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Growth on sublexical fluency progress monitoring measures in early kindergarten and relations to word reading acquisition

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ABSTRACT

Fluency with skills that operate below the word level (i.e., sublexical), such as phonemic awareness and alphabetic knowledge, may ease the acquisition of decoding skills (Ritchey & Speece, 2006). Measures of sublexical fluency such as phoneme segmentation fluency (PSF), letter naming fluency (LNF), and letter sound fluency (LSF) are widely available for monitoring kindergarten reading progress, but less is known about the relative importance of growth in each skill across the early months of formal reading instruction and their relation to subsequent decoding acquisition. With a sample of kindergarten students at risk for reading difficulties, this study investigated the extent to which initial status and growth in PSF, LNF, and LSF, administered on a progress-monitoring basis during the fall of kindergarten, were differentially predictive of word reading fluency skills at mid-year and growth across the second half the school year. We used two different fluency-based progress monitoring measures of word reading across the spring, one consisting entirely of phonetically regular consonant-vowel-consonant words, and the other that included phonetically regular and irregular words that varied in length. Results indicated that although initial status and fall growth in all sublexical fluency measures were positively associated with subsequent word reading, LSF across the fall of kindergarten was the strongest overall predictor of mid-year level and growth on both word reading measures, and unique in its prediction over the effects of LNF and PSF. Results underscore the importance of letter-sound knowledge for word reading development, and provide additional evidence for LSF as a key index of progress for at-risk learners across the early months of formal reading instruction.

1. Introduction

Reading words (i.e., decoding) is the primary goal of early reading instruction. Decoding represents a transition from emergent literacy to a new set of interconnected and increasingly complex skills that ultimately culminate in deep processing of text. Yet, decoding itself is a complex skill which requires the acquisition and coordination of several foundational, sublexical skills (i.e., skills that operate below the word level) such as processing phonemes within words, recognizing letters, and associating letters with

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sounds. Sublexical skills are targeted by several popular fluency-based measures for monitoring progress in early literacy skills. To improve our understanding of the skills measured by commonly-used progress monitoring tools and how growth in these skills fits within theoretical models of reading development, this study investigated at-risk kindergarten students' reading fluency in processing sublexical information and the extent to which growth in sublexical fluency across the fall of kindergarten was predictive of the acquisition of word reading skills during the latter half of the year. We focused on sublexical skills in two domains particularly important for decoding: Phonemic awareness and alphabetic knowledge.

1.1. Sublexical skills

1.1.1. Phonemic awareness

Phonological awareness is an aspect of language involved in the processing of speech sounds that has critical ties to reading development (Bus & van IJzendoorn, 1999; Kirby, Parrila, & Pfeiffer, 2003; Melby-Lervåg, Lyster, & Hulme, 2012; Torgesen, Wagner, Rashotte, Burgess, & Hecht, 1997). Phonemic awareness more specifically represents a child's perception that words are made up of a unique combination of individual sounds, that words can be taken apart by their sounds, and that those sounds can be blended together again to form a word. This critical insight is thought to facilitate the understanding that phonemes can be paired with printed letters (Ehri, 2002; Foy & Mann, 2006; Kim, Petscher, Foorman, & Zhou, 2010; Schatschneider & Torgesen, 2004; Snow, Burns, & Griffin, 1998). Therefore, working knowledge of phonemic awareness is important for beginning to connect phonemes to printed letters (Snow et al., 1998), connections which are facilitated and enhanced by knowledge of letter names (Piasta & Wagner, 2010; Share, 2004; Treiman & Kessler, 2003.

In addition to facilitating letter-sound connections, the ability to segment, blend, and manipulate words by phonemes is heavily implicated in decoding and spelling (Muter, Hulme, Snowling, & Taylor, 1997; Nation & Hulme, 1997; O'Connor, 2011), making the role of phonemic awareness in reading development likely a causal one (Wagner & Torgesen, 1987; Wagner, Torgesen, & Rashotte, 1994). Difficulties in phonological processing, highly characteristic of children with reading disabilities at the word-level (Elbro, Borstrøm, & Petersen, 1998; Melby-Lervåg et al., 2012), impair a child's ability to connect printed letters to phonemes, manipulate sounds to read words, and thus impede processes that are critical to the development of word reading.

1.1.2. Alphabetic knowledge

Alphabetic knowledge refers to skills in identifying printed letters by name or sound. Knowledge of letter names and sounds at the start of formal reading instruction tend to be the strongest predictors of subsequent reading achievement (Scarborough, 1998; Schatschneider, Fletcher, Francis, Carlson, & Foorman, 2004). Letter-sound knowledge provides essential information for decoding unknown words on a sound-by-sound basis, and subsequently, for mapping letter combinations to pronunciations in memory (Ehri, 1998, 2002; Hulme, Bowyer-Crane, Carroll, Duff, & Snowling, 2012; Share, 1995, 2008). Letter-name knowledge also affords several benefits for reading acquisition, including the facilitation of phonemic awareness development by directing a child's attention to more specific units of speech (Foulin, 2005; Treiman & Kessler, 2003), and because the majority of letter names provide information about their sounds, knowing letter names facilitates learning letter-sound correspondences (Foulin, 2005; Kim, Petscher, Foorman, & Zhou, 2010; McBride-Chang, 1999; Piasta & Wagner, 2010; Treiman & Kessler, 2003; Treiman & Rodriguez, 1999). Difficulty learning letter names or sounds is consistently observed among children with or at risk for reading difficulties or disabilities at the word-level (Elbro et al., 1998; Gallagher, Frith, & Snowling, 2000; Lyytinen et al., 2004; Piasta et al., 2018; Schatschneider & Torgesen, 2004; Torppa, Lyytinen, Erskine, Eklund, & Lyytinen, 2010).

Phonemic awareness and emerging alphabetic knowledge then interact during the early stages of reading instruction, providing essential skills for decoding words, and reciprocally reinforcing more sophisticated development in both areas as reading progresses (Burgess & Lonigan, 1998; Wagner et al., 1994). Consequently, the ability to read words develops through a connection-forming process in which pronunciations are bonded to units of letters, a process which is built upon basic sublexical skills in phonemic awareness and alphabetic knowledge (Ehri, 1998, 2005, 2014; Elbro & de Jong, 2017; Foorman, Francis, Novy, & Liberman, 1991; Seidenberg, 2005; Share, 2004, 2008).

1.2. Sublexical fluency

Beyond basic skills in phonemic awareness and alphabetic knowledge, a developing reader's speed, accuracy, and efficiency with these tasks may be important for facilitating reading development. The ability to identify alphabetic information *quickly* is uniquely predictive of subsequent reading skills (Hecht, Burgess, Torgesen, Wagner, & Rashotte, 2000; Joshi & Aaron, 2000; Ritchey & Speece, 2006; Schatschneider et al., 2004; Speece, Case, & Molloy, 2003). Complex skills such as reading fluency depend on proficiency with multiple lower-level components (Wolf & Katzir-Cohen, 2001), as rapid retrieval of symbolic information may be important for orchestrating higher-order reading processes (Georgiou, Parrila, & Papadopoulos, 2008; Kame'enui & Simmons, 2001; Kirby, Georgiou, Martinussen, & Parrila, 2010; Lervåg & Hulme, 2009; Richlan, 2019; Walsh, Price, & Gillingham, 1988; Wolf, Bowers, & Biddle, 2000). A considerable amount of research has established the relation among alpha-numeric rapid automatized naming (RAN) tasks and reading achievement (for reviews, see Kirby et al., 2010; Wolf et al., 2000). A goal of early reading instruction is to foster skills that enable students to read words quickly and with little conscious effort, and toward that end, research suggests that the speed of naming letters is more strongly associated with speed of reading words than untimed word reading accuracy (Katzir et al., 2006; Lervåg & Hulme, 2009; Schatschneider et al., 2004; Schatschneider, Carlson, Francis, Foorman, & Fletcher, 2002; Vaessen, Gerretsen, & Blomert, 2009).

Ritchey and Speece (2006) proposed the sublexical fluency hypothesis, which posits that the speed and accuracy with which sublexical information can be accessed and produced facilitates word reading development in ways similar to how reading fluency facilitates reading comprehension. Complex behaviors compete for limited cognitive resources, and freeing resources from lower-order tasks allows attention to be directed to higher-level processing (LaBerge & Samuels, 1974; Perfetti, 1985). In the case of decoding acquisition, the ease and efficiency with which words can be segmented, or letter names or sounds recalled with little conscious effort, may reduce cognitive load and thereby ease a student's acquisition of decoding skills. Conversely, slow, effortful, and error-prone processing of sublexical information may impede decoding processes that, for developing readers in the early stages of reading instruction, require considerable cognitive energy (Ritchey & Speece, 2006). Automaticity with sublexical skills likely reflects the sophistication and quality with which sound-symbol relations are represented in a learner's memory, and may enhance a developing reader's ability to connect increasingly larger units of letters to pronunciations, which in turn enables the rapid reading of words (i.e., "by sight") that is characteristic of proficient reading (Ehri, 2014; Hudson, Torgesen, Lane, & Turner, 2012; Richlan, 2019).

Measures of sublexical fluency are available via downward extensions of the curriculum-based measurement (CBM) framework (i.e., the repeated use of brief, standardized, rate-based measures for informing ongoing instructional decisions; Deno, 1985) to early literacy. Sublexical fluency measures include phoneme segmentation fluency (PSF), letter naming fluency (LNF), and letter sound fluency (LSF)[2] and are common among early reading assessment suites (National Center on Intensive Intervention [NCII], 2013).

Several studies have established that kindergarten and first grade performance on PSF, LNF, or LSF are predictive of future reading achievement when assessed at a single point in time (Burke, Crowder, Hagan-Burke, & Zou, 2009; Burke, Hagan-Burke, Kwok, & Parker, 2009; Catts, Petscher, Schatschneider, Sittner Bridges, & Mendoza, 2009; Clemens et al., 2019; Clemens, Hilt-Panahon, Shapiro, & Yoon, 2012; Clemens, Lai, Burke, & Wu, 2017; Elliott, Lee, & Tollefson, 2001; Goffreda & Diperna, 2009; Johnson, Jenkins, Petscher, & Catts, 2009; Kim, Petscher, Schatschneider, & Foorman, 2010; Reidel, 2007; Stage, Sheppard, Davidson, & Browning, 2001). Across studies, LNF and LSF tend to be stronger predictors whereas the predictive validity of PSF is less consistent. Lower relative predictive validity of PSF tasks may be due in part to the age at which skills were assessed, which has often involved students in the latter half of kindergarten or even first grade, well after formal reading instruction has begun.

Some scholars have recommended LSF as an ideal progress monitoring measure for kindergarten (Fuchs & Fuchs, 2004). However, other guidance documents, resources, and scholarly papers have recommended PSF as part of a set of measures for kindergarten progress monitoring (Kaminski, Cummings, Powell-Smith, & Good, 2008; NCII, 2013) or recommend PSF exclusively (Gersten et al., 2009) despite evidence that print-based measures that involve letters or words are stronger predictors of subsequent reading skills (Hammill, 2004; National Early Literacy Panel, 2008; Scarborough, 1998), especially after formal reading instruction has begun (Schatschneider & Torgesen, 2004).

We believe that research can better elucidate the ways in which sublexical fluency skills, which are often the target of progress monitoring measures, are indicative of developmental reading processes. Better understanding of sublexical fluency measures and the extent to which they provide insight into early reading development may improve decisions on how to best monitor progress for students in the beginning stages of formal reading instruction. One area in which more research is needed involves investigating the extent to which growth in sublexical fluency is associated with subsequent word reading development.

1.3. Growth in sublexical fluency and the prediction of subsequent reading skills

Rate of growth has been identified as an important variable for understanding students' skill acquisition and providing feedback for adjusting instruction (Fuchs & Fuchs, 1999), and is a key aspect of intervention decision-making models such as the data-based individualization framework (NCII, 2013). Studies have investigated the extent to which growth in sublexical fluency skills are predictive of subsequent reading achievement. Clemens et al. (2018) found that PSF growth across the second half of kindergarten was predictive of year-end reading skills, but it was not as strongly predictive as LSF growth. Other studies observed that PSF growth in kindergarten was not predictive of later reading achievement (Clemens et al., 2012; Ritchey & Speece, 2006). Growth in LSF and LNF during kindergarten have been shown to predict reading skills measured at the end of kindergarten (Catts, Herrera, Nielsen, & Bridges, 2015; Clemens et al., 2012) and first grade (Clemens et al., 2017). However, Al Otaiba et al. (2011) found that LNF growth across kindergarten was not associated with reading fluency in first grade, and Ritchey and Speece (2006) found that *decelerating* growth in LNF during the second half of kindergarten (i.e., students with stronger skills reaching ceiling levels) was associated with stronger year-end word identification skills.

1.3.1. Does growth in sublexical fluency predict growth in decoding?

Fewer studies have investigated the extent to which growth in sublexical fluency during the early stages of reading development is

[2] Although they are similar to RAN tasks, sublexical fluency measures like LNF and LSF differ in several ways. RAN tasks utilize a small set of 5–6 stimuli (letters, numbers, colors, or objects) that students are expected to know, arranged in random order and repeated across the measure. Scores on RAN tasks typically involve the amount of time taken to name all items in the list, regardless of errors. Conversely, sublexical fluency measures use a much larger set of stimuli (in some cases, the entire alphabet), and are scored in terms of the number of letters or sounds identified correctly. Thus, accuracy plays an important role in sublexical fluency measures compared to RAN tasks, as students are not expected to know all items. Additionally, phoneme segmentation tasks are markedly different from RAN tasks, as they measure the speed at which students can segment words spoken by an examiner and do not involve print.

predictive of the *rate of growth* in more complex reading skills later. Kindergarten reading instruction is uniquely dynamic; instruction initially targets the development of basic skills such as phonological awareness and alphabetic knowledge (i.e., letter names and sounds), and gradually transitions across the year to focus on decoding and reading simple texts. In what may be particularly relevant for students considered to be at risk for reading difficulties at the start of kindergarten, faster growth in sublexical fluency may indicate how readily they can apply those skills to more complex decoding tasks later in the year. Thus, faster growth in sublexical fluency may forecast faster acquisition of decoding, whereas low scores at kindergarten entry *and* low growth in sublexical fluency across the early part of kindergarten may be predictive of significant difficulties in acquiring decoding skills as instruction transitions across the latter half of kindergarten.

Three studies offer evidence that partially addresses these issues. Clemens et al. (2018) included LSF and PSF in their study of growth across the second half of kindergarten with students at risk for reading difficulties and found that growth in LSF was strongly correlated with change in students' word reading skills across the same period of time. PSF growth was also correlated with concurrent change in word reading, but to a lesser extent than LSF. LNF was not included in the study. Clemens et al. (2017) found that both initial status and growth in LNF and LSF across kindergarten were uniquely predictive of first-grade reading fluency, indicating the independent effects of each on subsequent text reading skills. Indirect effects were also observed for kindergarten LNF and LSF growth on students' reading fluency in second and third grades, but PSF was not included. Sáez, Nese, Alonzo, and Tindal (2016) examined the LSF growth trajectories of kindergarten students categorized according to their reading fluency at the end of second grade (i.e., low, average, and high). LSF growth across the kindergarten year was positively predictive of word reading fluency growth across first grade for students that finished second grade with low or average (but not high) oral reading fluency. To date, however, no studies have investigated growth in PSF, LNF, and LSF across the initial months of kindergarten, and the extent to which each are differentially predictive of subsequent growth in word reading skills during the latter half of the school year.

1.3.2. Does sublexical fluency growth differentially predict growth in reading different types of words?

Children learning to read in English will encounter phonetically regular words in which all letters represent their most common sounds, and phonetically irregular (i.e., "exception" words) which do not conform to letter-sound regularity or traditional phonics rules. Dual-route theories of word reading development (Castles & Coltheart, 1993; Coltheart, 2005) posit that phonetically regular words are processed through a non-lexical route in which knowledge of letter-sound correspondences are of primary importance, whereas irregular words are processed through a lexical route that relies on direct links between whole-word spellings and pronunciations.

In contrast, other perspectives suggest the ability to read *all* words relies on a common foundation (Harm & Seidenberg, 1999; Seidenberg, 2005, 2017), whereby word-specific knowledge is facilitated by phonemic awareness and alphabetic knowledge, which results in generalizable skills in reading words regardless of phonemic regularity (Aaron et al., 1999; Ehri, 1995, 2014; Elbro & de Jong, 2017; Griffiths & Snowling, 2002; Share, 2004, 2008). Evidence indicates that reading phonetically regular and irregular words are not independent skills (Aaron et al., 1999), and letter-sound instruction benefits the development of reading both word types (Foorman et al., 1991).

The extent to which growth in sublexical fluency differentially predicts subsequent achievement on different types of word reading measures has implications for how educators should interpret observed growth (or lack thereof) as evidence of successful acquisition of early foundational skills for decoding, or a reason to consider more intensive and individualized supports. Eventually, students must learn to read any type of word, and sublexical fluency measures that are predictive of general word reading skills (regardless of word type) would be preferable as ongoing indices of reading development and intervention response. The dual-route theory would predict that growth in letter sound fluency is strongly predictive of growth on measures involving phonetically regular words that can be successfully decoded using serial sound-by-sound correspondence, and relatively less predictive of growth on measures that include a range of phonetically regular and irregular words. Conversely, perspectives that maintain that reading regular and irregular words rely on a foundation of common skills would suggest that letter sound fluency would be the strongest predictor of development in reading both word types. Evidence indicates that phonemic awareness tasks begin to lose strength as predictors as students develop print-based skills, such as letter-sound correspondence (Melby-Lervåg et al., 2012; Schatschneider & Torgesen, 2004), skills which, as reviewed earlier, are facilitated by phonemic awareness. To our knowledge, this has not been investigated with LNF, LSF, and PSF, and with a sample of students with or at risk for reading difficulties who are most often the recipients of frequent progress monitoring and ongoing instructional decision-making.

1.4. Study purpose

The purpose of this study was to better understand how the skills indexed by sublexical fluency measures are involved in and predictive of word reading development during the early stages of formal reading instruction. Specifically, this study investigated the extent to which growth in sublexical fluency across the first half of kindergarten was predictive of the growth in word reading fluency skills later in the school year. The study also examined whether initial status and growth in PSF, LNF, and LSF were differentially predictive of word reading development depending on whether word reading was assessed with measures that consisted entirely of phonetically regular words, or measures that included both regular and irregular words. The study was focused on kindergarten students considered to be at risk for reading difficulties to better inform decisions for students who are most often the targets of supplemental interventions and progress monitoring.

2. Method

Data for the present study were drawn from a longitudinal project funded by the Institute of Education Sciences (hereafter referred to as the parent project). The parent project involved monitoring the reading progress of kindergarten students considered to be at risk for reading difficulties with a set of published early literacy skills measures, with follow-up assessment of students' reading outcomes. The data from the project are supporting multiple investigations aimed at better establishing the technical adequacy of tools available for monitoring kindergarten reading progress and enhancing understanding of longitudinal growth trends of students at risk for reading difficulties. Measures were selected from multiple publishers to provide coverage of important early literacy constructs (i.e., phonemic awareness, alphabetic knowledge, decoding), and to avoid focusing on one specific publisher or measure suite.

2.1. Participants

The present analyses involved 426 kindergarten students in the southwest United States who were recruited during two consecutive school years of the parent project ($n = 213$ in Years 1 and 2). Students were recruited from 77 classrooms (40 in Year 1 and 37 in Year 2) within 10 elementary schools (nine schools participated both years, an additional school was added in Year 2) from five school districts (four districts participated in both years, an additional district was added in Year 2). The average school-wide percentage of students that qualified for free or reduced-price lunch was 77%. The sample was 54.7% male (56.8% in Year 1, 52.6% in Year 2), 51.6% Hispanic (59.2% in Year 1, 44.1% in Year 2), 25.8% Black (22.5% in Year 1, 29.1% in Year 2), and 19.7% White (16.9% in Year 1, 22.5% in Year 2). English learners (ELs; 31.7% total, 34.3% in Year 1, 29.1% in Year 2) were included as part of the parent project if they were learning to read in English and received at least 50% of their instruction in English. EL status was controlled for statistically in the analyses (described below).

The participant identification process, as part of the parent project, involved a combination of teacher ratings of students' early literacy skills and direct assessments. In contrast to screening work that attempts to minimize screening “errors” in identification, the parent project sought to identify students who demonstrated at least some risk for subsequent reading difficulties with the understanding that a subset of students could ultimately demonstrate successful reading outcomes. Teachers ($N = 53$; 41 participated in both project years) first completed a version of the Reading Rating Form (Speece et al., 2010, 2011) with each student in their classroom, which rated students' alphabetic knowledge, phonological awareness, oral language, and overall reading skills. Teacher ratings have been used to identify young children at risk for reading difficulties and have been shown to be particularly useful when combined with direct assessments (Snowling, Duff, Petrou, Schiffeldrin, & Bailey, 2011; Speece et al., 2011). The Reading Rating Form in particular has demonstrated validity as part of a process for identifying at-risk readers in first and fourth grades (Speece et al., 2010, 2011). Parent consent was sought from the 5–8 lowest-rated students in each classroom. We verified low early literacy achievement with individually administered standardized assessments. Specifically, students that scored at or below the 40th percentile on either the Letter Identification or Phonological Awareness subtests of the Woodcock Reading Mastery Test, 3rd edition (Woodcock, 2011) were enrolled in the project.

2.2. Sublexical fluency measures

Sublexical fluency in the area of phonemic awareness was measured with an assessment of phoneme segmentation, which is considered one of the most important phonemic awareness skills for word reading (O'Connor, 2011). Sublexical fluency in the area of alphabetic knowledge was measured with an assessment of letter-name identification and a measure of letter-sound correspondence.

2.2.1. Phoneme segmentation fluency (PSF)

PSF from the EasyCBM system (Anderson et al., 2014) is an assessment of fluency in identifying phonemes in words. Students orally segment a series of words spoken by the examiner and receive one point for each separate and unique sound segment produced within one minute, which can include individual phonemes, syllables, or other word parts (no points are awarded when the student repeats a whole word). In previous work, kindergarten PSF scores have been found to correlate with measures of phonological awareness, letter sounds, and word reading with coefficients ranging from 0.39 to 0.58 (NCII, 2018), and PSF measures have demonstrated alternate forms reliability with kindergarten students ranging from.35 to.90 (NCII, 2018). With the current sample, average correlations between fall kindergarten administrations of PSF and year-end measures of timed and untimed word reading, timed and untimed decoding, and oral reading fluency ranged from.33 to.40 (Clemens & Lee, 2018). PSF demonstrated an average 2-week alternate form reliability coefficient of. 82 with students in the current analyses.

2.2.2. Letter naming fluency (LNF)

The Letter Names measure from the EasyCBM system (Anderson et al., 2014) was used to monitor LNF. On each alternate form, students were shown a list of 100 randomly-ordered upper- and lower-case letters. Students were instructed to read from left to right and identify the names of as many letters they could. The number of letters named correctly in one minute was recorded. If the student hesitated on a letter for three seconds, the name was provided and marked as an error. Letter sounds were not counted as correct. When assessed in kindergarten, LNF measures have demonstrated moderate to strong correlations with other early literacy skills and are predictive of subsequent reading achievement (e.g., Anderson et al., 2014; Clemens et al., 2017; Elliott et al., 2001; Goffreda & Diperna, 2009; Ritchey & Speece, 2006; Stage et al., 2001). Test-retest reliability exceeds 0.81 (Elliott et al., 2001; NCS

Pearson, 2012) and one-week alternate-form reliability exceeds.82 (Alonzo & Tindal, 2009; Anderson et al., 2014). With the current sample, average correlations between kindergarten fall LNF administrations and year-end measures of timed and untimed word reading, timed and untimed decoding, and oral reading fluency ranged from.38 to. 51 (Clemens & Lee, 2018). LNF demonstrated average 2-week alternate form reliability of. 88 with students in the current analyses.

2.2.3. Letter sound fluency (LSF)

LSF from the AIMSweb system (NCS Pearson, 2012) is an assessment of fluency in correctly identifying letter sounds. On each alternate form, students were shown a randomly ordered list of 100 lower-case letters and were instructed to read from left to right across each row and identify the sound of each letter. The number of letter sounds correctly identified in one minute was recorded. If the student hesitated on a letter for three seconds, the sound was provided and marked as an error. Consistent with AIMSweb scoring guidelines, only short-vowel sounds and the most common sounds for consonants (e.g., /k/for c) were accepted as correct responses. Letter names were not counted as correct. With kindergarten students, LSF performance is predictive of subsequent reading skills (e.g., Anderson et al., 2014; Clemens et al., 2017; Clemens et al., 2018; Elliott et al., 2001; Ritchey & Speece, 2006; Stage et al., 2001). Test-retest reliability for LSF exceeds 0.80 (Elliott et al., 2001), and the measure has demonstrated four-month alternate form reliability of 0.82 (NCS Pearson, 2012). With the current sample, average correlations between fall kindergarten LSF administrations and year-end measures of timed and untimed word reading, timed and untimed decoding, and oral reading fluency ranged from 0.45 to 0.56 (Clemens & Lee, 2018). LSF demonstrated average 2-week alternate form reliability of.86 with students in the current analyses.

2.2.4. Decodable word reading (DWR)

DWR from the FastBridge system (FastBridge, 2013) is an assessment of fluency reading phonetically regular real words in list form. All words on each alternate form follow a consonant-vowel-consonant (CVC) pattern. The test authors omitted high-frequency words. On each alternate form, the first 15–20 words include unique initial sounds. DWR is scored in terms of the number of words read correctly in one minute. Any words read incorrectly, omitted, or hesitations of longer than three seconds were scored as errors. Only words that were read as whole units were counted as correct (i.e., partially blended words or words sounded out without fully blending the sounds as a whole word were counted as incorrect). Previous work found that alternate-forms and test-retest reliability exceeded 0.97 with kindergarten students (Christ et al., 2015). DWR demonstrated average 2-week alternate form reliability of 0.88 with students in the current analyses. With the current sample, average correlations between DWR kindergarten administrations and year-end measures of timed and untimed word reading, timed and untimed decoding, and oral reading fluency ranged from 0.73 to 0.79 (Clemens & Lee, 2018).

2.2.5. Word reading fluency (WRF)

WRF from the EasyCBM system is an assessment of fluency in reading high-frequency words in list form. Each alternate form contains phonetically regular and phonetically irregular words that generally range in length from 2 to 6 letters. The total score consists of the number of words read correctly in one minute, and any words read incorrectly, omitted, or hesitations of longer than three seconds were scored as errors. Only words that were read as whole units were counted as correct (i.e., partially blended words or words sounded out without fully blending the sounds as a whole word were counted as incorrect). Prior work found that test-retest and alternate-forms reliability exceeded 0.87 with first graders (NCII, 2018). WRF demonstrated average two-week alternate form reliability of 0.91 with students in the current analyses. With the current sample, average correlations between kindergarten WRF administrations and year-end measures of timed and untimed word reading, timed and untimed decoding, and oral reading fluency ranged from 0.71 to 0.82 (Clemens & Lee, 2018).

2.3. Procedure

The present analyses used data collected as part of the parent project, which included LNF, LSF, and PSF data collected from October through mid-December of kindergarten (i.e., the “fall” time period), and DWR and WRF data collected from mid-January through early May (i.e., the “spring” time period). Students were administered the progress monitoring measures once every two weeks, resulting in five data points for LNF, LSF, and PSF across the fall, and eight data points for DWR and WRF across the spring. All measures were individually administered by project staff using standardized administration procedures specified by each publisher. Testing locations included unused classrooms, school libraries, and quiet sections of hallways.

2.3.1. Examiner training and assessment fidelity

Data collectors included study coordinators, graduate students, and advanced undergraduate students. A series of training sessions included an overview of best practices in assessment with systematic explanations and modeling of the specific protocol requirements for each measure. Following individualized practice sessions, trainees' fidelity was established through mock test administrations, which included feedback and modeled administrations by senior project staff. Lastly, trainees administered assessments to study participants under supervision of senior project staff and were required to demonstrate 100% fidelity with all assessment procedures and at least 95% inter-scorer agreement with a senior staff member before they could administer assessments independently. Follow-up fidelity checks were conducted 6 to 8 times per year, and inter-rater agreement (calculated as agreements divided by agreements plus disagreements) met or exceeded 95% for all measures at each time point. All measures were double-scored.

2.3.2. Student reading instruction and alignment with measured variables

Kindergarten teachers completed a questionnaire on the types of kindergarten reading curricula and intervention programs students received. The most common published core curricula used alone or with other programs were Journeys (52.5% of students; Houghton Mifflin Harcourt, 2010), Treasures (11.7% of students; Macmillan/McGraw-Hill, 2011), Senderos (8.4% of students; the dual-language companion to Journeys; Houghton Mifflin Harcourt, 2012), and Read Well (6.6% of students; Voyager Sopris Learning, 2010). The foci of the programs included phonological awareness, letter names, and letter sounds across the fall of kindergarten, with word reading emphasized across the second half of the year. Approximately 15% of students attended schools that did not use a published reading program in which cases the teachers used materials from various sources based on kindergarten state standards, which emphasized alphabetic knowledge, phonological awareness, and decoding.

With the second cohort (Cohort 2) of students, we asked teachers in the fall and spring to indicate whether specific skills were targeted in core instruction. Results of the fall survey indicated that phonological awareness and letter sounds were targets of instruction for 100% of the students, and letter names were an instructional target for 98% of students. The spring survey indicated that word study and phonics were targets of instruction for 100% of the students, including decoding (92% of students) and high-frequency word reading (100% of students).

In addition to core instruction, approximately 53% of students were exposed to supplemental computer programs, of which iStation (43.2% of students) and Starfall (34.8% of students) were most common. Both programs target early literacy skills including phonological awareness, alphabetic knowledge, and phonics. Finally, 61.4% of students received supplementary intervention support for reading in addition to core instruction and computer-based instruction. Of these students, enough information was provided to determine that 68.7% received supplementary interventions that emphasized phonics (including alphabetic knowledge, phonological awareness, and decoding) and/or reading practice. Therefore, we are confident that the vast majority (if not all) students in the present analyses were exposed to some form of instruction that taught skills measured by the progress monitoring tools investigated in this study.

2.3.3. Analyses of cohort equivalence

Data used in the present analyses were collected with two cohorts of kindergarten students across two consecutive school years. The student identification and recruitment procedures described earlier were identical for both cohorts. *t*-tests using data collected in the beginning of kindergarten indicated no statistically significant differences in average cohort performance on standardized measures of letter identification and phonological awareness. Chi-square tests indicated that students in the two cohorts did not differ statistically in terms of sex, English learner status, or ethnicity with the exception that Cohort 2 included fewer Hispanic students. Additionally, we ran a series of multiple group analyses comparing the growth models for Cohorts 1 and 2 on each progress monitoring measure included in the present study. Results indicated that the two cohorts did not differ with regard to growth trajectory shape (i.e., both cohorts demonstrated the same shape of growth on each measure), mean intercept and slope (i.e., groups did not differ in initial score or rate of growth on each measure), variance in intercept and slope (with the exception of LSF intercept variance, in which Cohort 2 demonstrated greater variance), and correlation between intercept and slope (i.e., cohorts demonstrated an equivalent relation between initial scores and rate of growth). Because the vast majority of comparisons indicated no statistically significant cohort differences, we aggregated data from both cohorts in all subsequent analyses.

2.4. Data analyses

The present analyses were focused on the degree to which October status (i.e., intercept) and rate of growth (i.e., slope) in PSF, LNF, and LSF across the fall of kindergarten were predictive of subsequent January status and growth across the spring in DWR and WRF. A series of unconditional first order latent growth models (LGMs; Meredith & Tisak, 1990) were used to model the growth of PSF, LNF, LSF, DWR and WRF. LGM was used because it is a flexible framework that allows for multiple estimated intercept and slope factors to be specified as predictors or outcomes in a model. The framework of LGM is represented as follows:

$$y_{it} = \eta_{0i} + \lambda_t \eta_{1i} + \varepsilon_{it}, \tag{1}$$

$$\eta_{0i} = \mu_{\eta_0} + \zeta_{0i}, \tag{2}$$

$$\eta_{1i} = \mu_{\eta_1} + \zeta_{1i}, \tag{3}$$

where y_{it} is the observed score for person i at time t; λ_t indicates the measurement occasion ($\lambda_t = 0, 1, \ldots, t - 1$); ε_{it} is the residual for person i at time t. η_{0i} and η_{1i} represent the intercept and slope factors, respectively. Specifically, the η_{0i} and η_{1i} factor scores are represented as a function of fixed effects (i.e., $\mu_{\eta 0}$ and $\mu_{\eta 1}$) and random effects (i.e., ζ_{0i} and ζ_{1i}), respectively. $\mu_{\eta 0}$ is the estimated average intercept across all individuals ($\lambda_t = 0$); ζ_{0i} is the deviation of the ith person's estimated intercept from the average intercept across all individuals; $\mu_{\eta 1}$ is the average estimated linear slope for the measure across adjacent time points and all individuals; and ζ_{1i} is the deviation of person's i's estimated linear slope from the average slope (Bollen & Curran, 2006).

All models were specified in M*plus* (version 7.4; Muthén & Muthén, 1998-2015), using the robust maximum likelihood (MLR) estimation method. Students' EL status (dummy coded; 1 = EL, 0 = non-EL) was included as a time-invariant predictor in all models to control for potential effects of EL status on spring DWR and WRF intercept and slope. Because students were nested within classrooms, the TYPE = COMPLEX option was applied to adjust the standard errors to account for the interdependence among observations within each classroom and to control for the inflation of Type I error rate (Peugh, 2010). This is also referred to as the design-based approach (McNeish, 2014; Wu & Kwok, 2012) that provides unbiased regression coefficient estimates and corresponding standard errors especially when the number of observations per each cluster is small (McNeish, 2014). Moreover, as McNeish, Stapleton, and Silverman (2017) suggested, the choice between a traditional hierarchical linear modeling approach and the design-based approach should be driven by the research questions. Given that our primary research interests focused on the interpretation of the regression coefficient estimates and the R^2 values at the student-level, we adopted the design-based approach as a more parsimonious way to handle the clustered data.

Before proceeding with the analyses, we examined whether adding a school-level cluster in addition to the classroom-level cluster explained students' variation on the dependent variables. Initially, the addition of school-level clustering resulted in model overfit (i.e., the random effects structure of the model including both classroom and school clusters was too complex for the given data). Subsequently, we calculated intraclass correlations (ICCs) as an alternative approach to determining whether the between-schools cluster explained students' variation on the dependent variables. This procedure revealed the between-schools ICCs of the dependent measures (DWR = 0.08 and WRF = 0.07) were low relative to the common ICC value of 0.40 that is found in longitudinal social research (Peugh, 2010). Additionally, we captured the ICC values in which classrooms and schools were included in the same unconditional model. For the DWR measure, the ICC values were 0.15 and 0.11 for the classroom- and school-levels, respectively, whereas the ICC values for WRF at the classroom- and school-levels were.17 and. 12, respectively. Finally, we examined the inclusion of a set of dummy coded variables in the six growth models where the first school was set as a reference category, and the other nine school-level clusters were indicated by each of the remaining dummy-coded variables. The results from the growth models with school-level dummy-coded variables did not distort estimates and inferences from our original analyses that employed TYPE = COMPLEX using the kindergarten classrooms as clusters. Therefore, the results of these steps suggested there was minimal between-school variability in DWR and WRF scores, thus an additional level (i.e., school-level clusters) was not considered herein.

Previous analyses (Clemens & Lee, 2018) examined the best-fitting growth trajectories of each measure across the fall or spring of kindergarten, including linear, quadratic, and unspecified (i.e., growth freely estimated). Linear growth represented the best fitting and most parsimonious way of modeling the trajectory of each measure included in the analyses.

2.4.1. Parallel process LGMs

Main analyses involved a form of parallel process growth modeling in which the LGM for each sublexical fluency measure administered across the fall was modeled with the LGM for each word reading measure administered across the spring. The resulting six models allowed us to investigate the extent to which the intercept and slope factors for each sublexical fluency measure were predictive of the intercept and slope factors for each word reading measure. The standardized path coefficients in these analyses indicate the expected *SD* unit change in the dependent variable for every *SD* unit change in the predictor, given the variables in the model. For example, a standardized path coefficient of 0.362 from PSF fall intercept to January DWR intercept indicates that every *SD* unit change in PSF fall intercept was associated with 0.362 *SD* unit change in January DWR status. All other standardized path coefficients across the results can be interpreted this way. The R^2 values in the analyses indicate the proportion of variance in word reading January status and spring slope explained by the intercept and slope factors for each sublexical fluency measure.

Model fitting procedures included specifying correlated residual terms between adjacent timepoints of the same measure, a modification that is considered acceptable given that error variance in repeated measures is likely related (Kline, 2016). All growth models were evaluated with the use of overall model chi-square tests along with commonly used fit statistics under the traditional SEM framework (Asparouhov & Muthén, 2018). In addition, local fit was examined using standardized residuals of covariance/correlation matrix (Appelbaum et al., 2018).

2.4.2. Missing data procedures

Missing data were due to student absences and unexpected changes in school schedules when make-up assessments were not possible. The mean percentage of cases in which data were missing was 14.4% (range = 11.3% to 20.0%) for PSF, 14.3% (range = 11.5% to 19.2%) for LNF, 14.8% (range = 12.7% to 20.0%) for LSF, 20.1% (range = 14.6% to 37.3%) for DWR, and 20.2% (range = 14.6% to 37.8%) for WRF. To test whether the underlying missing data mechanisms met assumptions of missing completely at random (MCAR; Little & Rubin, 1987), we used Little's (1988) MCAR test, which is a multivariate way to test whether missing data follow MCAR or not (see details in Little, 1988; Enders, 2010). Little's MCAR test provides a chi-square value, and a non-significant chi-square value indicates that missing data follow the MCAR mechanism. The results from Little's MCAR test ranged from $\chi 2(54) = 60.451$ (Fall LSF) to $\chi 2(226) = 250.758$ (Fall LSF) with *p* values ranging from 0.112 to 0.748. Therefore, the non-significant chi-square tests suggested the missing data mechanisms satisfied assumptions of MCAR. Subsequently, missing data were handled using full information maximum likelihood (FIML), which uses all available information in the dataset and provides unbiased results when missing data are present (Enders, 2010).

2.4.3. Investigating the unique effects of the sublexical fluency predictors

Combining the three LGMs for each sublexical fluency measure as predictors of DWR or WRF resulted in non-convergence issues, due to the complexity of modeling four LGMs simultaneously. Therefore, we sought alternatives for modeling the sublexical fluency predictors together. As a less-complex alternative to parallel process growth modeling, we used observed variables for the sublexical fluency measures as predictors. We used Time 1 scores for each measure as the intercept variables. For the fall sublexical fluency slope variables, we calculated each students' slope (ordinary least squares) across the five data points from the fall. Then, we included the predictors in two additional models that investigated the unique effects of intercept and growth in the sublexical fluency measures on spring intercept and growth in DWR and WRF. Therefore, each sublexical fluency measure had two variables, intercept (Time 1

Table 1
Descriptive statistics for primary variables.

		Fall 1	Fall 2	Fall 3	Fall 4	Fall 5
Letter naming fluency	*M*	18.00	20.17	23.77	26.28	28.62
	SD	*13.71*	*13.86*	*15.60*	*15.64*	*16.26*
	Min	0.00	0.00	0.00	0.00	0.00
	Max	52.00	60.00	63.00	66.00	75.00
Letter sound fluency	*M*	5.92	8.45	11.23	13.65	17.42
	SD	6.84	8.47	10.98	12.15	13.67
	Min	0.00	0.00	0.00	0.00	0.00
	Max	37.00	43.00	49.00	65.00	60.00
Phoneme segmentation fluency	*M*	7.07	10.84	12.64	16.74	19.26
	SD	9.18	11.97	13.09	15.39	16.30
	Min	0.00	0.00	0.00	0.00	0.00
	Max	49.00	49.00	56.00	58.00	60.00

		Spring 1	Spring 2	Spring 3	Spring 4	Spring 5	Spring 6	Spring 7	Spring 8
Decodable word reading	*M*	1.93	2.67	3.02	3.30	4.39	5.13	4.73	6.34
	SD	4.90	5.72	5.82	6.30	6.82	7.46	7.57	9.05
	Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Max	45.00	46.00	47.00	45.00	43.00	42.00	50.00	56.00
Word reading fluency	*M*	3.16	3.69	4.13	4.15	5.15	6.33	6.58	8.27
	SD	4.32	4.90	5.40	5.59	5.47	7.08	6.99	8.98
	Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Max	42.00	47.00	54.00	59.00	38.00	53.00	52.00	64.00

Note. Measures were administered once every two weeks in kindergarten. Fall time points were collected from October to mid-December. Spring time points were collected from mid-January to May.

score) and slope, and these six variables were modeled as predictors of the DWR and WRF LGMs in separate models (displayed in Figs. 3 and 4). EL status was included as a predictor of the DWR and WRF factors, as in the previous analyses. The determinant of the correlation matrix of the predictors was 0.213, which was greater than the cut-off criteria of 0.00001 (Field, 2013), suggesting that multicollinearity among the six predictors was unlikely.

3. Results

Descriptive statistics for all measures and time points are reported in Table 1. The parallel process models in which the LGMs for PSF, LNF, and LSF were modeled with the DWR and WRF LGMs are displayed in Figs. 1 and 2. To reduce the number of figures we reported the associated path coefficients and R^2 values for these models together, but it should be noted that each sublexical fluency LGM was modeled separately with each word reading LGM.

Growth models were evaluated using the exact fit test and approximate fit indices (Asparouhov & Muthén, 2018). As reported in Table 2, the global chi-square (χ^2) statistic and its associated p values were evaluated. Since the χ^2 goodness-of-fit statistic is well known to be sensitive to the sample size, we also considered global model fit indices. Although the overall model chi-square tests as shown in Table 2 were significant ($p < .05$), all six growth models still demonstrated adequate fit to the data considering conventional criteria for root mean square error of approximation (RMSEA; ≤ 0.08; MacCallum, Browne, & Sugawara, 1996), comparative fit index (CFI; ≥ 0.95; Hu & Bentler, 1999), and standardized root mean square residual (SRMR) ≤ 0.08 (Asparouhov & Muthén, 2018; Hu & Bentler, 1999), as well as Hu and Bentler's (1999) joint model fit criteria in which a CFI value of 0.96 or greater paired with a SRMR value of 0.10 or less is considered acceptable fit.

In addition, we examined the local fit of the six growth models using standardized residuals (z scores) of the covariance/correlation matrix. A z score < 1.96 indicates the observed covariance structure and the model implied covariance structure do not differ on a statistically significant basis. We found that there were only a few (up to six) out of 91 standardized residuals that exceeded 1.96 for each of the six growth models, indicating there was no substantial source of model misspecification.

The standardized path coefficients (*ß*s) are reported in all figures. Unstandardized and standardized path coefficients with standard errors are reported in Table 3. Because each sublexical fluency measure was considered with each word reading measure separately, the strength of individual path coefficients should be interpreted in relation to the counterpart path coefficient for the same measure and not directly compared across measures. Proportion of variance (R^2, reported in Table 3 and Figs. 1 and 2) in the intercept and slope factors for DWF and WRF explained by the respective sublexical fluency measures is more appropriate for comparisons across measures, and direct comparison of path coefficients is more appropriate in the last step of our analyses in which the predictors were modeled simultaneously. Results for the prediction of DWR are discussed first, followed by the results for WRF.

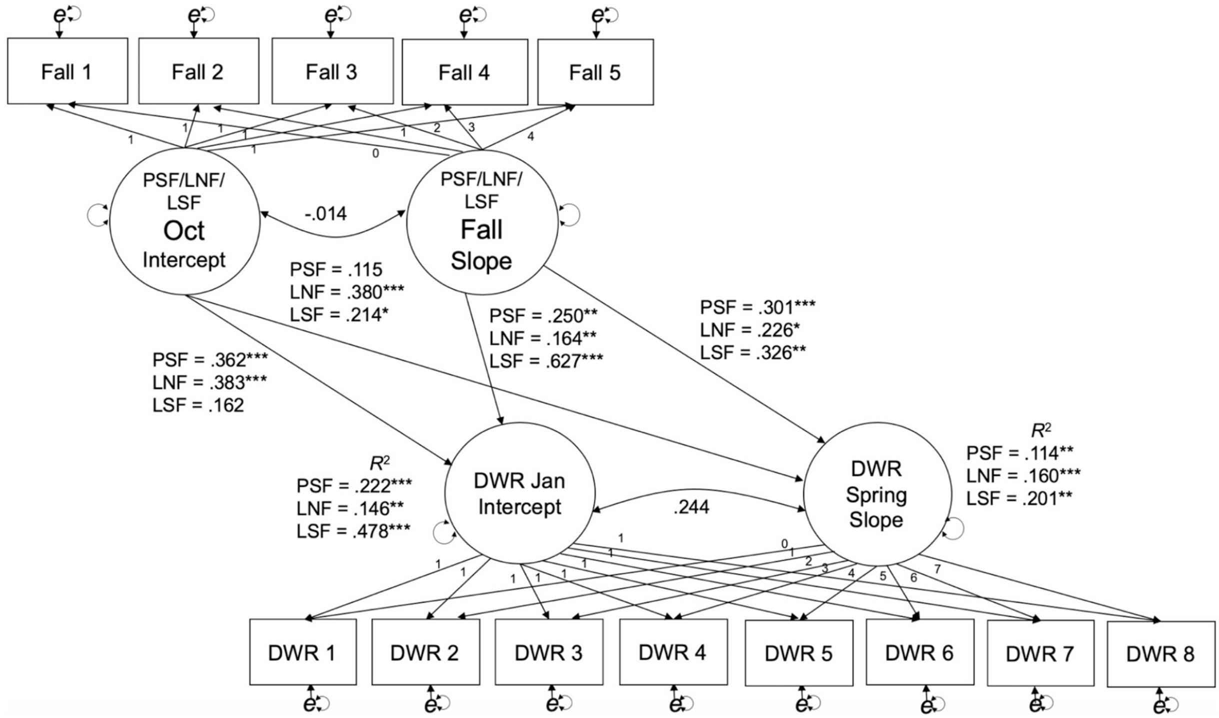

Fig. 1. Latent growth model results depicting the prediction of kindergarten Decodable Word Reading (DWR) January intercept and spring slope using intercept and growth in each of the sublexical fluency measures administered across the fall. Standardized path coefficients are reported. To reduce the number of figures, we report the results of the separate models for each sublexical fluency measure. All measures were administered once every two weeks in kindergarten. Fall time points were collected from October to mid-December. Spring DWR time points were collected from mid-January to May. Students' English learner status was included as a predictor of the DWR factors. Unstandardized coefficients and standard errors are reported in Table 3. LNF = Letter Naming Fluency; LSF = Letter Sound Fluency; PSF = Phoneme Segmentation Fluency. *$p < .05$. **$p < .01$. ***$p < .001$.

3.1. Parallel process LGMs predicting intercept and slope in decodable word reading.

As reported in Fig. 1 and Table 3, October intercept and fall slope in PSF were statistically significant predictors of January status in DWR, ßs = 0.362 ($p < .001$) and 0.250 ($p = .003$), respectively, indicating that both made unique contributions to the prediction of subsequent DWR performance in January. Initial status in PSF was not a statistically significant predictor (ß = 0.115, $p = .134$) of rate of growth in DWR from January to May, in contrast to fall growth in PSF (ß = 0.301, $p < .001$). Overall, fall intercept and slope in PSF explained 22.2% and 11.4% of the variance in DWR intercept and slope, respectively.

Intercept and slope in LNF were statistically significant predictors of January performance in DWR although intercept was a stronger predictor relative to slope, ßs = 0.383 ($p < .001$) and 0.164 ($p = .004$), respectively. A similar pattern was observed when considering LNF intercept and slope as predictors of DWR spring slope, ßs = 0.380 ($p < .001$) and 0.226 ($p = .013$), respectively. Together, LNF intercept and slope accounted for approximately 14.6% of the variance in DWR January status, and 16.0% of the variance in DWR spring slope.

Initial status in LSF was not a statistically significant predictor of January DWR, ß = 0.162 ($p = .077$), however, LSF slope was a much stronger and statistically significant predictor, ß = 0.627 ($p < .001$). LSF intercept and slope were both significant predictors of DWR slope across the spring, ßs = 0.214 ($p = .033$) and 0.326 ($p = .002$), respectively. Considered together, LSF intercept and slope explained 47.8% of the variance in January DWR, and 20.1% of the variance in DWR spring slope. In summary, of the sublexical fluency variables, LSF intercept and growth explained the most variance in students' January status in fluency reading decodable CVC words, as well as how quickly students grew in the skill across the spring.

3.2. Parallel process LGMs predicting intercept and slope in word reading fluency

As reported in Fig. 2 and Table 3, October status in PSF and fall growth were statistically significant predictors of January status in WRF, ßs = 0.316 ($p < .001$) and 0.226 ($p = .008$), respectively. PSF intercept and slope were also predictive of WRF spring slope, ßs = 0.199 ($p = .013$) and 0.300 ($p < .001$), respectively, as PSF slope was a slightly stronger predictor than intercept. PSF intercept and fall slope accounted for 19.1% of the variance in WRF January status, and 17.0% of the variance in WRF rate of growth across the spring.

As observed with DWR, LNF fall intercept was a stronger predictor than LNF fall slope in predicting January WRF, ßs = 0.469

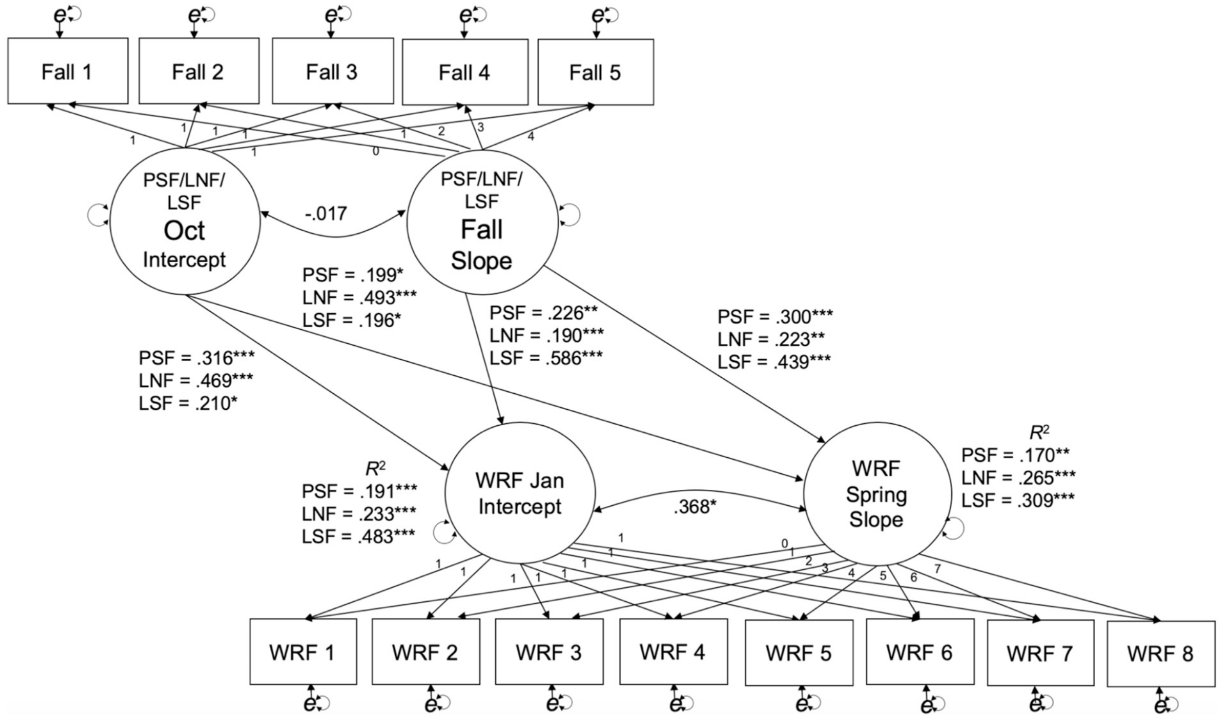

Fig. 2. Latent growth model results depicting the prediction of kindergarten Word Reading Fluency (WRF) January intercept and spring slope using intercept and growth in each of the sublexical fluency measures administered across the fall. To reduce the number of figures, we report the results of the separate models for each sublexical fluency measure. All measures were administered once every two weeks in kindergarten. Fall time points were collected from October to mid-December. Spring WRF time points were collected from mid-January to May. Students' English learner status was included as a predictor of the WRF factors. Unstandardized coefficients and standard errors are reported in Table 3. *$p < .05$. **$p < .01$. ***$p < .001$.

Table 2
Model fit statistics: parallel process latent growth models.

Model	χ^2 (*df*)	RMSEA (90% CI)	CFI	SRMR
PSF & DWR	147.512*** (79)	0.045 (0.034, 0.056)	0.974	0.032
LNF & DWR	124.374*** (78)	0.037 (0.024, 0.049)	0.986	0.028
LSF & DWR	153.518*** (77)	0.048 (0.037, 0.059)	0.972	0.036
PSF & WRF	260.767*** (79)	0.073 (0.064, 0.083)	0.961	0.041
LNF & WRF	235.084*** (78)	0.069 (0.059, 0.079)	0.971	0.037
LSF & WRF	230.838*** (77)	0.068 (0.058, 0.079)	0.966	0.039

Note. LNF = letter naming fluency; LSF = letter sound fluency; PSF = phoneme segmentation fluency; DWR = decodable word reading; WRF = word reading fluency, CI = confidence interval; RMSEA = root mean square error of approximation; CFI = comparative fit index; SRMR = standardized root mean square residual.
*** $p < .001$.

($p < .001$) and 0.190 ($p < .001$), respectively, and WRF spring slope, *ß*s = 0.493 ($p < .001$) and 0.223 ($p = .002$), respectively. Together, October LNF status and fall slope explained approximately 23.3% of the variance in January WRF, and 26.5% of the variance in WRF slope.

October LSF and fall LSF slope were statistically significant predictors of January status in WRF, *ß*s = 0.210 ($p = .018$) and 0.586 ($p < .001$), respectively, with slope again being a more important predictor than intercept. Similarly, LSF intercept and fall slope were predictive of subsequent rate of growth in WRF, *ß*s = 0.196 ($p = .010$) and 0.439 ($p > .001$), respectively. As observed in the prediction of DWR, LSF variables again accounted for a sizeable proportion of variance in subsequent WRF. LSF intercept and slope explained 48.3% of the variance in January WRF, and 30.9% of the variance in spring WRF slope. In short, compared to the other sublexical fluency measures, LSF intercept and slope across the fall of kindergarten explained the most variance in January level and subsequent rate of growth in WRF.

Table 3
Parallel process latent growth model results.

	Decodable word reading					
	DWR January Incpt		DWR spring slope			
	Unst. (*SE*)	St. (*SE*)	Unst. (*SE*)	St. (*SE*)	DWR Incpt R^2 (*SE*)	DWR slope R^2 (*SE*)
PSF Oct Incpt→	0.189*** (0.047)	0.362*** (0.066)	0.011 (0.007)	0.115 (0.077)	0.222*** (0.050)	0.114** (0.036)
PSF fall slope→	0.371**(0.105)	0.250**(0.084)	0.086*** (0.023)	0.301*** (0.060)		
EL status →	0.256 (0.672)	0.027 (0.071)	0.028 (0.153)	0.015 (0.083)		
LNF Oct Incpt→	0.126*** (0.024)	0.383*** (0.057)	0.024*** (0.005)	0.380*** (0.062)	0.146*** (0.042)	0.160*** (0.045)
LNF fall slope→	0.322* (0.125)	0.164** (0.058)	0.085* (0.037)	0.226* (0.092)		
EL status →	1.081 (0.715)	0.114 (0.075)	0.262 (0.187)	0.144 (0.095)		
LSF Oct Incpt→	0.113 (0.061)	0.162 (0.092)	0.029* (0.012)	0.214* (0.100)	0.478*** (0.064)	0.201*** (0.060)
LSF fall slope→	1.199*** (0.230)	0.627*** (0.070)	0.120*(0.046)	0.326** (0.108)		
EL status →	1.223* (0.534)	0.130* (0.055)	0.134 (0.164)	0.074 (0.086)		
	Word reading fluency					
	WRF January Incpt		WRF spring slope			
	Unst. (*SE*)	St. (*SE*)	Unst. (*SE*)	St. (*SE*)	WRF Incpt R^2 (*SE*)	WRF slope R^2 (*SE*)
PSF Oct Incpt→	0.153*** (0.046)	0.316*** (0.069)	0.016* (0.006)	0.199* (0.080)	0.191*** (0.051)	0.170*** (0.050)
PSF fall slope→	0.311** (0.093)	0.226** (0.085)	0.067*** (0.017)	0.300*** (0.067)		
EL status →	−0.666 (0.537)	−0.076 (0.061)	−0.128 (0.133)	−0.090 (0.095)		
LNF Oct Incpt→	0.144*** (0.020)	0.469*** (0.063)	0.024*** (0.004)	0.493*** (0.060)	0.233*** (0.056)	0.265*** (0.061)
LNF fall slope→	0.347** (0.107)	0.190*** (0.047)	0.066** (0.023)	0.223** (0.071)		
EL status →	0.508 (0.609)	0.058 (0.069)	0.089 (0.148)	0.063 (0.102)		
LSF Oct Incpt→	0.137* (0.054)	0.210* (0.089)	0.021** (0.007)	0.196* (0.076)	0.483*** (0.073)	0.309*** (0.070)
LSF fall slope→	1.043*** (0.217)	0.586*** (0.084)	0.126*** (0.026)	0.439*** (0.075)		
EL status →	0.279 (0.438)	0.032 (0.049)	−0.026 (0.135)	−0.018 (0.096)		

Note. Models are depicted in Figs. 1 and 2, and model fit statistics are reported in Table 2. Arrows indicate the variable was a predictor of the intercept and slope variables on the right, and the unstandardized and standardized coefficients indicate the strength of the path. Incpt = intercept; Unst. = unstandardized path coefficients; St. = standardized path coefficients; *SE* = standard error; LNF = letter naming fluency; LSF = letter sound fluency; PSF = phoneme segmentation fluency; DWR = decodable word reading; WRF = word reading fluency; EL = English leaner (included as a time-invariant predictor).
* $p < .05$.
** $p < .01$.
*** $p < .001$.

3.3. Examining unique effects: modeling the sublexical fluency predictors simultaneously

As a last step in the analyses, we examined whether intercept and growth in the fall sublexical fluency measures were uniquely predictive of January intercept and growth in DWR and WRF across the spring. In other words, we were interested to see the extent to which intercept and slope of each sublexical fluency measure were predictive of spring intercept and slope in the word reading measures while controlling for the predictive effects of the other sublexical fluency variables. Results are reported in Figs. 3 and 4 (unstandardized coefficients and standard errors are reported in Table 3).

Results were consistent with the individual growth model analyses. LSF intercept and slope demonstrated the strongest path coefficients of all the measures. Although the PSF and LNF variables were statistically significant predictors in select cases, all LSF paths were statistically significant predictors of intercept and slope for both DWR and WRF over and above the effects of the other predictors in the model.

4. Discussion

The sublexical fluency hypothesis posits that students' fluency and automaticity with skills that operate below the word level, such as phonemic awareness and alphabetic knowledge, may ease the acquisition of decoding skills (Ritchey & Speece, 2006). Measures of sublexical fluency such as phoneme segmentation fluency (PSF), letter naming fluency (LNF), and letter sound fluency (LSF), are widely available for monitoring reading progress of kindergarten children with or at risk for reading difficulties. Because growth can be viewed as a variable of instructional responsiveness and a key factor in informing instructional decisions (Stecker, Fuchs, & Fuchs, 2005), this study sought to extend the sublexical fluency hypothesis by investigating the extent to which growth in sublexical fluency skills, as measured by PSF, LNF, and LSF, forecasts decoding acquisition for at-risk learners in kindergarten.

Table 4
Model results: simultaneous predictors of spring word reading.

	Decodable word reading							
	DWR January intercept				DWR spring slope			
	Unst.	(*SE*)	St.	(*SE*)	Unst.	(*SE*)	St.	(*SE*)
PSF Oct intercept →	0.115***	(0.031)	0.239***	(0.052)	−0.006	(0.007)	−0.064	(0.070)
PSF fall slope→	0.147*	(0.064)	0.125*	(0.061)	0.025**	(0.008)	0.110**	(0.038)
LNF Oct intercept →	−0.079*	(0.032)	−0.247**	(0.092)	−0.009	(0.005)	−0.141	(0.080)
LNF fall slope→	−0.111	(0.085)	−0.078	(0.054)	0.012	(0.017)	0.046	(0.062)
LSF Oct intercept →	0.221**	(0.078)	0.340**	(0.122)	0.051***	(0.032)	0.335***	(0.091)
LSF Fall slope→	0.824***	(0.147)	0.522***	(0.051)	0.101**	(0.032)	0.335***	(0.091)
EL status →	0.238	(0.497)	0.025	(0.052)	0.059	(0.137)	0.032	(0.073)

	Word reading fluency							
	WRF January intercept				WRF spring slope			
	Unst.	(*SE*)	St.	(*SE*)	Unst.	(*SE*)	St.	(*SE*)
PSF Oct intercept→	0.080*	(0.033)	0.182**	(0.062)	0.001	(0.005)	0.021	(0.067)
PSF fall slope→	0.093	(0.050)	0.086	(0.053)	0.019*	(0.008)	0.106*	(0.045)
LNF Oct intercept→	−0.033	(0.027)	−0.110	(0.081)	0.005	(0.004)	0.109	(0.092)
LNF fall slope→	−0.021	(0.070)	−0.016	(0.052)	0.014	(0.013)	0.066	(0.060)
LSF Oct intercept →	0.194***	(0.060)	0.325***	(0.099)	0.022**	(0.007)	0.225**	(0.071)
LSF fall slope→	0.688***	(0.145)	0.475 ***	(0.063)	0.074***	(0.021)	0.319***	(0.083)
EL status →	−0.362	(0.473)	−0.041	(0.053)	0.046	(0.125)	−0.032	(0.089)

Note. Models are depicted in Figs. 3 and 4. Arrows indicate the variable was a predictor of the intercept and slope variables on the right, and the unstandardized and standardized coefficients indicate the strength of the path. Unst. = unstandardized path coefficients; St. = standardized path coefficients, *SE* = standard error. Models displayed in Figs. 3 and 4. LNF = letter naming fluency; LSF = letter sound fluency; PSF = phoneme segmentation fluency; DWR = decodable word reading; WRF = word reading fluency; EL = English learner.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

4.1. Summary of findings

The Decodable Word Reading (DWR) measure administered from January to May of kindergarten is a fluency-based measure of real (but low frequency) phonetically regular words that all follow a CVC spelling pattern. Although LNF and PSF scores in October were predictive of students' DWR level in January, the most variance in January DWR status was explained by LSF predictors, of which LSF growth was the strongest predictor based on the magnitude of the standardized coefficients. LSF factors accounted for the most variance in DWR growth across the second half of kindergarten, and LSF growth was the primary predictor.

The WRF measure administered from January to May of kindergarten is a fluency-based measure consisting of real, high-frequency, phonetically regular and irregular words that generally range from 2 to 6 letters in length. LSF October intercept and growth across the fall again accounted for the most variance in January WRF status and growth across the spring.

Additional analyses that controlled for the effects of all the predictors found that LSF intercept and slope demonstrated the strongest coefficients in predicting subsequent intercept and slope on both word reading measures. LSF was also the only measure in which intercept was uniquely predictive of both intercept and slope in subsequent word reading.

4.2. LSF as a predictor of subsequent word reading

It is notable that, in the growth modeling analyses, LSF variables across the fall of kindergarten were the strongest predictors of subsequent performance on both word reading measures. For beginning readers, the low frequency but highly regular and consistent nature of the words in the DWR measure may allow it to function similarly to measures of decodable pseudowords. That is, students with fair letter-sound knowledge and a working understanding that decoding involves processing letters on a serial basis then blending the sounds back together can use this approach to read words across the measure. Therefore, it is not surprising that growth in the efficiency of identifying letter-sound correspondences, as indexed by LSF, was the strongest predictor of subsequent DWR performance.

Perhaps more notable is that LSF intercept and growth across the fall of kindergarten were also the strongest predictors of subsequent performance on WRF. In contrast to DWR, WRF includes both regular and irregular words of varying lengths and spelling patterns such as consonant blends, r-controlled vowels, and words with silent-e. Although all three sublexical fluency measures were predictive of subsequent WRF performance, LSF stood out as the measure in which initial status and fall growth explained the most

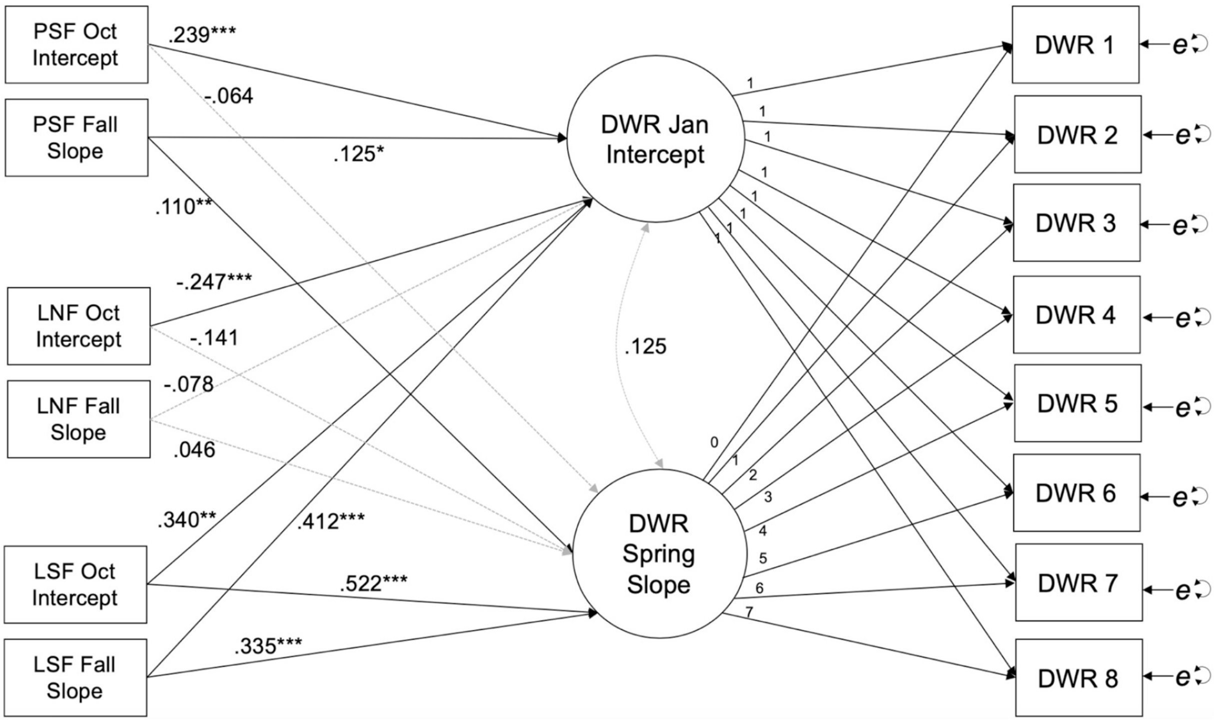

Fig. 3. Model results depicting the prediction of kindergarten Decodable Word Reading (DWR) January intercept and spring slope by intercept and growth the sublexical fluency measures included simultaneously. Standardized path coefficients are reported. Light grey paths were not statistically significant. Spring DWR time points were administered once every two weeks from mid-January to May. Students' English learner status was included as a predictor of the DWR factors. Correlations among the predictors were included in the model but were omitted from the figure to reduce visual complexity. Unstandardized coefficients and standard errors are reported in Table 4. Model fit: χ^2 = 148.250* (72); RMSEA = 0.050 (0.039, 0.062); CFI = 0.960; SRMR = 0.045. *p < .05. **p < .01. ***p < .001.

variance in WRF status at mid-year and subsequent growth across the spring. LSF was also the only measure that was uniquely predictive of WRF intercept and growth when all predictors were included.

Why would growth in LSF continue to be the strongest predictor of growth on the less regular and less predictable words of WRF? One possibility is that, because WRF included both regular and irregular words, students were more likely to read the regular words correctly, thereby explaining the relation of LSF growth to growth on WRF. However, this does not appear to be entirely the case. Although extensive item-level analyses were beyond the scope of the present study, we were able to examine students' responses to the WRF items on a descriptive basis. Descriptive data indicated that students did not read phonetically regular words more accurately than irregular words, in fact, the opposite was often true. Across the first 10 items on the WRF probes (i.e., the items that most students were most likely to see), 30–50% of the words were irregular, however, students' average accuracy in reading irregular words was 46% compared to an average of 35% accuracy on regular words. For example, on the third WRF probe, "is" was read more accurately than "it" or "top" (54.5% versus 43.5% and 26.2%, respectively), and on the fifth WRF probe, "he" (40.1%) was read with similar accuracy to "top" (39.5%) and more accurately than "fast" (20.9%). Thus, the strength of LSF as a predictor of WRF development was not entirely due to the inclusion of regular words on WRF.

We believe the results are consistent with connectionist models of reading development, which hold that all words exist on a continuum of spelling-sound consistency (Harm & Seidenberg, 1999; Seidenberg, 2005). Irregular words are not completely arbitrary in terms of the letter-sound relations they contain, in fact, a high proportion of letters in most irregular words conform to their most common sounds, and a great deal of overlap in letter-sound correspondence exists between regular words and similarly spelled irregular words. For example, what students learn about the word "had" (regular) overlaps and is relevant for "has" and "have" (both irregular; Seidenberg, 2017). Rather than reading regular and irregular words using separate routes or processes, establishing connections between word spellings and pronunciations originates from well-developed knowledge of letter-sound relations (Ehri, 1992, 1998, 2014). These linkages form an ever-expanding network in which new, more complex, and more diverse spelling-sound connections are facilitated by previously learned connections (Ehri, 1992; Harm & Seidenberg, 1999; Seidenberg, 2005).

Recent perspectives consider two-step processes in word reading development; one step in which letters are recoded as sounds, and a second step in which the word is recognized, which in some cases involves recognition of slightly different spelling-specific pronunciations (Elbro, de Jong, Houter, & Nielsen, 2012). This process has also been referred to as "set for variability" (Elbro & de Jong, 2017; Savage, Georgiou, Parrila, & Maiorino, 2018; Tunmer & Chapman, 2012) as the reader must possess some level of flexibility in their knowledge of letter-sound correspondences to read words accurately in a semi-regular writing system, such as

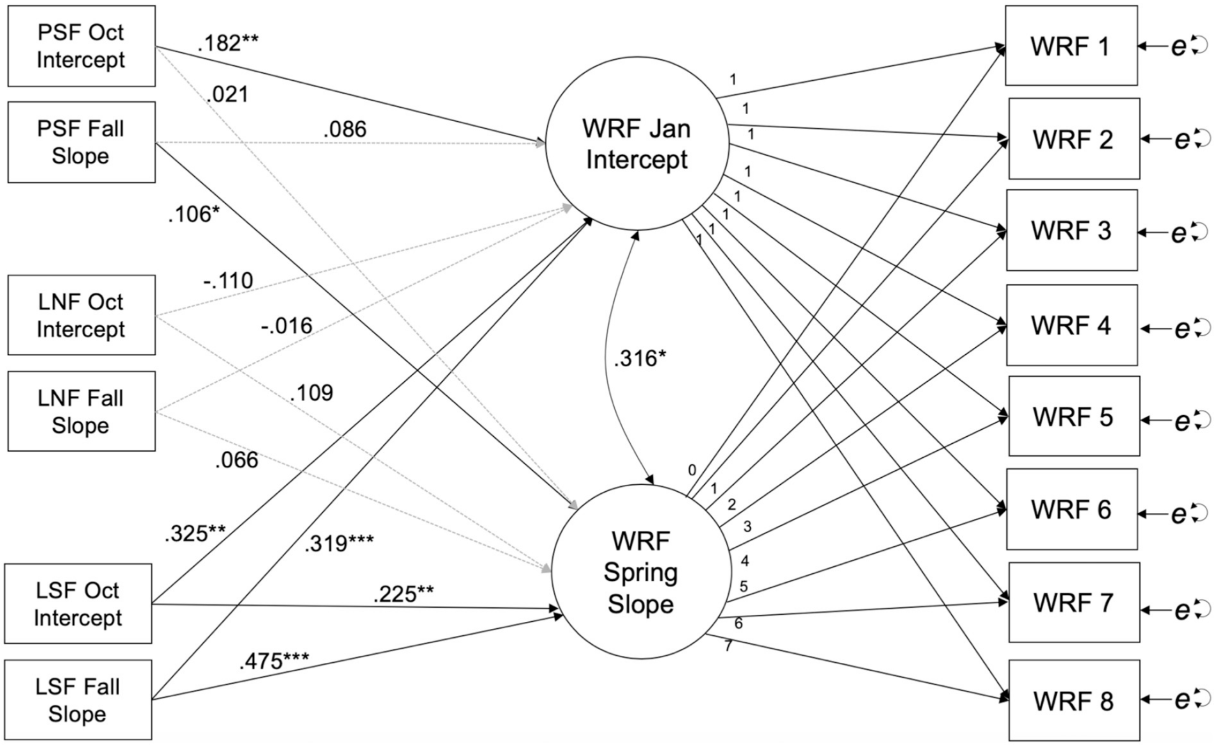

Fig. 4. Model results depicting the prediction of kindergarten Word Reading Fluency (WRF) January intercept and spring slope by intercept and growth the sublexical fluency measures included simultaneously. Standardized path coefficients are reported. Light grey dashed paths were not statistically significant. Spring time points (WRF) were administered once every two weeks from mid-January to May. Students' English learner status was included as a predictor of the WRF factors. Correlations among the predictors were included in the model but were omitted from the figure to reduce visual complexity. Unstandardized coefficients and standard errors are reported in Table 4. Model fit: χ^2 = 256.110* (72); RMSEA = 0.078 (0.068, 0.089); CFI = 0.947; SRMR = 0.053. *p < .05. **p < .01. ***p < .001.

English. A critical point is that the process that connects spellings to pronunciations is made possible by acquiring letter-sound associations, learned to an extent that they are recognized immediately and with little conscious effort (Elbro & de Jong, 2017). Significant difficulties in reading words originate through difficulties in establishing reliable and efficient connections between phonemes and printed letters, which impairs the students' ability to form more connections and build a network of spelling-pronunciation linkages. Therefore, evidence from the current study converges with prior research and perspectives underscoring letter sound fluency as perhaps the most important foundational skill that students acquire in early reading instruction.

Recently, Protopapas, Katopodi, Altani, and Georgiou (2018) hypothesized that reading fluency imposes unique demands that involve managing multiple stimuli in sequence, a form of "cascaded" processing in which a word is processed while the previous word is uttered, the next one viewed and processed, and so on. They posited that this form of cascaded processing of serial stimuli requires additional cognitive or attentional resources than what are required for reading single words in isolation, and is at least partly responsible for the correlation between word reading fluency and RAN tasks. As both word reading measures in the present study relied on serial processing, the relation of LSF to subsequent growth in word reading skills may be due in part to the fact that LSF and the word reading measures both involve cascaded processing of multiple stimuli in sequence, like that suggested by Protopapas et al. Students that are able to readily connect printed letters with sounds on a serial basis quickly may be demonstrating stronger growth in skills facilitative of the cascaded processing demands inherent to reading. This explanation is incomplete, because LNF also relies on very similar serial processing of stimuli even though LSF was a stronger predictor overall. It may be that, because students likely knew fewer letter sounds than letter names at the start of the year, the acquisition of letter-sounds across the fall of kindergarten, combined with serial processing aspects proposed by Protopapas et al., were both involved in the stronger relation of LSF to subsequent word reading development than LNF.

We have left out another important aspect of word reading development, that being the development of semantic (i.e., vocabulary) knowledge. "Triangle" models of word learning suggest that words are represented in memory in three ways: Orthographically (how the word is spelled), phonologically (how the word is pronounced), and semantically (what the word means). Over time, word meanings are connected to word spellings, thus completing the spelling-sound-meaning triangle important for word knowledge (Harm & Seidenberg, 1999; Perfetti, 2007; Seidenberg, 2005). Our present results do not attempt to account for these relations, rather, our results provide evidence for sublexical fluency skills that support orthographic—phonological linkages in the development of word reading.

4.3. Consideration of letter naming fluency

LNF performance was predictive of subsequent reading skills on both word reading measures, however, initial status was a stronger predictor relative to growth. These results are consistent with prior work indicating that letter name knowledge is one of the strongest predictors of subsequent reading skills at kindergarten entry (National Early Literacy Panel, 2008; Scarborough, 1998). Still, growth in LNF across the fall was a positive and statistically significant predictor of subsequent word reading. These results expand on those of Ritchey and Speece (2006) and Al Otaiba et al. (2011), who found that LNF growth across either the second half of kindergarten or the full year held an inverse relation with subsequent word reading skills, which suggested that students who were still growing in LNF at later stages of kindergarten experienced weaker reading outcomes. In the present study, we only examined LNF growth across the fall of kindergarten, which may be a period in which growth is indicative of successful future reading growth trajectories. Thus, the time in which LNF is measured is important.

Teaching letter names in conjunction with letter sounds leads to stronger letter-sound acquisition (McBride-Chang, 1999; Piasta & Wagner, 2010), thus underscoring its relevance as an instructional target in early kindergarten. Evidence also indicates that letter name knowledge is used directly in word reading (Ehri & Wilce, 1985; Roberts, 2003; Treiman & Kessler, 2003; Treiman & Rodriguez, 1999), even for adults (Bowman & Treiman, 2002). Ehri (2014) suggested that letter name knowledge may benefit word reading by strengthening grapheme-phoneme correspondences and by providing more information to aid learning and recall, which enhances the bonds between word spellings and pronunciations. Treiman and Kessler (2003) posited that letter name knowledge provides beginning readers with insight that word spellings are not arbitrary, and that letters provide information on how words are pronounced. These perspectives, combined with the present results, challenge the position of Good and Kaminski (2011) that letter names are not valid targets for instruction or progress monitoring. Nevertheless, LSF variables demonstrated greater strength in terms of their ability to predict subsequent growth in word reading efficiency, thus making LSF a more preferable option for monitoring kindergarten reading progress than LNF.

4.4. Consideration of phoneme segmentation fluency

In most instances, PSF fall intercept and slope were statistically significant predictors of January status and spring growth for both word reading measures. Phonemic segmentation skills are among the most important foundational skills for reading development outside of print-based skills, because the ability to breach words by isolating individual phonemes, rather than perceiving them as whole units, paves the way for associating individual phonemes with letters and using that information to decode (Ball & Blachman, 1991; Snow et al., 1998). Its importance as a foundational skill is likely why it is so commonly recommended for monitoring progress in kindergarten.

Despite the relations observed between PSF growth and subsequent reading skills, PSF was still generally a weaker predictor than the LSF variables in the prediction of subsequent word reading development. The most likely reason for the difference is that LSF is a print-based skill and more directly involved in beginning decoding and word recognition. Skills in phonemic segmentation facilitate students' development in letter-sound correspondence (Schatschneider & Torgesen, 2004), thus, LSF can be viewed in part as an outcome of phonemic segmentation skills. Our results do not diminish the importance of phonemic awareness skills. Rather, our results should promote a better understanding of the place of phonemic segmentation skills within the process of reading development, and by extension, a more careful consideration of the value of monitoring phonemic segmentation skills after instruction in print-based skills has begun. More specifically, the present results magnify the importance of letter-sound correspondence as critical skill for monitoring reading progress in early kindergarten.

4.5. Implications for practice

The results offer several implications for data-based decision-making with kindergarten students at risk for reading difficulties. Progress monitoring is a key aspect of supplemental interventions for struggling learners, providing teachers with timely feedback to adjust instruction to meet students' needs. Recommendations for kindergarten progress monitoring include PSF alone (Gersten et al., 2009); PSF with other measures (e.g., Kaminski et al., 2008); or LNF, PSF, and LSF as options without definitive recommendations on measures that are most important (NCII, 2013). Our results are consistent with the recommendations of Fuchs and Fuchs (2004) that LSF is a parsimonious and important option for monitoring kindergarten reading progress. Although we found that LNF and PSF measured in October of kindergarten are predictive of subsequent decoding skills, growth in LSF across the first half of kindergarten may be an ideal measure for this time period as an indicator of reading skill acquisition and predictor of the rate at which students grow in word reading. Growth in LSF not only serves as an index of responsiveness to early reading instruction, but as our results demonstrated, growth in LSF can serve as a predictor of future status and the rate at which students acquire decoding skills in the future. Thus, students who demonstrate low growth in LSF during the first half of kindergarten should be viewed as ideal candidates for supplemental interventions to improve skills that are critical for the development of decoding and word recognition.

These results should inform more focused decisions regarding measures best suited for monitoring kindergarten reading progress. We do not believe it is particularly helpful for publishers to offer educators a large number of measures as options for monitoring kindergarten reading progress without guidance on which may be the most important indicators of reading acquisition. In later grades, a general outcomes measurement perspective which focuses on skills that are reflective of overall achievement (Deno, 1985, 2003), has typically been avoided in kindergarten given the dynamic and rapidly changing nature of reading instruction and reading development itself. However, as we observed in this study, LSF serves as a key index of general outcomes specific to the early months of formal reading instruction. By providing an index in growth in letter-sound acquisition, a primary target of kindergarten reading instruction and a skill that is highly predictive of word reading skills (regardless of the types of words), LSF may be an ideal choice for monitoring progress in the fall of kindergarten and providing insight on students that are not on track for successful decoding acquisition, and thereby signaling the need for customized intervention support.

4.6. Limitations

Several limitations of this study must be acknowledged. First, we gathered information on instruction and interventions implemented for each student, which indicated that the vast majority received instruction in the skills measured in this study, but we did not have resources to support direct observations. Thus, we did not have data on the quality of teachers' instruction or observational data on the amounts of time in which instruction focused on specific skills. Second, we intentionally restricted the sample to at-risk learners to focus on a population for whom progress monitoring is most relevant; this focus permits recommendations for at-risk learners but precludes generalization to a full range of learner profiles. Third, ELs in this project were learning to read in English and were receiving at least 50% of their instruction in English, therefore our results may not extend to EL populations for whom the language of instruction is different. Fourth, our item-level analyses described in the discussion were preliminary and descriptive (more extensive item-level analyses were beyond the scope of the present paper), however, more detailed item-level analyses are anticipated to determine whether reading certain word types correctly was more likely given particular skill profiles on the sublexical fluency measures (e.g., whether greater accuracy with vowels is associated with differential accuracy in word reading).

5. Conclusion

Sublexical fluency across the early months of kindergarten, in this case, phoneme segmentation fluency, letter naming fluency, and letter sound fluency, were predictive of subsequent status and rates of growth in word reading across the later portion of the school year. However, letter sound fluency, particularly growth across the fall, was the strongest predictor of subsequent word reading fluency irrespective of whether the word reading measure was made up entirely of phonetically regular words. Findings underscored the critical importance of letter sound knowledge for word reading development and provide additional support for LSF as a progress monitoring measure for at-risk learners across the early months of formal reading instruction.

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