reflect phonological and alphabetic fluency.

Initial Sound, Phoneme Segmentation, Letter Naming, and Nonsense Word Fluency

We selected initial sound, phoneme segmentation, letter naming, and nonsense word fluency from the *Dynamic Indicators of Basic Early Literacy Skills* (DIBELS; Good & Kaminski, 2002). DIBELS is a short-duration early literacy measure that indexes sublexical fluency, which researchers can use to dynamically monitor reading acquisition (Good, Simmons, & Kame'enui, 2001). Moreover, researchers have placed DIBELS within a prevention-oriented problem-solving model (Good, Gruba et al., 2001), and schools have widely adopted it (e.g., Reading First; Chard et al., 2008). DIBELS has become an established metric that elementary schools use to measure response to intervention (Simmons et al., 2008). DIBELS is also one of the few measures that combine fluency with phonological and alphabetic knowledge (Rathvon, 2004).

Kaminski and Good (1996) were among the first to investigate the combining of fluency with phonological and alphabetic knowledge using DIBELS. Examining letter naming fluency and phoneme segmentation fluency in 37 kindergarteners and 41 first graders, they found criterion-related validity coefficients that ranged from .43 to .90. Results of a multivariate test revealed differences for both measures between kindergarten and first-grade students. However, the study's small number of participants limits its findings. Also, many of the current DIBELS measures were not included (e.g., nonsense word fluency).

Elliott, Lee, and Tollefson (2001) investigated letter naming fluency, sound naming fluency, initial phoneme ability, and phonemic segmentation ability in 75 kindergarteners. They found concurrent criterion-related validity correlations ranging from .12 to .81. However, their findings comprise limited utility because two of the four measures did not index fluency with accuracy.

Good, Simmons et al. (2001) reported modest predictive validity correlations for initial sound fluency and phoneme segmentation fluency. They reported a correlation of .34 between initial sound fluency at the middle of kindergarten and phoneme segmentation fluency at end of kindergarten, which in turn correlated with nonsense word fluency during the middle of first grade, at .38. Of note is that Good et al. focused on classification accuracy. They did not examine the validity of using nonsense word fluency or letter naming fluency for kindergarten. Instead, they focused on the development of cut scores for initial sound and phoneme segmentation fluency.

With a sample of 86 kindergarteners, Hintze, Ryan, and Stoner (2003) found correlations from .09 to .63 for letter naming fluency, initial sound fluency, and phoneme segmentation fluency and the phonological awareness, phonological memory, and the rapid naming composites from the *Comprehensive Test of Phonological Processing* (Wagner et al., 1999). Hintze et al. concluded that initial sound fluency and phoneme segmentation fluency were associated more closely with the test measures of phonological awareness, whereas letter naming fluency was associated with phonological awareness and rapid naming.

Speece, Mills, Ritchey, and Hillman (2003) investigated a modified letter naming fluency measure (including only lowercase letters) and nonsense word fluency, examining the extent to which they correlated with subsequent performance on the *Woodcock–Johnson Psycho-Educational Battery–Revised* Letter Word Identification and Word Attack subtests and oral reading fluency. Letter naming fluency at the end of kindergarten correlated with the Letter Word Identification subtest at .55, the Word Attack subtest at .44, and oral reading fluency at .69. The predictive criterion-related validity coefficients for nonsense word fluency correlated with the Letter Word Identification subtest at .59, the Word Attack subtest at .59, and oral reading fluency at .71. Although Speece et al. concluded that nonsense word fluency and letter naming fluency were valid measures, their small sample size (like that of Kaminski & Good, 1996) limits their findings.

Rouse and Fantuzzo (2006) investigated the convergent, discriminant, and predictive validity of letter naming fluency, phoneme segmentation fluency, and nonsense word fluency from end of kindergarten to end of first grade. Results of their canonical correlation analysis revealed that letter naming fluency was strongly associated with the structure of the *Test of Early Reading Ability–Third Edition* (TERA3; Reid, Hresko, & Hammill, 2001). Together, the three sublexical measures explained 51.9% of the variance in the instructional reading test from the *Developmental Reading Assessment* (Beaver, 1997). Letter naming fluency was the strongest predictor of the instructional reading test, followed by nonsense word fluency and phoneme segmentation fluency. Interestingly, letter naming fluency and phoneme segmentation fluency were better predictors than nonsense word fluency on the vocabulary, language, and reading subtests from the *TerraNova* (CTB/McGraw-Hill, 1997).

Letter Sound Fluency

We included letter sound fluency (Shinn & Shinn, 2002) in this study because letter identification is a prerequisite for phonological recoding and development of phoneme decoding. At the time of this study, DIBELS did not include letter sound fluency; therefore, we review it here separately. Specifically, we found four studies that examined letter sound fluency.

Stage, Sheppard, Davidson, and Browning (2001) performed one of the first studies to use the rapid identification of letter sounds in kindergarten (i.e., letter sound fluency). They used letter sound fluency and letter name fluency to predict the oral reading fluency of 59 children from the end of kindergarten through first grade (i.e., first-grade growth). Stage et al. found that letter name and letter sound fluency strongly correlated with rate of growth and with the oral reading fluency at each first-grade time point: Letter sound fluency correlated with Time 1 at .72, Time 2 at .77, Time 3 at .73, Time 4 at .71, and rate of growth at .59. However, although the authors found that letter sound fluency contributed to the prediction of oral reading fluency, letter naming fluency was a stronger predictor.

Ritchey and Speece (2006) used letter name fluency, letter sound fluency, phoneme segmentation fluency, and related accuracy measures with 92 kindergarteners. The fluency measures were administered five times to model growth in word reading and spelling from the middle to the end of kindergarten. The authors concluded that the sublexical fluency explained a small but unique amount of variance in word reading and spelling beyond the contribution of accuracy. Moreover, they found growth in sublexical fluency to be related to word reading and spelling outcomes.

Speece and Case (2001) used letter sound fluency with oral reading fluency to screen first- and second-grade children. They demonstrated an approach to use fluency-based measures to classify children as having a reading disability. In a follow-up study, Speece and Ritchey (2005) used letter sound fluency to classify a subsample of first- and second-grade children from their 2001 study. They grouped children into at-risk and nonrisk groups and monitored them for differences in growth on oral reading fluency. The authors reported that letter sound fluency in middle of the first-grade year significantly predicted growth in oral reading fluency from that point to the end of the year. Although encouraging, the results of the Ritchey and Speece (2006) and Speece and Case (2001) studies are limited in their generalization to kindergarten, given that the researchers conducted them in the first and second grades.

In summary, there is strong overall validity evidence for measures that index phonological and alphabetic fluency in kindergarten students. However, there are gaps in the literature that researchers need to address. Most of the researchers in this area tended to focus on correlational approaches using the measures themselves as observed variables. No researchers used either factor analysis or structural equation modeling to investigate the relationships between the kindergarten sublexical measures and the phonological and alphabetic constructs they reportedly represent. Moreover, no researchers used all five sublexical measures to model reading acquisition in kindergarten. In particular, they tended to neglect the use of letter sound fluency or nonsense word fluency. For example, Good, Simmons et al. did not examine letter sound fluency as a measure; moreover, they did not examine nonsense word fluency until first grade.

Rationale and Research Questions

We had several reasons for conducting the present study. First, the field needs to identify how phonological and alphabetic fluency work together to predict emerging reading ability in kindergarten. Sublexical measures of alphabetic fluency have received inadequate attention in kindergarten. Much of the published research on alphabetic fluency has focused on first grade and beyond (i.e., Burke & Hagan-Burke, 2007; Compton, 2000; Compton, Fuchs, Fuchs, & Bryant, 2006; Hagan-Burke, Burke, & Crowder, 2006; Ritchey & Speece, 2006; Speece & Case, 2001). Good, Simmons et al. focused on phonological awareness in kindergarten; they did not emphasize alphabetic fluency until first grade. Yet, we need to examine how early we can give alphabetic measures. Alphabetic fluency may be a viable construct that should be targeted for monitoring and intervention in kindergarten as opposed to first grade.

Second, the field needs to examine the relationship between sublexical fluency measures and the phonological and alphabetic constructs they reportedly represent—in particular, the degree to which phonological fluency can predict emerging reading ability (Blachman, 1997, 2000). Some have posited that phonological awareness is a causal component in reading acquisition (Wagner & Torgesen, 1987), whereas others have placed more emphasis on alphabetic knowledge (Ehri, 2005).

Third, and closely related to the previous two issues, is the validity of the sublexical fluency measures themselves. Researchers of sublexical fluency measures have established their concurrent criterion-related validity (Elliott et al., 2001), discriminate validity (Rouse & Fantuzzo, 2006), predictive validity (Good, Simmons et al., 2001; Hintze et al., 2003; Speece et al., 2003), and classification validity (Good, Simmons et al., 2001; Ritchey & Speece, 2006). Moreover, scholars widely acknowledge that phonological awareness and alphabetic knowledge both contribute to reading acquisition. However, some have criticized the validity of combining phonological and alphabetic knowledge with fluency to create measures that index sublexical fluency (Goodman, 2005, 2006; Paris, 2005; Pressley, Hilden, & Shankland, 2005; Shanahan, 2006). Examining how phonological and alphabetic fluency relate to one another, as well as to emerging reading ability, will add to their predictive and construct validity.

Data used in this study were collected as part of an outreach project funded by the Office of Special Education programs (Burke & Hagan-Burke, 2002-2006, Project CBIS: Comprehensive Behavioral and Instructional Support: An Outreach Model for Diverse Learners). We developed a multi-year data set from a model demonstration school that participated as a primary research site. As part of Project CBIS, we benchmarked the school on DIBELS three times per year for the length of the project (Good & Kaminski, 2002). In addition to DIBELS, we administered various other fluency-based predictors (e.g., LSF) along with criterion measures of interest at the different benchmark periods during the project. Although based on a single, albeit large K-2 primary school, Project CBIS has resulted in a large multi-year longitudinal data set that has allowed for a series of studies examining multiple facets of phonological and alphabetic relationships. For example, Burke, Hagan-Burke, Kwok, and Parker (2009) examined the predictive validity of initial sound fluency, phoneme segmentation fluency, letter naming fluency, and nonsense word fluency. A path model was created using a sample of 218 kindergarteners over a 3-year period. Results of the path analysis indicated that the measures were valid in predicting evermore complex reading skills (e.g., automatic sight word recognition, phoneme decoding, reading fluency, and comprehension) in a developmental progression from the middle of kindergarten to second grade. In another study using the same sample, Burke, Crowder, Hagan-Burke, and Zou (2009) compared two path models for predicting second-grade reading fluency. The path model that better represented the data was one in which phoneme segmentation and letter naming fluency had direct effects on first-grade nonsense word fluency. In addition, Burke, Crowder, et al. found that when they entered a measure of automatic sight word recognition into the path model, kindergarten phoneme segmentation, letter naming fluency, and first grade nonsense word fluency did not have direct effects on second-grade reading fluency.

In the current study, we use the early literacy measures to model relationships with external criterions not previously examined and restrict our analysis to just kindergarten. We focus on using the Project CBIS data set to model sublexical fluency measures administered at the middle of kindergarten to predict end-of-kindergarten criterions of emerging reading ability within the context of a structural equation model. We posed four main research questions:

To what degree does a structural model reflecting phonological and alphabetic fluency and early reading ability fit the sublexical fluency data (i.e., model fit)?

To what degree is phonological and alphabetic fluency (or rather sublexical fluency) related to the constructs they are intended to represent?

To what degree does a phonological fluency construct predict an alphabetic fluency construct, and to what degree do both constructs predict emerging reading ability?

Does an alphabetic fluency construct mediate the relationship between a phonological fluency construct and emerging reading ability?

To answer the first question, we constructed a measurement model and subsequent structural equation model and tested them for adequate fit. We answered the second question by examining the standardized coefficients between the measures and their representative constructs. We investigated the third question, predicting emerging reading ability, by examining the standardized coefficients among the constructs. Finally, we examined the last question with a specific test regarding mediation.

Method

Participants and Setting

We conducted the study in a large primary school in northern Georgia, serving all prekindergarten through second-grade students in a rural school district. This school served as the primary site for Project CBIS. The sample consisted of 225 kindergarteners. Of those, demographic data were available for 177: 89 students were boys and 88 were girls. The mean age of the students was 5 years, 8 months. Approximately 60% (n = 107) were Caucasian; 34% were African American (n = 60); 1% were Hispanic (n = 2); 4% were multiethnic (n = 7); and 1 student was Asian. Subsidized school lunch eligibility was used as an indicator of socioeconomic status. Thirty-seven percent (n = 66) received free school lunch; approximately 3% (n = 5) received partial financial assistance; and 60% (n = 106) received no financial assistance. Twenty-seven students (15%) received some type of special services under a label of developmental disability. We eliminated no students from the sample because of low scores or a documented disability.

Predictors

We selected four subtests from DIBELS designed for administration during kindergarten (Good & Kaminski, 2002). In addition, we administered one measure of letter sound fluency, which was not a subtest of DIBELS (Shinn & Shinn, 2002). We selected DIBELS initial sound fluency and phoneme segmentation fluency (Good & Kaminski, 2002) to represent a phonological fluency construct. Furthermore, we used DIBELS letter naming fluency and nonsense word fluency (Good & Kaminski, 2002), as well as letter sound fluency (Shinn & Shinn, 2002), to represent sublexical components of the alphabetic fluency construct. We administered all sublexical fluency measures in the middle of the kindergarten year.

Initial sound fluency. We selected DIBELS initial sound fluency as a measure that combines emerging awareness of phonemes with fluency. To administer this measure, the examiner presents a series of pictures to each child as stimulus items for the selection and production of initial sounds. During the administration of initial sound fluency, students point to the picture that matches the initial sound of a word that the examiner produces. After the student identifies three of four pictures on a page, he or she produces the initial sound of the fourth picture, which the examiner names. First, the examiner labels each picture by name: "This is *ball*, *rock*, *tree*, and *horse*." Next, the examiner asks the child to identify the picture that begins with the target sound. "Which picture begins with /r/?" Using the same prompt, the examiner asks the child to identify two other items by sound. The examiner completes the page format by asking the student to produce a target sound: "What sound does *horse* begin with?"

Examiners then record cumulative latency of response so that they can report the final score in total correct initial sounds per minute. Good and Kaminski (2002) reported an alternate-form reliability for initial sound fluency at .72 in the middle of kindergarten.

Phoneme segmentation fluency. We used DIBELS phoneme segmentation fluency as a measure of rapid retrieval of phonemes and phonemic analysis. Phoneme segmentation fluency is a measure of phonemic awareness that assesses a student's ability to fluently segment three- and four-phoneme words into their individual phonemes (Good & Kaminski, 1996). The examiner orally presents words of three to four phonemes and asks the student verbally to produce each phoneme. For example, if the examiner says "dog," the student produces the three sounds "/d/ /o/ /g/" to receive three points for the word.

Each correctly spoken phoneme is scored a point, and incorrect phonemes are not counted. The total number of correctly spoken phonemes in 1 minute is the score for phoneme segmentation fluency. Test–retest reliability for phoneme segmentation fluency is .85 (Elliott et al., 2001). Investigators have reported equivalent-form reliability as .88 (Good & Kaminski, 1996).

Letter naming fluency. We used DIBELS letter naming fluency for a measure of rapid naming of letters. During the letter naming fluency administration, an examiner presents the student with a series of upper- and lowercase letters randomly arranged in rows on a standard sheet of paper (8.5 × 11.0 in.). The student orally identifies the names of as many letters as she or he can and stops at the end of 1 minute.

The score is the number of correctly named letters in 1 minute. Reliability estimates for letter naming fluency range from .88 to .93 (Good & Kaminski, 1996).

Nonsense word fluency. We used DIBELS nonsense word fluency for a measure of phonological recoding. For nonsense word fluency, the administrator presents the student with a list of vowel–consonant and consonant–vowel–consonant nonwords (e.g., *wuj*, *ig*, *tav*). The administrator then asks the student to read the entire word or verbally produce each letter sound. For example, if the word is *wuj*, then the student could generate the separate sounds, "/w/ /u/ /j/," or pronounce them as a blended word, "wuj." The scorer counts each correct letter sound, whether produced individually or as a blended unit. The final score consists of the total correct sounds generated within 1 minute. Reliability estimates for nonsense word fluency average near .80 (Elliott et al., 2001).

Letter sound fluency. We used letter sound fluency (Shinn & Shinn, 2002) as a measure of rapid generation of letter sounds. For letter sound fluency, students name the most common sounds made by a series of letters printed in random order on a page. The series includes consonants and vowels, but only short vowel sounds are scored as correct. The final score is the number of sounds that the student correctly speaks in 1 minute. Regarding criterion-related validity, letter sound fluency measures correlate at .58 with the *Woodcock Johnson III Broad Reading Cluster* (Woodcock & Johnson, 1990) and .68 with the *Test of Phonological Awareness Skills* (Elliot et al., 2001; Wagner et al., 1999).

Criterion Measures

We administered two criterion measures from the TERA3 (Reid et al., 2001) at the end of kindergarten and combined them into a construct, early reading ability. Both criterion measures represent generalized reading skills rather than the discrete skill sets represented by the sublexical fluency measures.

Test of Early Reading Ability–Third Edition. The TERA3 (Reid et al., 2001) is a norm-referenced measure of early reading ability. We used the Alphabet and Conventions subtests to represent a construct, emerging reading ability. The Alphabet subtest includes items that probe students' ability to recognize print, name letters, and identify sight vocabulary. The Conventions subtest includes items measuring abilities such as book handling, distinguishing between upper- and lowercase letters, capitalizing, and spelling. Average coefficient alphas for subtests administered across ages were .90 for the Alphabet subtest and .83 for the Conventions subtest. Alternate-form reliability ranged from .82 to .95, whereas test–retest reliability coefficients ranged from .88 to .99. Concurrent validity between the *Stanford Achievement Tests–Ninth Edition* Total Reading subtest (Harcourt Brace & Company, 1996) and the TERA3 Alphabet subtest was .62. The *Stanford Achievement Tests–Ninth Edition* Total Reading subtest correlated with the TERA3 Conventions subtest at .66. The *Woodcock Reading Mastery Test–Revised* Word Identification subtest (Woodcock, 1998) correlated with the Alphabet subtest at .61 and with the Conventions subtest at .47.

Procedures

We strictly followed administration protocols using the guidelines provided in the DIBELS testing manual (Good & Kaminski, 2002) and the TERA3 administration manual, as well as guidelines provided by Shinn and Shinn (2002). We carefully trained a group of data collectors who were graduate students in special education to administer the predictor and the criterion measures for each administration period. The first-time graduate students assisted with the project; they completed three 2-hour training sessions, followed by a fourth in which they administered portions of each measure to one of the researchers or to a doctoral student with experience administering the measures. For students who failed to deliver each measure using the standardized procedures, we provided them with additional practice and feedback until their delivery was accurate. Only then did we schedule a data collector to administer measures on-site.

It took approximately 3 weeks to assess all the students during each assessment period. During all administration sessions at the school, the first two authors and one senior data collector rotated among data collectors, conducting reliability checks. In the middle of the year, we conducted reliability checks on 35 students, observing .87 for initial sound fluency, .95 for letter naming fluency, .90 for letter sound fluency, .91 for phoneme segmentation fluency, and .95 for nonsense word fluency. Debriefings occurred immediately after any reliability check during which we observed procedural administration errors. We also observed data collectors scoring each measure. Again, we corrected errors and gave feedback as necessary.

The school provided schedules for all classrooms with students involved in the study. This information allowed us to efficiently schedule administrations and maximize the number of students whom we could assess within a given day. The majority of test administration sessions occurred in empty classrooms as designated by the school. A doctoral student with experience administering early literacy indicators and working with the school pulled students from their teachers' classrooms and escorted them to one of the graduate students trained to administer the measures. Typically, three to six data collectors were administering the measures at any given time. In general, no more than three testing sessions occurred simultaneously in a given classroom, to decrease distractions for the children being assessed. Administrators escorted the students back to their classrooms immediately after the testing session.

Data Analysis

For this study, we focused on creating a structural equation model of reading acquisition based on phonological awareness, aspects of the alphabetic principle, and how they work together to predict emerging reading ability. We uploaded data from the assessment periods into Mplus 4.21 (Muthén & Muthén, 2007). Structural equation modeling is a multivariate technique that researchers can use to model constructs and relationships among constructs. We developed an initial hypothesized model based on previous research on early literacy indicators (Good, Simmons et al., 2001; Hintze et al., 2003; Speece et al., 2003).

We analyzed the early literacy data in Mplus and evaluated the overall fit of the model using chi-square. The chi-square statistic represents the difference between the original covariance matrix and the implied covariance matrix. A low value indicates that the hypothesized model accounted for a majority of the covariance in the original model. Unfortunately, the chi-square statistic is sensitive to nonnormal distributions, and it tends to become significant as the sample size increases (Hu & Bentler, 1998). Moreover, distributions in sublexical fluency data in kindergarten tend not to be normally distributed (Good, Simmons et al., 2001). In part, this lack of normality is likely due to the measurement of early literacy skills that are only emerging in kindergarten. For example, nonsense word fluency in middle of kindergarten is typically positively skewed, reflective of an emerging skill. However, the measure becomes negatively skewed as children attain alphabetic mastery (Good, Simmons et al., 2001).

To adjust for the nonnormal distributions, we used maximum likelihood estimation with robust standard errors and a mean-adjusted chi-square statistic test (Muthén & Muthén, 2007). To account for the dependency among the observations (i.e., children within clusters by teacher), we conducted the analyses using the "type = complex" feature in Mplus.[1] For model identification, we adopted the reference-variable/unit-loading identification strategy (Kline, 2004) in which we fixed one of the factor loadings of each latent construct to 1.0. To supplement chi-square and evaluate practical fit, we used several other indices. First, we report both the comparative fit index (CFI) and the Tucker–Lewis Index (TLI; Hu & Bentler, 1998). We use the CFI and the TLI to compare the hypothesized model to a baseline model in which all variables are presumably uncorrelated. Both the CFI and the TLI will approach a maximum value of 1 depending on whether the hypothesized model fits better than the baseline model; the general cutoff value for CFI and TLI is .90 or higher for indication of good fit. Second, we report the root mean square error of approximation (RMSEA). RMSEA reflects the fit of the population data to the model. A generally acceptable cutoff value of .08 or less indicates an adequate fit of a model. Last, we represent the difference between the residual elements of the original and reproduced covariance matrix by the standardized root mean square residual (SRMR). Values less than .08 indicate a relatively good model fit.

Table 1
Zero-Order Correlations and the Statistics for All Variables

Scale		1	2	3	4	5	6	7
PF	1. ISF	—						
	2. PSF	*.50*	—					
AF	3. LNF	.51	.54	—				
	4. LSF	.49	.60	*.77*	—			
	5. NWF	.58	.65	*.74*	*.81*	—		
Criterion	6. TERA_A2	.29	.32	.42	.40	.31	—	
	7. TERA_C2	.37	.43	.46	.47	.42	*.74*	—
M		19.00	16.76	33.84	20.77	18.71	18.82	8.73
SD		12.57	16.26	17.48	14.73	16.45	6.79	4.17
ICC		.01	.02	.05	.07	.05	.01	.02

Note: Valid $N = 225$. All correlations were significant at $p < .05$ (two-tailed). Italics denote indicators within each construct. PF = phonological fluency; IFS = initial sound fluency at Time 1; PSF = phoneme segmentation fluency at Time 1; AF = alphabetic fluency; LNF = letter naming fluency at Time 1; LSF = letter sound fluency at Time 1; NWF = nonsense word fluency at Time 1; TERA_A2 = *Test of Early Reading Ability–Third Edition*, Alphabet subtest at Time 2; TERA_C2 = *Test of Early Reading Ability–Third Edition*, Conventions subtest at Time 2; ICC = intraclass correlation.

Results

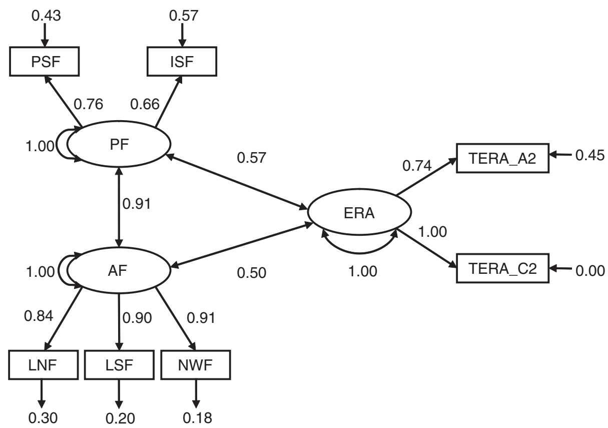
Descriptive Statistics and Correlations

We calculated descriptive statistics for the early literacy measures administered at the midpoint of kindergarten, as well as for each criterion measure administered at the end of kindergarten. Table 1 presents these descriptive statistics, including means, standard deviations, the zero-order correlations, and the intraclass correlations. The correlations between indicators within each construct (in italics) were all significant, ranging from .50 to .81. Also, all correlations between indicators across different constructs were significant (at $p < .05$, two-tailed).

The first research question focused on the degree to which the proposed structural model fit the phonological and alphabetic fluency data. We constructed a hypothesized measurement model to specify the relationships between the manifest variables and the latent variables. Figure 1 presents the results of the analysis for the measurement model. We used the reference variable strategy for the model identification, and Figure 1 presents the standardized solutions. According to the overall model test and the fit indices, this model fit the data adequately, $\chi^2(12) = 27.595$, $p = .006$; TLI = .972; CFI = .984; RMSEA = .076 (90% confidence interval, 0.039–0.114); SRMR = .028. All the coefficients were significant at $p < .05$ (two-tailed).

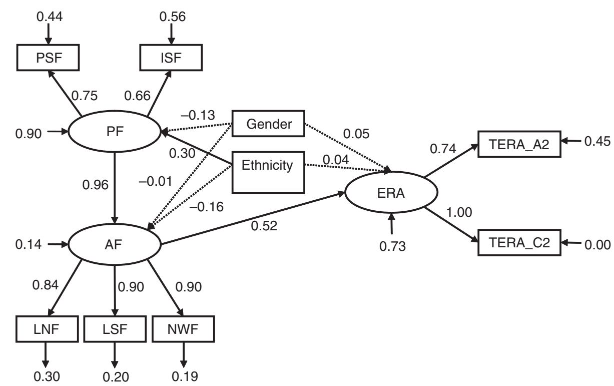
Results indicated that the structural model based on the modified measurement model was a good fit with the data collected. We based the structural model on the measurement model presented in Figure 1 and analyzed it using the "type = complex" feature of Mplus, which can take into account the nonindependency among the observations. Figure 2 presents the final model. As with the measurement model, we used the reference variable strategy for the model identification of the structural model;

Figure 1
Measurement Model



Note: The model fit the data adequately, $\chi^2(12) = 27.595$, $p = .0063$; comparative fit index = .984; Tucker–Lewis index = .972; root mean square error of approximation = .076 (90% confidence interval, 0.039–0.114); standardized root mean square residual = .028. All coefficients are standardized and significant at $p < .05$ (two-tailed). PSF = phoneme segmentation fluency at Time 1; ISF = initial sound fluency at Time 1; PF = phonological fluency; ERA = early reading ability; TERA_A2 = *Test of Early Reading Ability–Third Edition*, Alphabet subtest at Time 2; TERA_C2 = *Test of Early Reading Ability–Third Edition*, Conventions subtest at Time 2; AF = alphabetic fluency; LNF = letter naming fluency at Time 1; LSF = letter sound fluency at Time 1; NWF = nonsense word fluency at Time 1.

Figure 2
Structural Equation Model



The model fit the data adequately, $\chi^2(21) = 50.641$, $p = .0003$; comparative fit index = .970; Tucker–Lewis index = .950; root mean square error of approximation = .079 (90% confidence interval, 0.052–0.107); standardized root mean square residual = .034. For gender and ethnicity, "male" and "Caucasian" are each coded as 1 and "female" and "other ethnical groups" as 0. All path coefficients are standardized coefficients and significant at $p < .05$ (two-tailed) except the dashed ones. PSF = phoneme segmentation fluency at Time 1; ISF = initial sound fluency at Time 1; PF = phonological fluency; ERA = early reading ability; TERA_A2 = *Test of Early Reading Ability–Third Edition*, Alphabet subtest at Time 2; TERA_C2 = *Test of Early Reading Ability–Third Edition*, Conventions subtest at Time 2; AF = alphabetic fluency; LNF = letter naming fluency at Time 1; LSF = letter sound fluency at Time 1; NWF = nonsense word fluency at Time 1.

Figure 2 presents the standardized solutions. According to the overall model test and fit indices, the final model provided an adequate practical fit, $\chi^2(21) = 50.641$, $p < .001$; TLI = .950; CFI = .970; RMSEA = .079 (90% confidence interval, 0.052–0.107); SRMR = .034. As with the measurement model, all path coefficients were standardized coefficients and significant at $p < .05$ (two-tailed). All coefficients were similar to those in the measurement model, notwithstanding the absence of the path between phonological fluency and the outcome criterion of emerging reading ability.

Results indicated an adequate practical fit with a three-construct model consisting of phonological fluency, alphabetic fluency, and emerging reading ability. The adequate fit with the observed variables provides some degree of confidence regarding the construct validity of the early literacy indicators; that is, they are modeling the constructs they purportedly represent.

The second question focused on the degree to which the individual early literacy measures loaded on the phonological and alphabetic fluency constructs they intended to represent. We honor this question in the structural model in Figures 1 and 2, via the arrows connecting individual phonological and alphabetic fluency measures to their respective constructs. Phoneme segmentation fluency had the highest loading on the phonological construct, followed by initial sound fluency. Phoneme segmentation is a more complex skill than that of identifying initial sounds. Thus, the higher loading is consistent with Schatschneider, Francis, Foorman, Fletcher, and Mehta's finding (1999) that phonemic awareness functions as a unidimensional construct that varies depending on the complexity of the task. Nonsense word fluency and letter sound fluency had equal weights, and both were slightly higher than letter naming fluency. These results reinforce other studies suggesting that nonsense word fluency, letter naming fluency, and letter sound fluency reflect an alphabetic construct (Ritchey & Speece, 2006; Speece & Case, 2001; Stage et al., 2001).

The third question focused on the degree to which phonological fluency predicted alphabetic fluency and whether either construct predicted emerging reading ability. We honor this question via the directional arrows from phonological fluency to alphabetic fluency and from the phonological and alphabetic fluency constructs to emerging reading ability in Figures 1 and 2. As indicated from the measurement model (Figure 1), there is a relationship among all three constructs when the connections between the constructs are correlations.

The study's last research question examined the relation between phonological fluency and emerging reading ability. The mediation effect between the two for alphabetic fluency was significant, based on a Sobel test for mediation ($Z = 4.98$, $p < .05$; Sobel, 1982). The test indicated that the alphabetic construct fully mediated the relationship between phonological fluency and early reading ability. Indeed, the coefficient of the direct path from phonological awareness to early reading ability became nonsignificant after we included the alphabetic principle in the model.

Discussion

We should emphasize several key findings. The first is that the three-construct model underscores the importance of phonological and alphabetic fluency in reading acquisition. In particular, the model fit lends support to emphasizing phonological fluency and alphabetic fluency in kindergarten and their relationship to emerging reading ability. One should interpret this finding in the context of conflicting viewpoints on the relative role of phonological versus alphabetic skills. Few would argue that early literacy constructs and skills are interdependent; however, some researchers do seem to emphasize some skills over others. Some researchers have placed more emphasis on phonological skills rather than on alphabetic skills in reading acquisition (Good, Simmons et al., 2001). Others have tended to emphasize alphabetic over phonological skills (Gough & Tunmer, 1986; Hoover & Gough, 1990). For example, Ehri (1995) indicated that the primary cause of most reading disabilities is the breakdown in the process required for reading words from print. However, Wolf and Bowers (1999) hypothesized that deficits in phonological skills, as combined with naming problems, are the cause of reading disabilities. Note that fluency is a component in all the predictors used in this study. Although not tested, children who have naming deficits are likely to have low scores across the sublexical fluency measures.

Several popular assessments commonly used in kindergarten studies seem to reflect the conflicting points of view on what to emphasize in early literacy. For example, the *Comprehensive Test of Phonological Processing* (Wagner et al., 1999) assesses phonological awareness, phonological memory, and rapid naming but does not contain an alphabetic subtest. Likewise, the TERA3 (Reid et al., 2001) contains an Alphabet subtest but not a phonological awareness subtest or a naming subtest. Regardless, whereas we acknowledge that early literacy constructs and skills are often theoretically interdependent, results of the present study seem to emphasize the importance of alphabetic fluency (also see Vellutino, Fletcher, Snowling, & Scanlon, 2004).

A second key finding focuses on the relationship of phonological and alphabetic fluency to emerging reading ability. Whereas phonological fluency was predictive of alphabetic fluency, the alphabetic fluency construct mediated the relationship between phonological fluency and emerging reading ability. Some have suggested that phonological awareness is causal to reading (Wagner & Torgesen, 1987). Although phonological awareness is certainly important, focusing on phonological awareness alone in kindergarten is not likely prudent. The role of phonological awareness should be considered with other types of alphabet-related knowledge required for reading development.

A third key finding is that an adequate fit of the model with the collected data argues for the construct validity of the phonological and alphabetic fluency measures themselves. Creating measures that combine phonological and alphabetic knowledge with fluency has come under criticism (e.g., Goodman, 2006). The goodness-of-fit indexes indicate that the measures are reflecting the phonological and alphabetic fluency constructs they theoretically represent.

Limitations

As with most studies, this study has several limitations. First, we gathered the data as part of a technical assistance project. As part of our outreach effort, and consistent with human subjects protocols used in this project, we shared the data and corresponding instructional recommendations described by Good and Kaminski (2002) with the school administrators and teachers. Such sharing of data could have influenced interventions developed by the school and, subsequently, the results.

Second, and anecdotally, the school had a multisensory phonological awareness program in place at the kindergarten level. Moreover, the school had several prekindergarten classes that served many of the students before their entry into kindergarten. Variables that we did not examine, such as curricular effects, additional intervention, and the quality of preschool experiences, could have affected the data. Inferences to other populations should be made with caution, and replication is needed with other schools that use curricula with different emphasizes.

Third, interrater agreement and verification of test-retest reliability for this sample of children were limited. Because of logistical problems and limited resources, we did not conduct a thorough examination of interrater reliability or test-retest reliability for either the predictor or criteria measures. Although there are guidelines for the reliability of the measures (Good & Kaminski, 2002; Reid et al., 2001), sample-specific reliability is ideal.

Last, we focused our data collection on modeling sublexical fluency in a general population of students. The strength of the associations between the reading constructs may change with a sample restricted to children who already have reading disabilities or deficits in phonological and alphabetic skills.

Issues and Considerations for Research and Practice

One should consider several issues for special education research and practice based on the results of this study. A primary issue relates to (a) whether prevention-oriented models at the kindergarten level should emphasize phonological fluency, alphabetic fluency, or both and (b) if both, which measures best represent these constructs, which are so important to reading acquisition. This issue is particularly salient in kindergarten rather than first grade and beyond. In kindergarten, some skills are only emerging. For example, the phonological and alphabetic skill sets represented by phoneme segmentation, letter sound, and nonsense word fluency are not well developed. Children typically establish other skills, as reflected by initial sound and letter naming fluency, by the end of kindergarten (Good, Simmons et al., 2001).

The current study provided evidence of the construct and predictive validity of phonological and alphabetic fluency measures for kindergarten. Furthermore, it provided evidence indicating that researchers can use them to model reading acquisition in kindergarten. However, the structural model suggests that phonological fluency alone is insufficient for reading acquisition. Results of the structural model suggest that rapid identification and retrieval of phonemes represent a phonological fluency construct that is not directly predictive of emerging reading ability.

One would expect the more general body of research in reading acquisition to provide guidance on which measures to select for kindergarten. Unfortunately, some researchers emphasize phonological knowledge and fluency in kindergarten (e.g., Good, Simmons et al. 2001; Wagner & Torgesen, 1987; Wagner et al., 1997; Wagner et al., 1999) and generally place greater emphasis on the alphabetic measures in first grade. Others (e.g., Ritchey & Speece, 2006) seem to place more emphasis on the alphabetic measures in kindergarten. Moreover, the correlational research on phonological awareness, alphabetic knowledge, and reading acquisition is mixed (Castles & Coltheart, 2004; Ritchey & Speece, 2006; Schatschneider, Fletcher, Francis, Carlson, & Foorman, 2004). Although some view phonological processing and awareness as being causally related to reading (Wagner & Torgesen, 1987), there is some disagreement on the formation of this causal relationship (Snowling, 2000), as well as the degree of the relationship (Castles & Coltheart, 2004). Some researchers have posited alternative explanations. For example, some have advocated a reciprocal causation model in which phonological awareness is the product, not the cause, of reading ability (Foorman, Francis, Novy, & Liberman, 1991). Others have indicated that phonological awareness and other alphabetic skills are best seen within the context of a multicausal system (Foorman, 1994; Hume, Snowling, Caravolas, & Carroll, 2005). Each perspective is likely to influence what kindergarten skills teachers should emphasize.

Within the literature, researchers have found phonological and alphabetic measures comparable in their predictions with word reading. For example, Ritchey and Speece (2006) reported that phoneme segmentation fluency was not predictive of word reading, although it was predictive of spelling. Others failed to find robust support for segmentation at the phoneme level. For example, Schatschneider et al. (2004) observed that at the beginning of kindergarten, phonological awareness, letter naming speed, and letter knowledge were roughly comparable in predicting word identification skills. The relationship between phonological awareness and reading acquisition changes over time (Wagner et al. 1994; Wagner et al., 1997), and, clearly, there is a phonological component to most all alphabetic measures (Snowling, 2000). However, Schatschneider et al. remarked, "Given the theoretical importance of phonological awareness skills, it is surprising that these tasks are not more strongly related to reading skills development when measured in kindergarten" (p. 266).

In the reading and special education research literature, scholars widely accept a relationship between phonological awareness and reading ability (Blachman, 2000; Castles & Coltheart, 2004; Grossen, 1997; Kame'enui & Simmons, 2001; Simmons & Kame'enui, 1998). However, it may be that phonological awareness is beneficial insofar as it provides a cognitive framework for alphabetic tasks, such as identification of letter sounds and phonological recoding (Castles & Coltheart, 2004; Foorman et al., 1991), rather than the cause of more generalized reading skills. Given the mediated model provided in this study, we should caution special education teachers and researchers about selecting phonological awareness indicators for monitoring sublexical fluency without also taking into account other print-related skills associated with reading acquisition.

A second issue is the degree to which automaticity in cognitive processes is involved in predicting reading outcomes. This issue is salient to letter naming fluency. The results for letter name fluency are similar to findings from other studies that found rapid letter naming to be associated with reading outcomes. However, it continues to be unclear whether letter naming fluency's strong prediction is due to letter name knowledge or rapid naming speed. Letter name knowledge is thought to be an important facilitator to mastering the alphabetic principle (Snowling, 2000; Treiman & Rodriguez, 1999). Foulin (2005) indicated that letter naming speed must be considered separately from knowledge only. Researchers interpret the relationship between rapid letter naming and reading ability differently in the literature. For some, letter naming fluency indexes the quality of phonological access (Wagner & Torgesen, 1987). For others, it indexes the efficacy of orthographic processing, without letter name knowledge being important (Foulin, 2005; Wolf & Bowers, 1999).

Cognitive naming speed, as described by Wagner and Torgesen (1987) and Wolf and Bowers (1999), is likely a factor in all the sublexical fluency measures used in this study. Certainly, there is a connection between letter naming fluency and speed of cognitive processing. For example, Hintze et al. (2003) reported moderate to strong relationships with the Rapid Color Naming and Rapid Object Naming subtests of the *Comprehensive Test of Phonological Processing* and letter naming fluency. However, Schatschneider et al. (2004) found that rapid naming of letters was a better predictor than rapid naming of objects. As they pointed out, "it is not simply performance on any speeded naming task that is important. Rather, it is RAN [rapid automatized naming] tasks that have an orthographic component that seem to be important" (p. 280). Comparative studies using measures of letter knowledge, rapid letter naming, and more general naming speed may disentangle variance related to rapid naming and letter knowledge and may provide better clarification on why rapid naming of letters is such a robust predictor.

A third issue is whether researchers should use letter sound fluency in kindergarten. We found surprisingly little evidence in the literature review of this measure. Letter sound fluency represents the rapid processing of grapheme–phoneme relationships (Stage et al., 2001) and would seem ideal to administer in kindergarten. However, we need further research on whether it is a viable measure in kindergarten and, in particular, how it relates to letter naming and phonological measures. Rathvon (2004) observed, "Although in theory letter sound fluency should be a better predictor of reading than letter naming fluency because it reflects a greater depth of grapheme-phoneme knowledge and automaticity, research has yielded little support for this hypothesis to date" (p. 124). For example, in the Stage et al. study (2001), letter sound fluency correlated strongly with oral reading fluency in first grade, but letter name fluency produced a stronger prediction. Moreover, Schatschneider et al. (2004) thought that measures of letter knowledge that involved sounds would be more predictive than measures that involved names; however, they found that the differences at the beginning of kindergarten were not statistically significant.

The fourth issue concerns nonsense word fluency. Findings from the current study supported nonsense word fluency as reflecting an alphabetic construct in kindergarten. Nonsense word fluency appears to be a viable measure; however, we have more discussion on its application in kindergarten. Nonsense word measures are arguably "the most direct way of assessing a child's decoding skill" (Snowling, 2000, p. 89). In the research literature, the reading of nonsense words has consistently discriminated between normal readers and those with reading disabilities (Rack et al., 1992; Treiman, Goswami, & Bruck, 1990). For example, Herrmann et al. (2006) conducted a meta-analysis of 34 studies of the nonword reading performance of students with reading disabilities and matched control groups and found a Cohen *d* (Cohen, 1977) of .65. Rathvon (2004) indicated that "pseudoword reading is an essential component of any early reading diagnostic assessment" (p. 141). However, early literacy researchers have not traditionally emphasized the use of pseudowords in kindergarten, and they typically do not use tests that include nonsense words until first grade (Rathvon, 2004; Torgesen et al., 1999). Nevertheless, nonsense word fluency is one of the few early literacy measures available that measures alphabetic knowledge through automaticity of reading pseudowords (Fuchs, Fuchs, & Compton, 2004; Rathvon, 2004).

The results of this study indicate that nonsense word fluency may be a viable measure to administer as early as middle of kindergarten. However, because of the complexity of the task, nonsense word fluency may not be appropriate for beginning of kindergarten. Further research is needed regarding whether letter sound or nonsense word fluency would be more appropriate measures for screening and progress monitoring and how early we can give alphabetic fluency measures.

To summarize, kindergarten is a critical time in which to focus prevention and early intervention efforts. Research on the development and validation of sublexical measures in early literacy is crucial to the prevention of reading failure and disability. The final structural model provided in this study offered evidence of how phonological and alphabetic fluency measures relate to their underlying constructs. Moreover, the three-construct model illustrates how the constructs work together to predict emerging reading ability. Because of the mediated effect of alphabetic fluency on phonological fluency and emerging reading ability, the findings suggest that we give emphasis to alphabetic fluency in kindergarten.

Note

1. The "type = complex" feature in Mplus is one of the options for analyzing multilevel data, which takes the dependency into account by adjusting the standard errors of the parameter estimates. Another option for analyzing multilevel data in Mplus is the "type = twolevel" feature. With "type = twolevel," Mplus analyzes the data with the random intercept model in which the overall variance–covariance matrix is split into a within-level variance–covariance matrix and a between-level variance–covariance matrix. One can fit different models to different-level variance–covariance matrices. However, in this study, we focus on the within-level (or student-related) variables, not the between-level (or teacher-related) variables. Hence, we adopted the "type = complex" feature to analyze all the models, which can take the multilevel structure/dependency into account while providing a simpler model for presentation.

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