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Research Article

Reading Risk in Children With Speech Sound Disorder: Prevalence, Persistence, and Predictors

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Purpose: The purpose of this study was to determine the extent to which school-age children with speech sound disorder (SSD) exhibit concomitant reading difficulties and examine the extent to which phonological processing and speech production abilities are associated with increased likelihood of reading risks.
Method: Data were obtained from 120 kindergarten, first-grade, and second-grade children who were in receipt of school-based speech therapy services. Children were categorized as being "at risk" for reading difficulties if standardized scores on a word decoding measure were 1 *SD* or more from the mean. The selected predictors of reading risk included children's rapid automatized naming ability, phonological awareness (PA), and accuracy of speech sound production.
Results: Descriptive results indicated that just over 25% of children receiving school-based speech therapy for an SSD exhibited concomitant deficits in word decoding and that those exhibiting risk at the beginning of the school year were likely to continue to be at risk at the end of the school year. Results from a hierarchical logistic regression suggested that, after accounting for children's age, general language abilities, and socioeconomic status, both PA and speech sound production abilities were significantly associated with the likelihood of being classified as at risk.
Conclusions: School-age children with SSD are at increased risk for reading difficulties that are likely to persist throughout an academic year. The severity of phonological deficits, reflected by PA and speech output, may be important indicators of subsequent reading problems.

Children with speech and language difficulties are disproportionately represented among those with reading disorders (Adlof, 2017; Adlof & Hogan, 2018; Cabbage et al., 2018; Catts et al., 2005), with some reports suggesting that up to 25% of children who receive speech-language therapy may concurrently receive reading supports (Gosse et al., 2012). It is well established that children with primarily language-based deficits are at heightened risk for concurrent and/or subsequent reading problems and can demonstrate difficulties with word decoding and reading comprehension (Bishop & Adams, 1990; Catts, 1993; Murphy et al., 2016). Research focused on children who exhibit speech production difficulties, such as those with speech sound disorder (SSD), are also at increased risk for reading deficits (Anthony et al., 2011; Cabbage et al., 2018; Foy & Mann, 2012; Lewis et al., 2006, 2015, 2018; Raitano et al., 2004; Smith et al., 2005), although findings for this diagnostic group are equivocal (see Pennington & Bishop, 2009, for a review) and somewhat minimal in scope. That is, not only are there mixed findings regarding the prevalence of reading difficulties in children with SSD, but little is known as to whether these risks are persistent in children who receive speech therapy and the factors that may be associated with risk status.

In this study, we address this gap in the literature and examine the extent to which young children who are receiving school-based speech therapy for speech sound/articulation difficulties exhibit concurrent risks for reading difficulties specific to word decoding (hereafter referred to as *RD*) throughout an academic year. Understanding the risks for RD in this particular clinical subgroup is important not only because children with SSD represent a large proportion of those who receive school-based speech therapy (American Speech-Language-Hearing Association, 2018) and addressing reading difficulties is within the scope of practice for speech-language pathologists (SLPs; American

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Speech-Language-Hearing Association, 2016), but because word decoding is a strong predictor of subsequent reading comprehension ability (Keenan et al., 2008; Kendeou et al., 2009; Language and Reading Research Consortium [LARRC] & Chiu, 2018). Thus, enhancing our understanding of how prevalent RD might be among young children with SSD is critical for ensuring that sufficient services are provided early and that later reading difficulties may be mitigated. To that end, we examine the extent to which children with SSD exhibit risk for concurrent RD at the beginning and end of an academic year and seek to identify the relevant and malleable factors that may be associated with that risk.

Prevalence of RD in Children With SSD

A large body of research supports the idea that word decoding is heavily contingent on intact phonological skills, such as phonological awareness (PA; Bradley & Bryant, 1983; Catts et al., 2015; Hogan et al., 2005; LARRC & Chiu, 2018; Wagner & Torgesen, 1987) and rapid automatized naming (RAN; Wolf & Bowers, 2000). As such, it seems logical that children with SSD, whose speech sound difficulties are often phonologically based (e.g., Cabbage et al., 2018; Peterson et al., 2009; Preston et al., 2013; Raitano et al., 2004), would be at increased risk for difficulties in understanding and applying the grapheme–phoneme connections needed for sounding out words. However, evidence regarding the prevalence of RD in children with SSD is scarce. Certainly, there are numerous studies suggesting that, as a group, children with SSD are more likely to experience reading and spelling difficulties compared to typically developing children (Lewis et al., 2011), regardless of whether they have concomitant language impairment (LI; Lewis et al., 2018) and even if their speech errors are considered normalized (Farquharson, 2015; Lewis et al., 2015; Raitano et al., 2004). Raitano and colleagues, for example, examined the extent to which 5- and 6-year-old children who had either a history of or current SSD, with or without concomitant LI, performed more poorly on measures of emergent literacy compared to an age-matched control group. Results showed that, as a group, children with SSD had significantly lower scores on measures of PA and alphabet knowledge, indicating potential risks to difficulties with word decoding. These differences were particularly pronounced for children with persistent SSD and/or concomitant LI. However, this study also included a subgroup of children whose speech sound errors were considered to have "normalized." This subgroup of children could exhibit age-appropriate errors according to Speech Disorders Classification System (Shriberg & Austin, 1997); this was reflected in their lower standardized scores on a single-word elicitation task. Importantly, despite having mild speech sound errors and expressive language abilities within the average range, this subgroup also performed more poorly on measures of PA, compared to children in the control group.

Other studies have further modified these findings with the caveat that the children with SSD who exhibit reading difficulties are more likely to have concomitant language deficits, rather than isolated SSD (Catts, 1993; Peterson et al., 2009; Sices et al., 2007). Peterson et al. (2009), for instance, longitudinally followed the same group of children from Raitano et al.'s (2004) study through school age. Using a measure of reading fluency to determine rates of reading disorder, they found that 22% of children who had SSDs between the ages of 5 and 6-years achieved scores that would place them "at risk" for a reading disorder when they were 7–9 years old. This is in comparison to only 5.4% of children in the control group (n = 37). Further analyses determined that children's language skills, rather than the severity of children's speech output errors, were a more reliable predictor of literacy outcomes, which was a composite score of single-word reading, spelling, and reading comprehension.

Overall, very few studies have reported the rate of RD risk in children with SSD. However, there is some evidence of overlap between RD and speech sound production errors, even among children who may not have an SSD diagnosis. Foy and Mann (2012), for example, examined the speech errors produced by kindergartners (n = 92) who were categorized as "at risk" or "no risk" for reading difficulties, based on scores from a standardized measure of emergent literacy. Children in the "at-risk" category demonstrated significantly more speech errors compared to children in the "no-risk" category, suggesting a correlation between speech sound accuracy and early reading ability. Moreover, these relations were consistent over an academic year, such that children in the "at-risk" category continued to exhibit more speech errors at the end of the school year compared to children in the "no-risk" category. The measure used to determine risk categories, however, was not a direct measure of word decoding ability, thus limiting more direct conclusions concerning relations between speech sound errors and reading skills.

Considered together, research indicates that children with SSD, particularly those whose speech errors are present at school age, may be at heightened risk for RD. To date, however, research examining the actual rate of overlap of SSD and RD is extremely limited. As such, a clear understanding of the proportion of school-age children with SSD who may require reading supports remains understudied. Therefore, in this study, we determine the extent to which early elementary school–age children who receive therapy for speech sound/articulation difficulties exhibit concurrent risk for RD.

Persistence of Risks for RD

An important complement to this investigation is to also understand the persistence of risks for RD among children receiving school-based speech therapy services. That is, it is relatively unknown whether children with SSD who begin school with poor word decoding skills are able to catch up to their peers by the end of the school year or if they continue to have difficulties throughout the year. Results from Foy and Mann (2012) indicate that children who begin the school year in a risk status are likely to remain so throughout the year. Accordingly, studies comparing the reading development of school-age children with varying abilities suggest that, although children with LI consistently perform more poorly than their typically developing peers, the overall trajectory pattern is comparable between the two groups (e.g., Morgan et al., 2011). Few studies have determined whether risk for RD changes over an academic year, particularly for children with SSD. This is an important clinical question to consider; if children with SSD with concomitant risks for RD are able to overcome these deficits after a year of school-based services, then perhaps the need to identify these children is less urgent.

Concomitant LI as a Predictor of RD Risk

As reviewed above, there is considerable evidence that some proportion of children with SSD are likely to exhibit RD as well and that the risks for RD are exacerbated when children have co-occurring language deficits. The extant literature that has examined additional skills associated with RD risk status in young children has yielded somewhat mixed results. Catts et al. (2001), for instance, found that kindergarteners' letter identification skills, sentence imitation, PA, RAN, and maternal education were each significantly associated with second-grade reading comprehension outcomes in a large and heterogeneous sample of children (n = 604). Conversely, Murphy et al. (2016) conducted a similar analysis to predict RD risk in preschool children with LIs (n = 136). Their results showed that 27% of the preschoolers with LI could be classified as "at risk" for RD based on standard scores of a measure of word recognition. In addition to letter knowledge and overall language abilities, children's print knowledge was associated with risk status; surprisingly, neither PA nor RAN was significantly associated with RD risk.

In samples of children with SSDs, longitudinal and follow-up studies have similarly reported equivocal results. For example, Young et al. (2002), in a follow-up investigation, examined the language and reading skills of adults who had histories of SSDs with and without LI in childhood. Largely, the SSD-only group performed equally to a typically developing control group and better than the comorbid SSD and LI group. However, the only measure on which the SSD-only group differed from the control group was word reading. In contrast, Lewis et al. (2018) longitudinally followed children with SSD with and without comorbid LI. They reported that, at both middle childhood and adolescence, children with SSD and comorbid LI had significantly lower scores on measures of word reading, spelling, and PA compared to both children with SSD only and typically developing children. When examining predictors of persistent deficits with spelling, they found that the group of children with SSD only performed better than children with both SSD and LI. For this reason, the authors concluded that SSDs in isolation are not likely to increase the risk for spelling deficits. Similarly, Sices et al. (2007) found that preschool-age children with SSD and comorbid LI were at greater risk for deficits in preliteracy skills than were children with SSD only.

Although these studies utilized different outcome variables and included participant groups of varying ages and language abilities, these rather disparate findings underscore the possibility that the variables associated with RD risk may diverge across clinical subgroups of children.

Predicting RD Risk in Children With SSD: Theoretical Considerations

For children with SSD, whose deficits often result from an impaired phonological system (Sutherland & Gillon, 2005), [it stands to reason that their inherent difficulties with PA and additional phonologically based skills (e.g., phonological working memory; see Farquharson et al., 2018) would activate compensatory mechanisms to facilitate the word decoding process. There is little evidence to date to inform which set or sets of skills are significantly associated with RD risk in children with SSD specifically. However, findings from Peterson et al. (2009) indicate that, in addition to oral language abilities, PA is likely an important factor for word decoding in children with SSD. In addition, research including children with dyslexia, whose reading difficulties are similarly rooted in phonological deficits, frequently exhibit difficulties with both PA and RAN. In accordance with the double deficit hypothesis (Wolf & Bowers, 2000), PA and RAN are unique and independent contributors to reading success or inadequacy (Manis et al., 2000; Wolf & Bowers, 2000). Extensive work has now substantiated the importance and unique contributions of PA and RAN to identifying RD (e.g., Sideridis et al., 2019; Vellutino et al., 2004; Wolf et al., 2000). As such, it seems prudent to include these two skills when examining risk for RD in a population of children with SSDs.

The psycholinguistic model of speech processing (Stackhouse & Wells, 1997) may be particularly useful for understanding the extent to which children with SSD experience RD (Stackhouse & Wells, 1997). Whereas the double deficit hypothesis focuses on the contributions from PA and RAN, the psycholinguistic model considers several aspects of the speech processing system. This includes input processing (auditory skills, phoneme discrimination) to lexical and phonological processing (storage of lexical and phonological representations, access to and retrieval of lexical and phonological representations) to speech output (accurate speech sound production) in order to isolate and identify the skills or characteristics for which children exhibit deficits. For instance, Terband et al. (2019) used the psycholinguistic framework as a basis for distinguishing between certain diagnostic categories and, subsequently, how to appropriately plan treatment for children with SSD. Within their application of this framework, children who exhibit difficulty at multiple levels of phonological knowledge may be diagnosed with a disorder instead of a delay.

Similarly, then, treatment would focus on improving input processing, phonological processing, and speech sound production.

Accordingly, the psycholinguistic framework facilitates the perspective that inaccurate or disordered speech sound production may be the manifestation of a more generally impaired phonological processing system, in which a range of phonological and lexical skills may be implicated, which then affects the ability to sound out or decode written words. Put simply, speech sound output relies on access to lexical and phonological representations and the ability to discern and manipulate segments of speech. Speech production is a reflection of the state of the phonological system and may thus be implicated as children learn to apply phoneme–grapheme correspondence needed for word decoding. Examining the extent to which varying speech processing skills, including speech production accuracy, contribute to word decoding may be useful in understanding how best to identify children with SSD who are at risk for RD. In this way, we are simultaneously testing a component of the psycholinguistic model and the double deficit hypothesis for children with SSDs. Specifically, we consider the extent to which phonological skills (PA and RAN) and speech production are associated with RD risks in school-age children who are receiving speech sound/articulation therapy.

Purpose of the Current Study

To date, it remains relatively unclear how many children with SSD, who are receiving services from an SLP, may also benefit and/ or require direct services from a reading specialist or special education teacher. There are very few studies that have sought to determine reading risks among school-age children with SSD—a population that is consistently one of the largest on many school-based SLP caseloads. As such, it is possible that many SLPs may be unsure of which children are at greatest risk or, more importantly, may be unsure of which indicators of reading risk are most relevant for children with SSD. Although several theoretical frameworks can be helpful for understanding which skills and abilities may relate to RD risk, evidence for children with SSD is lacking. This study addresses this gap by (a) examining the proportion of children with SSD who exhibit risk for RD at the beginning of their academic year, (b) determining the extent to which children remain in or move out of risk status at the end of the academic year, and (c) determining the speech processing variables (i.e., RAN, PA, speech production) that may contribute to initial RD risk status.

Method

Participants

Participants included 120 children who were in current receipt of school-based speech-language therapy in public schools within a southern and midwestern state. Participants in this study were a subset of those from a three-cohort descriptive study of business-as-usual practices in school-based speech-language therapy sessions (Speech Therapy Experiences in the Public Schools [STEPS]); that is, SLPs were asked to deliver therapy as they normally would and were not asked to focus on any specific goals or topics. The larger study aimed to examine and identify characteristics of school-based therapy that were associated with gains in children's language skills over an academic year. Although the study, which included 293 participants in total, primarily sought to investigate outcomes for children with LI, eligible participants also included children with speech/articulation goals and children with concomitant speech and language difficulties. As such, participants in the STEPS study represent a clinically identified sample of young children who are typically served in the public schools.

At the start of the academic year, school-based SLPs were asked to identify up to 10 children on their caseloads who met three general eligibility criteria: (a) were in current receipt of school-based speech-language therapy; (b) were in kindergarten, first grade, or second grade; (c) did not have a severe cognitive impairment that would impact their ability to complete study tasks; and (d) primarily communicated in English. SLPs forwarded recruitment materials, including materials for informed consent to caregivers of children meeting these criteria. For information about the complete sample in the larger study, including recruitment processes, see Tambyraja, Schmitt, et al. (2015). As part of the larger study, research staff were provided with the Individualized Education Program (IEP) of each participating child. The IEPs were coded according to the therapy targets that were outlined (i.e., vocabulary, grammar, fluency, articulation).

This study only focused on the subset of children (n = 120) selected for this study that included those who (a) had at least one IEP goal pertaining to speech sound/ articulation targets (e.g., *Within one school calendar year, the child will produce appropriate sound patterns for the velar sounds /k/ and /g/*) and (b) had completed the assessment of word decoding in the beginning of the year (fall). The majority of these children had both speech and language goals outlined in their IEP (n = 78, 68%), indicating concomitant speech and language difficulties. Of particular interest to the present work, five children in this study had literacy-focused goals as well. The present sample included 32 kindergartners, 83 first-graders, and five second-graders. The majority of children were male (n = 78), and a range of ethnicities were represented, with 55% being Caucasian. Based on parent report, a small proportion of children had additional diagnoses, including attention-deficit disorder and/or inattentiveness (n = 8), developmental disorder (n = 4), autism (n = 3), and epilepsy (n = 1). Levels of maternal education were used as a proxy for socioeconomic status (SES). Table 1 includes additional descriptive data for predictor variables, including information on children's age, race, and ethnicity.

Procedure

Study procedures were approved by the institutional review board at The Ohio State University. STEPS was a

Table 1. Participant characteristics and demographic information (n = 120).

Variable	*n*	%
Child age in months		
M	77.41	
SD	7.49	
Range	60–96	
Grade		
Kindergarten	32	27.5
First grade	83	68.3
Second grade	5	4.2
Gender		
Male	78	65
Female	42	35
Highest level of maternal education		
Less than high school	10	8.3
High school graduate	23	19.2
Some college	18	15
Associates degree	14	11.7
College graduate or higher	34	28.3
Not reported	21	17.5
Race/ethnicity		
White/non-Hispanic Caucasian	66	55
Hispanic	6	5
Black/African American	9	7.5
Asian	5	4.2
Other	7	5.8
Not reported	28	22.5

3-year cohort study in which children participated for a full academic year. Following consent into the study, children completed several standardized language and literacy assessments. Assessments were administered at the beginning (fall) and the end (spring) of the academic year in individual testing sessions, within 6-week testing windows, by a trained field assessor in a quiet room. Field staff included both doctoral students and other senior-level research staff. Training components for each measure included (a) review of assessment manual and procedures, (b) completion of an online module about the measure and achieve a score of 100% on a test administration quiz, (c) completion of a mock assessment, and (d) live observation of the assessor's initial test administration by the research project manager.

Measures

Several measures were used to address the study's main research questions. The primary outcome variable of interest was children's word decoding skills at the beginning and ending of the academic year, to determine the extent to which children might be considered "at risk" at each time point. Predictor variables of interest included children's RAN times, PA, and percent consonants correct (PCC) from a speech sample at the beginning of the year. Covariates included children's age, overall language ability, and SES, operationalized as the highest level of maternal education. These variables were considered covariates in the analyses, as these were already expected to be correlated with word decoding skills.

Decoding Risk

Children's decoding ability was measured with the Word Attack subtest of the Woodcock–Johnson III Tests of Achievement (Woodcock et al., 2001) at the beginning and end of the school year. The Word Attack subtest required that children decode lists of increasingly complex nonwords. Raw scores were converted to standardized scores, which were used in the analyses. For the purposes of this study, children's scores were categorized as "at risk" if their standard score was 1 *SD* or more from the mean (i.e., standard score of 85 or less). Test–retest reliability for children ages 4–7 years for the Word Attack subtest is .79.

RAN

Children's ability to name shapes and colors as quickly as possible was tested with the Shapes and Colors subtest of the Clinical Evaluation of Language Fundamentals–Fourth Edition (Semel et al., 2003), which required that children name visually presented shapes and colors and shape–color combinations. All stimuli were presented in a 6 × 6 grid. Children were timed as they named the colors and shapes (e.g., blue circle), and the total number of errors was also recorded. For this study, the total time, in seconds, that it took for children to complete the task was used in the analyses. Test–retest reliability for RAN naming time is .87.

PA

Children's PA abilities were assessed with the Catts Deletion Task (Catts et al., 2001). This task measures children's ability to provide a verbal response to requests to delete phonological structures of varying size (word, syllable, phoneme) from a larger word (i.e., "*say cowboy without cow*"; "*say sit without /s/*"). The test has a total of 21 items, and responses are scored as either *correct* (1) or *incorrect* (0). Raw scores were used in the analyses.

PCC

PCC was calculated from a connected speech sample, gathered during a story retell task. The Narrative Assessment Protocol (Justice et al., 2010) was used to obtain a connected speech sample. To administer this test, the examiner showed the child the wordless picture book, *Frog, Where Are You?,* while reading the accompanying text for the story. Children were then asked to retell the story while looking at the pictures. On average, children's retells were approximately 3 min in length, allowing for an adequate connected speech sample (Heilmann et al., 2008, 2010; Shriberg et al., 1997). All story retell tasks were videotaped and returned to the lab to be transcribed (see Farquharson et al., 2020, for a full description of transcription procedures).

Following the transcription of children's responses, three research assistants were trained to review the videos and phonetically transcribe children's responses and thus note every speech sound production error in each sample. The training process included the completion of five practice samples that were compared to a master set so that disagreements of misunderstandings could be discussed. Next, each assistant completed three reliability videos and was required to meet at least 85% agreement to the master answer key before phonetically transcribing the data used in this study. Two drift checks were also included throughout the transcription period, and 20% of the videos were double-transcribed (interrater reliability was adequate at 88%). Each child's PCC score was calculated by dividing the number of correctly produced consonants by the total number of consonants attempted and multiplying by 100.

Child Age

Given the range of ages and grades in this study, children's age was considered a covariate in the analyses. Children's age in months was calculated based on the date of their inclusion in the study.

Language Skills

As part of the language and literacy assessment battery, children were administered the Core Language subtests (Concepts and Following Directions, Word Structure, Recalling Sentences, and Formulated Sentences) of the Clinical Evaluation of Language Fundamentals–Fourth Edition (Semel et al., 2003) as an index of oral language ability. Standard scores from the subtests are combined to yield a composite score (i.e., Core Language), for which 100 is the mean and the standard deviation is 15. Internal consistency reliability for the Core Language subtests ranges from .80 to .93.

SES

After providing consent for the child to participate in the study, caregivers completed a family background questionnaire, gathering basic demographic and health history information. Responses to questions about mothers' highest level of education were used as a proxy for SES. Participant characteristics and demographic information are presented in Table 1.

Results

Risks to Reading at the Beginning of the Year

The first aim of this study was to determine the proportion of children in receipt of school-based speech therapy who exhibit concurrent risk for RD, as determined by scores on a measure of word decoding. Descriptive analyses indicated that 26.2% of children with SSDs (n = 33) achieved a standard score of 85 or below on the word decoding measure, thus potentially meeting a criteria of "reading risk" at the beginning of the academic year. Of note, only three children who met the reading risk criteria had literacy-focused goals on their IEP. Descriptive statistics on all predictor variables and word decoding for the entire sample are presented in Table 2. An independent-samples t test confirmed that the at-risk and not-at-risk subgroups were significantly different with respect to age, standardized language scores, RAN, PA, and the word decoding measures but were not significantly different with respect to PCC. Results of the t tests and effect sizes are reported in Table 2.

Persistent Reading Risk

The second research question sought to understand the extent to which children might either move out of risk status by the end of the academic year or remain at risk. Based on standard scores of the Word Attack subtest in the spring, results indicated that approximately one third of children who were at risk at the beginning of the year moved out of risk status by the end of the academic year, Specifically, of the 33 children who were categorized as at risk in the fall, 21 children remained at risk at the end of the year; only 12 children moved out of the risk category at the end of the school year. As seen in Figure 1, the standard scores for children who remained at risk on the measure of word decoding did not increase throughout the academic year, whereas children who moved out of risk status demonstrated considerable improvement throughout the year.

Given these findings, it was of further interest to understand which characteristics might differentiate the children who moved out of risk status from those who remained at risk. An independent-samples t test was used to compare the group of children who moved out of risk status from those who remained at risk. As shown in Table 3, although the mean scores on many of the selected predictor variables differed between groups, the group mean differences were not statistically significant.

Predictors of Reading Risk

The third research question sought to determine the variables that contributed to the "at-risk" classification. Correlations between the predictor variables and children's word decoding skills are shown in Table 4. Although logistic regression does not require the dependent and independent variables to be related linearly, this analysis does require that the independent variables are linearly related to the log odds. To test this assumption, linearity of the continuous variables with respect to the logit of the dependent variable was assessed with the Box and Tidwell (1962) procedure. Based on this assessment, all continuous independent variables were found to be linearly related to the logit of the dependent variable.

A hierarchical logistic regression was performed using SPSS software (Version 24.0) to ascertain the extent to which speech processing variables (i.e., RAN, PA, PCC) would be significantly associated with meeting RD risk criteria or not, after controlling for children's age, language ability, and SES. A hierarchical model was used to evaluate the variance accounted for by each of the speech processing variables after including the covariates and each prior variable. This process allowed for a step-by-step investigation of each variables' unique contribution to RD risk

Table 2. Descriptive statistics for predictor and outcome variables.

Variable	Total sample (*N* = 120) *M* (*SD*) [Range]	No risk (*n* = 87) *M* (*SD*) [Range]	At risk (*n* = 33) *M* (*SD*) [Range]	Effect size
Age in months	77.41 (7.49) [60–96]	75.92 (8.01) [60–96]	81.35 (6.33) [70–95]**	0.75
Language	73.69 (17.69) [40–115]	77.97 (16.48) [40–115]	62.42 (15.96) [40–97]***	0.96
RAN (s)	114.41 (53.61) [29–361]	108.10 (41.20) [35–246]	131.03 (75.71) [29–361]*	0.38
PA (raw)	7.53 (7.69) [0–21]	9.10 (7.84) [0–21]	3.39 (5.51) [0–20]***	0.84
PCC	86.21 (7.7) [0.60–0.99]	86.65 (7.8) [0.60–0.99]	85.03 (7.6) [0.71–0.97]	0.21
WD (SS)	94.05 (14.46) [57–126]	101.00 (9.39) [86–126]	75.73 (7.94) [56–85]***	2.96
WD (raw)	4.15 (3.39) [0–19]	4.93 (2.63) [2–19]	2.09 (1.10) [0–5]	1.41

Note. Language = Core Language subtests of the Clinical Evaluation of Language Fundamentals–Fourth Edition (CELF-4); RAN= rapid automatized naming of objects and colors (CELF-4); PA = phonological awareness (Catts Deletion Task); PCC = percent consonants correct; WA = Word Attack subtest of the Woodcock–Johnson III Test of Achievement; SS = standard score.

*p = .01. **p < .01. ***p < .001.

status. The initial model that included just the covariates was significant, $\chi^2(3) = 24.03$, $p < .001$, Nagelkerke $R^2 = .27$; child age ($B = -0.071$, $p = .024$), SES ($B = -0.328$, $p = .018$), and oral language ability were significantly associated with being classified in the at risk group ($B = -0.034$, $p = .034$). These results suggest that, when only considering the selected covariates, children who were older were more likely to be in the RD risk group; children with stronger language skills and from higher SES backgrounds were less likely to be categorized into the RD risk group. As seen in Table 5, each speech processing variable was added in subsequent steps to determine the unique amount of variance added by each variable. Step 2 indicated that RAN was not significantly associated with RD risk prediction and the addition of this variable accounted for only negligible additional variance. Results from Steps 3 and 4 suggest that the addition of PA and PCC each accounted for unique significant variance. Notably, PCC explained additional variance in the model even after accounting for the covariates and PA.

The final hierarchical logistic regression model that included all variables was statistically significant ($\chi^2 = 22.98$, $p < .001$, −2LL = 73.69). The final model explained 50.8% (Nagelkerke R^2) of the variance in reading risk status and correctly classified 82.7% of cases. Results indicated that children who were older were significantly more likely to exhibit reading risk ($B = 0.270$, $p < .001$); in addition, children who came from higher SES backgrounds ($B = -0.430$, $p = .007$) had stronger PA ($B = -0.213$, $p = .003$), and higher PCC ($B = -9.66$, $p = .042$) were less likely to exhibit reading risk. RAN and children's overall language abilities did not significantly contribute to the prediction of reading risk in the final model. Although language was a significant predictor in earlier steps of the model, this association was no longer significant after PA was added. Children's

Figure 1. Standard scores at the beginning and end of year on the Word Attack subtest of word decoding for children identified as being at persistent risk for reading difficulties versus children who moved out of risk status.

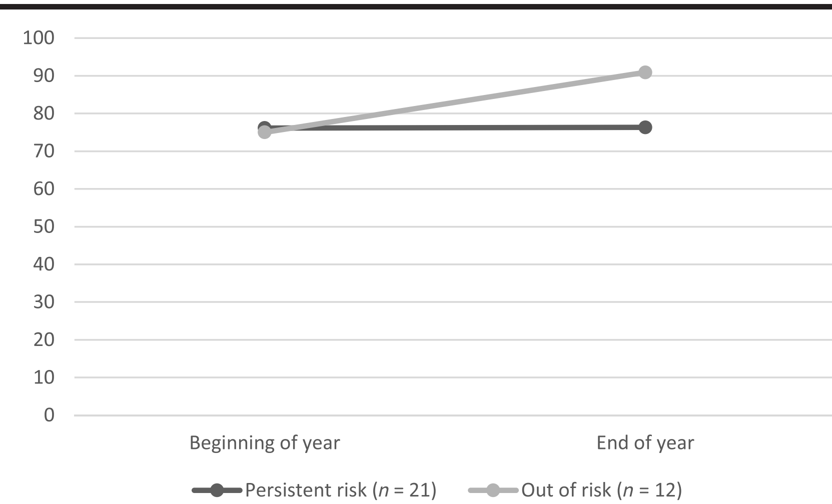

Table 3. Differences between children who remained or moved out of risk status at the end of the school year on the predictor variables.

Variable	Persistent risk (n = 21)	Out of risk (n = 12)	
	M (*SD*) [Range]	*M* (*SD*) [Range]	Effect size
Age in months	80.33 (6.36) [70–95]	83.13 (6.11) [71–91]	0.45
Language	61.10 (15.59) [40–97]	64.75 (16.95) [42–91]	0.22
RAN (s)	129.10 (76.80) [29–341]	134.42 (77.01) [54–361]	0.07
PA (raw)	2.33 (4.42) [0–15]	5.25 (6.85) [0–20]	0.01
PCC	85.21 (7.76) [0.72–0.97]	84.72 (7.69) [0.71–0.94]	0.06

Note. Language = Core Language subtests of the Clinical Evaluation of Language Fundamentals–Fourth Edition (CELF-4); RAN = rapid automatized naming of objects and colors (CELF-4); PA = phonological awareness (Catts Deletion Task); PCC = percent consonants correct.

language scores and PCC were moderately correlated (r = .56), but examination of the variance inflation factor (VIF) indicated that multicollinearity was not a concern.

Discussion

This study aimed to understand the overlap of SSD and risks for RD throughout an academic year for children receiving school-based services. Furthermore, we considered the extent to which applying components of the psycholinguistic framework of speech processing, specific to speech processing and speech output, might inform our understanding of which aspects of children's phonological systems that contributed to at-risk identification. Results from this work yielded two main findings, which will be discussed in further detail below. First, these data showed that approximately one quarter of the children in this study who were receiving school-based speech therapy were likely to exhibit concomitant decoding difficulties that may place them at risk for RD and that, for the majority of these children, the risks remain consistent throughout their academic year. Second, results supported certain aspects of the psycholinguistic theory of speech processing in that both PA and PCC were significantly associated with reading risk status, even after accounting for effects from age, language ability, and SES. This study significantly advances our clinical knowledge about the prevalence of RD in children with SSD and further informs our theoretical understanding of the ways in which variants of phonological knowledge converge in relation to children's early acquisition of word decoding abilities.

Table 4. Correlations among language, speech processing predictors and word decoding.

Variable	Language	RAN	PA	PCC	WD
Language	—	–.072	.552**	.306**	.519**
RAN		—	–.134	–.036	–.055
PA			—	.181*	.303**
PCC				—	.083
WD					—

Note. Language = Core Language subtests of the Clinical Evaluation of Language Fundamentals–Fourth Edition (CELF-4); RAN = rapid automatized naming of objects and colors (CELF-4); PA = phonological awareness (Catts Deletion Task); PCC = percent consonants correct; WD = Word Attack subtest of the Woodcock–Johnson III Test of Achievement.

*p < .05. **p < .01.

Reading Risks in Children With SSD

To date, there have been very few studies examining the extent to which school-age children with SSD experience

Table 5. Hierarchical logistic regression predicting reading risks from speech processing variables.

Variable	*B*	Wald	Exp(β)	*p*	R^2 change
Step 1					.355
Age	0.130	10.055	1.138	.002	
Language	–0.048	7.146	0.953	.008	
SES	–0.328	5.596	0.721	.018	
Step 2					.005
Age	0.129	10.064	1.138	.002	
Language	–0.047	6.727	0.954	.009	
SES	–0.335	5.794	0.715	.016	
RAN	0.003	0.584	0.455	.445	
Step 3					.095
Age	0.207	14.855	1.230	.000	
Language	–0.010	0.185	0.991	.667	
SES	–0.349	5.524	0.705	.019	
RAN	0.002	0.180	1.002	.672	
PA	–0.164	7.329	0.849	.002	
Step 4					.046
Age	0.257	16.140	1.293	.000	
Language	–0.004	0.002	1.004	.882	
SES	–0.442	7.612	0.643	.006	
RAN	0.003	0.296	1.003	.586	
PA	–0.204	8.726	0.816	.039	
PCC	–9.817	4.281	0.000	.043	

Note. Language = Core Language subtests of the Clinical Evaluation of Language Fundamentals–Fourth Edition (CELF-4); SES = socioeconomic status based on levels of maternal education; RAN = rapid automatized naming of objects and colors (CELF-4); PA = phonological awareness (Catts Deletion Task); PCC = percent consonants correct.

concurrent reading difficulties. The extant literature in this area has primarily reported on the long-term reading outcomes of children who had been identified as having SSD in the preschool years (Lewis et al., 2011, 2000; Raitano et al., 2004; Sices et al., 2007). In these studies, children whose SSD persisted into the school-age years demonstrated overall poorer abilities, pertaining to not only speech production but also language and literacy. Conversely, children whose speech difficulties resolved were more likely to demonstrate age-appropriate reading skills (e.g., Bishop & Adams, 1990). Data from this study converge with previous reports in that, consistent with the critical age hypothesis (Nathan et al., 2004), children demonstrating speech and language difficulties at school age are at highest risk for RD. Moreover, results from this study suggest that the odds of being classified as "at risk" was greater for older children. This finding lends support to the idea that persistent speech difficulties are likely to extend to associated skills, such as word decoding. Similar to results from Peterson et al. (2009) and Gosse et al. (2012), data from the current work indicated that approximately 25% of children receiving school-based speech therapy may have concurrently qualify for reading-related services as well, which is consistent with recent work examining RD risk in young children with LI as well (Murphy et al., 2016; Tambyraja, Farquharson, et al., 2015).

In general, the fact that 25% of children who receive school-based services may also require reading supports is a notable clinical concern. More troubling, however, are the results suggesting that, even at the end of the year, the majority of these children remain in the at-risk status. On the one hand, this persistent reading risk, even after a full year of school and speech therapy, is not fully surprising, as research indicates that many SLPs are uncomfortable working on literacy within the context of therapy (Blood et al., 2010; Katz et al., 2010) and, indeed, rarely incorporate literacy-focused activities during most therapy sessions (Tambyraja et al., 2014). Furthermore, these results accord with some longitudinal studies of children's reading development showing that children who begin at a deficit, comparable to their peers, are likely to continue to perform more poorly, even if making gains (Morgan et al., 2011). This finding underscores the importance of addressing reading skills within school-based therapy, as these difficulties are unlikely to be resolved throughout the natural course of an academic year.

Predictors of Reading Risk

In this study, we chose variables to represent children's phonological knowledge according to the double deficit hypothesis (i.e., PA and RAN, Wolf & Bowers, 2000), but also some elements of the psycholinguistic framework (i.e., Stackhouse & Wells, 1997). The psycholinguistic framework delineates the various processes and skills that are implicated in phonologically oriented tasks to yield a precise understanding of the ways in which these processes and skills interact. Germane to our current sample, the psycholinguistic framework considers the contribution of speech sound production accuracy to phonological processing skills. As such, these two frameworks differentially supported the idea that speech sound production ability—paired with phonological knowledge tasks—would be predictive of reading risk in children with SSDs.

Interestingly, we found that, after accounting for children's language skills, age, and SES, only PA and PCC were significantly with an increased likelihood of being identified as being at risk. That is, RAN was not a significant predictor of reading risk in our clinically identified sample of children with SSDs. Previous support for the double deficit hypothesis (Wolf & Bowers, 2000) suggests that PA and RAN are tasks that both contribute to word decoding ability and can thus be used to subgroup children with dyslexia, a phonologically based reading impairment. That is, children who only exhibit deficits in PA are considered to have a phonological impairment; those who only have difficulty with RAN only are considered to have a rate deficit. However, children exhibiting difficulty with both tasks are considered to have a "double deficit." When considering our findings through this lens, it appears that children with SSDs may not necessarily exhibit a double deficit but may perhaps conversely be more appropriately subgrouped as having a primarily phonological impairment.

Studies of typically developing children have indicated that PA and RAN, along with verbal working memory, all account for variance in word decoding abilities (e.g., Wagner et al., 1994). Research involving children with language-learning disabilities, however, differs, as was seen in this study. In the larger study of these participants, Tambyraja, Farquharson, et al. (2015) found that only PA was significantly associated with word decoding skills, and that RAN and verbal short-term memory were not significant predictors. Those findings accord with some previous research of children who are deaf/hard of hearing such that PA and speech production abilities were stronger predictors of word decoding, compared to RAN performance (e.g., Dyer et al., 2003), also seen in children with cerebral palsy (Peeters et al., 2009). These somewhat disparate findings may indicate that when phonological knowledge is intact, skills such as RAN, memory, as well as PA, are robust indicators of word decoding ability. For children whose phonological systems may be compromised in some way, however, their ability to apply processes for word decoding are much more closely associated with the skills that represent their phonological knowledge, such as PA and speech production accuracy.

Considered within a psycholinguistic framework, children's phonological knowledge, particularly as represented by their PA, and accuracy of speech sound production are associated with their ability to apply phonological knowledge in word decoding tasks. These results lend support to the idea that these skills are interconnected and indeed may provide clinicians with additional information for how best to identify children who could benefit from support in these areas.

The use of a hierarchical approach to examining variance accounted for by each of the selected predictors raised several additional interesting points. Most notably, although children's language scores were significantly associated with reading risk classification in the earlier steps of the model, these relations were no longer significant after adding PA to the model. To some extent, these results diverge from previous studies examining factors that predict reading outcomes in children with SSD. For example, Sices et al. (2007) used a hierarchical linear regression analysis to identify the skills that predicted preschool children's early reading and writing skills. In earlier steps of the regression model, a factor score representing SSD severity (combined scores from a standardized articulation test as well as PCC) predicted both reading and writing; however, after comorbid LI was entered in the model as a dichotomous predictor, SSD severity was no longer significant. Results from this study may differ from this work both because the outcome measure used by Sices and colleagues was not specific to word decoding, and the participants were much younger. Additionally, the predictor of SSD severity was operationalized as a factor score reflecting multiple measures of articulation. However, it is also possible that, because most of the children in the current study exhibited generally poor language skills, performance on measures such as PA, as well as their PCC, offered even more information about the probability of being classified as at risk for reading difficulties. In short, language skills were indeed predictive of risk status, but PA and PCC were predictive of risk status, above and beyond that of language, in this clinically identified sample of children receiving school-based services.

Limitations and Future Directions

This study makes a notable contribution to our knowledge of the likely co-occurrence of SSD and risk for RD in school-age children, and the skills and characteristics that are most closely associated with the likelihood of being at risk; however, there are some limitations that must be acknowledged that future research should address. First, this study included only one measure of speech production accuracy. Although PCC is a valid and clinically relevant method of evaluating children's overall intelligibility, additional standardized measures should be included in future work for a more comprehensive understanding of the relations between phonological processes and word decoding. Second, this study originally aimed to examine the speech therapy experiences of children with LI who may or may not have had concomitant SSD. In other words, although this was a clinically representative sample, it did not include children initially selected due to speech difficulties. As such, the subset of children in the present investigation may have included an overrepresentation of children with less severe speech production difficulties. Future research should aim to ascertain clinical samples of children whose primary impairment is SSD and replicate the procedures and analyses of the present work. In particular, it would be of interest to further understand how to differentiate children with SSD who progress sufficiently throughout the year and move out of "risk status" based on the nature of their SSD. Although our findings suggested that SSD severity, based on PCC, was not different between children whose risk status persisted or not, it is possible that children whose SSD stems from a phonologically based disorder may be more likely to continue to exhibit difficulties with word decoding, compared to children whose SSD is primarily articulatory or associated with a motor speech disorder.

Third, this study included a relatively broad age range of children, but only a small sample of second-graders. Future work may seek to focus more on this grade level, as children would have had ample instruction in word decoding by then, and rates of decoding deficits among children with SSD may be more precise. Finally, although this research followed children for a full academic year, future research may aim to longitudinally examine children throughout their early elementary school years and determine subsequent relations to reading comprehension as well. Research suggests that decoding skills are often highly correlated with reading comprehension skills (LARRC & Chiu, 2018); the extent to which this is the case for children with phonologically based disorders specifically is understudied. Such studies can further inform our understanding of the long-term impacts of SSD on reading achievement and more precisely address the skills that are likely to be most affected.

Conclusions

SSD is one of the most common pediatric communication disorders; most school-based SLPs serve a large proportion of children with SSD and are also responsible for supporting their reading and academic success more generally. However, identifying which children with SSD may be at greatest risk for RD can be challenging. This study found that approximately one quarter of children receiving speech therapy would likely also qualify for reading supports and that only a small percentage of those children improved their reading skills sufficiently throughout the school year. Although this study was unable to specify the characteristics of children that differentiated those who moved out of risk status, results did suggest that the severity of children's speech production errors, as well as their PA skills, were significantly associated with being at risk for RD, even after accounting for age, language, and SES. Because PA was significantly associated with RD risk, paired with results of previous intervention research, we do recommend the incorporation of PA activities into speech sound therapy sessions. Indeed, previous studies have found this to be a successful addition to treatment (e.g., Al Otaiba et al., 2008; Gillon, 2000). This study supports the idea that speech production, PA, and word decoding are interrelated for children with SSD. However, future work should include more rigorous examinations of the types of reading supports that children do indeed receive throughout the year and the effects of those supports on decreasing difficulties with word decoding.

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