Phonological Processing and Reading in Children With Speech Sound Disorders

Susan Rvachew
McGill University, Montreal, Quebec, Canada

Purpose: To examine the relationship between phonological processing skills prior to kindergarten entry and reading skills at the end of 1st grade, in children with speech sound disorders (SSD).
Method: The participants were 17 children with SSD and poor phonological processing skills (SSD-low PP), 16 children with SSD and good phonological processing skills (SSD-high PP), and 35 children with typical speech who were first assessed during their prekindergarten year using measures of phonological processing (i.e., speech perception, rime awareness, and onset awareness tests), speech production, receptive and expressive language, and phonological awareness skills. This assessment was repeated when the children were completing 1st grade. The Test of Word Reading Efficiency was also conducted at that time. First-grade sight word and nonword reading performance was compared across these groups.
Results: At the end of 1st grade, the SSD-low PP group achieved significantly lower nonword decoding scores than the SSD-high PP and typical speech groups. The 2 SSD groups demonstrated similarly good receptive language skills and similarly poor articulation skills at that time, however. No between-group differences in sight word reading were observed. All but 1 child (in the SSD-low PP group) obtained reading scores that were within normal limits.
Conclusion: Weaknesses in phonological processing were stable for the SSD-low PP subgroup over a 2-year period.

Key Words: speech sound disorders, reading disability, speech perception, phonological awareness

Converging evidence indicates that speech sound disorders (SSD) overlap with reading disability (RD) at a number of levels. As a group, children with SSD have difficulty with phonological awareness tasks (Bird, Bishop, & Freeman, 1995; Larrivee & Catts, 1999; Raitano, Pennington, Tunick, Boada, & Shriberg, 2004; Rvachew, Ohberg, Grawburg, & Heyding, 2003; Webster, Plante, & Couvillion, 1997). Given the central role of phonological processing in reading acquisition, it is not surprising therefore that reading and spelling difficulties have been documented among children with SSD or a history of SSD (Bird et al., 1995; Larrivee & Catts, 1999; Lewis, Freebairn, & Taylor, 2000, 2002). Cofamiliality of SSD and RD is well established, and direct evidence of a genetic linkage is emerging (Lewis et al., 2004; Smith, Pennington, Boada, & Shriberg, 2005; Stein et al., 2004; Tunick & Pennington, 2002).

The overlap between SSD and RD is not complete, however. It is generally accepted that SSD comprises different subtypes (Dodd, 1995; Leitao, Hogben, & Fletcher, 1997; Shriberg, Austin, Lewis, McSweeny, & Wilson, 1997), and it is clear that not all children with SSD have difficulty learning to read (Bishop & Adams, 1990). Many recent studies have had the purpose of identifying a subset of the SSD population that is at specific risk for RD, an endeavor that is important from the research and clinical perspectives. Efforts to discover the causes of SSD require a reliable means to segregate homogeneous subsets of children who misarticulate speech sounds. Valid identification of distinct subtypes may have clinical benefits, because these subtypes may respond differentially to specific intervention approaches (Crosbie, Holm, & Dodd, 2005).

One approach to this problem has been to subtype children with SSD on the basis of a reported family history of speech problems. For example, Shriberg et al. (2005) compared children whose parents reported two or more biological, nuclear family members with speech or language problems to children with no reported history of such difficulties in the family. It was proposed that these children formed a subtype termed "speech delay-genetic" that is characterized by an underlying cognitive-linguistic deficit (as opposed to an auditory, motoric, or psychosocial deficit). One difficulty

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with this approach is that it relies upon the validity of parent reports of family history. Although it has been argued that parents provide valid reports of speech and language problems in family members (Tunick & Pennington, 2002), it seems unlikely that parents can retrospectively identify the specific type of difficulties experienced (i.e., speech delay, dyspraxia, residual errors, stuttering, and even specific language impairment may be confounded in these reports). Furthermore, several if not all of these disorders are familial but may not necessarily share the same genetic basis. For example, the debate about whether dyspraxia and other forms of SSD are behaviorally and genetically distinct is far from resolved (for discussion, see Lewis et al., 2004).

Comorbid language impairment has been proposed as a marker for the risk of RD among children with SSD. Some studies have reported that children with isolated SSD are not at risk for RD (Bishop & Adams, 1990; Lewis et al., 2000). Other studies, however, have shown that children with SSD but age-appropriate language skills demonstrate poorer phonological awareness skills than expected for their age (Bird et al., 1995; Rvachew et al., 2003). Children with concomitant language impairment clearly demonstrate more severe difficulty with phonological awareness than children with isolated SSD. Two explanations for this latter finding have been offered. It has been suggested that language impairment serves as an additive risk factor for RD alongside the risk associated with SSD (Raitano et al., 2004). Viewed from a somewhat different perspective, strong language skills may be a protective factor that helps to prevent RD in children who nonetheless have an underlying deficit in phonological processing (Snowling, Bishop, & Stothard, 2000).

Severity of the speech disorder itself has also been suggested as a means of identifying those children at most risk for literacy deficits (Justice, Invernizzi, & Meier, 2002). Bird et al. (1995) did find that children with poor literacy outcomes produced more articulation errors on average than children with good literacy outcomes. However, the groups of children who experienced good or poor literacy outcomes both had SSD in the severe range in their study. Rvachew, Chiang, and Evans (2007) observed a trend toward a relationship between severity of the speech disorder and phonological awareness difficulties among children with a broader range of severity levels. However, this relationship was not statistically significant, and one third of the children with mild SSD scored below normal limits on a test of phonological awareness skills in kindergarten. Similarly, Shriberg et al. (2005) found that children with SSD and a family history of speech-language problems did not differ from children with SSD and no family history with respect to severity of the speech disorder.

A related variable is the profile of speech sound errors produced by the child with SSD. The presence of unusual error patterns has been associated with a greater likelihood of difficulties with phonological awareness (Broomfield & Dodd, 2004; Leitao & Fletcher, 2004). Shriberg et al. (2005) observed that children with a family history of speech and language problems produced a higher proportion of omission errors and a lower proportion of distortion errors, relative to children with SSD and no such family history. Rvachew et al. (2007) reported that prekindergarten-age children who failed a phonological awareness test produced a greater frequency of syllable structure errors (which involve omissions by definition) than did children who passed this test. One year later, the children with poor phonological awareness skills were more likely to produce atypical errors than the children with good phonological awareness. However, the mean number of errors that were atypical was quite high for both groups. Similarly, Broomfield and Dodd (2004) found that the failure rate on a test of phonological awareness was 93% of children with "inconsistent deviant" errors but 75% of children with typical phonological process errors. In sum, these studies show that error type profile is only weakly related to phonological awareness; the presence of syllable structure or atypical errors is not a reliable indicator of the presence or absence of a phonological processing deficit.

A more promising marker for the risk of RD among children with SSD is persistence of the speech problem past the age of school entry (Nathan, Stackhouse, Goulandris, & Snowling, 2004; Raitano et al., 2004; Rvachew et al., 2007), but the utility of this finding is questionable. Both researchers and clinicians have an interest in identifying these children at a very young age. As yet, preschool predictors of persistence of the speech deficit have not been identified. Furthermore, persistence of the speech disorder may reflect environmental rather than biological factors, such as the appropriateness of the timing, type, and intensity of interventions provided before the child begins school.

Another potential indicator could be speech perception abilities, a variable that is closer to the proposed core deficit in phonological processing than articulation accuracy itself, which reflects both phonological and motoric factors. Whether or not individuals with RD have difficulties with basic auditory processing remains a controversial and unresolved issue (Halliday & Bishop, 2006; Studdert-Kennedy, 2002). A relationship between reading and/or phonological awareness and categorical perception of speech is frequently observed, however (Chiappe, Chiappe, & Siegel, 2001; Joanisse, Manis, Keating, & Seidenberg, 2000; Manis et al., 1997; McBride-Chang, 1995; Mody, Studdert-Kennedy, & Brady, 1997; Nittrouer, 1996; Rvachew & Grawburg, 2006; Serniclaes, Sprenger-Charolles, Carre, & Demonet, 2001). Speech perception deficits have even been observed in infants with a family history of RD, using both physiological and behavioral measures (Leppanen, Pihko, Eklund, & Lyytinen, 1999; Lyytinen et al., 2004). It is also known that some, although not all, children with SSD have difficulties with speech perception (Broen, Strange, Doyle, & Heller, 1983; Edwards, Fox, & Rogers, 2002; Hoffman, Daniloff, Bengoa, & Schuckers, 1985; Rvachew & Jamieson, 1989). It therefore seems reasonable to ask whether children who demonstrate concomitant difficulties with speech articulation and speech perception might be at risk for poor reading skills.

This research report examines the predictive relationship between speech perception and phonological awareness abilities (when measured prior to kindergarten entry) and reading (when measured at the end of first grade).

Method

Participants

Speech-language pathologists at two pediatric hospitals were asked to refer 4- and 5-year-old children who were receiving or waiting to receive speech therapy for remediation of an SSD during their prekindergarten year. The selection criteria were as follows: (a) score below the 16th percentile on a standardized assessment of articulation skills some time during the prekindergarten year; (b) primary diagnosis of SSD of unknown origin (although concomitant language impairment and suspected dyspraxia of speech were not exclusionary criteria); (c) normal hearing and oral-motor function documented by the child's clinician (on the basis of the hospital's standard screening procedures with follow-up audiology assessments as necessary) prior to referral to the study; and (d) native speaker of English. Children whose SSD was secondary to other conditions such as sensory-neural hearing loss, Down syndrome, cerebral palsy, or cleft palate were excluded.

Children with typically developing speech were recruited from day care and preschool programs by sending letters home with the children to inform parents about the study and ask them to volunteer their children's participation. These children were required to be normally developing and healthy according to parent and teacher report and to speak English as their first language.

The parents of 110 children volunteered their child for participation in this longitudinal study. This report describes outcomes for the 68 children who completed the entire study protocol through to the final assessment at the end of first grade. Sixteen children were excluded from this report because they participated in an experimental intervention to improve their speech perception and phonological awareness skills in the interval between the prekindergarten and first-grade assessments. Also excluded from this report are 13 children who were lost to follow-up before the Grade 1 assessment, 5 children who repeated kindergarten rather than progressing to first grade, 4 children who were recruited as typically developing but who scored below normal limits for articulation accuracy, and 4 children with typically developing speech but borderline normal receptive vocabulary skills and relatively low family socioeconomic status (SES).

The final sample comprised 68 children, 35 of whom had typically developing speech. The children were first assessed prior to kindergarten entry when their age ranged from 53 to 67 months. A second assessment took place at the end of the kindergarten year, but these results will not be reported here because they have been described elsewhere (Rvachew, 2006). The final assessment took place as the children were completing first grade, at which time their ages ranged between 75 and 93 months. Upon entry to the study, SES was rated for each child's family by combining the parents' occupation and level of education to yield a Blishen score (Blishen, Carroll, & Moore, 1987). The resulting Blishen scores ranged from 31 (high school not completed) to 101 (professional credentials), with a mean of 58 (some post-secondary education). Some of the children attended French immersion schools in which the language of instruction was French for half the school week and English for the remainder of the week, specifically 1 child in the SSD-low PP group (6%), 3 children in the SSD-high PP group (19%), and 13 children with typically developing speech (37%).

Procedures

Most children were tested in a single 75-min session, although some were tested in two 40-min sessions. The tests were administered by speech-language pathologists hired on contract or by graduate students in speech-language pathology under the supervision of speech-language pathologists with certification from the Canadian Association of Speech-Language Pathologists. These tests were administered in fixed order to assess receptive vocabulary, articulation, speech perception, phonological awareness, and reading skills. A speech sample was also recorded at the end of the test session while the child and assessor talked about a picture book. The same assessment protocol was used for both assessments except that the reading test was administered only during the Grade 1 assessment.

Receptive vocabulary. Receptive vocabulary size was assessed using the Peabody Picture Vocabulary Test—III (PPVT–III; Dunn & Dunn, 1997).

Articulation. The Goldman Fristoe Test of Articulation—Second Edition (GFTA–2; Goldman & Fristoe, 2000) provided a measure of articulation ability during picture naming.

Percentage consonants correct. Speech samples were recorded using a picture book (*Carl Goes Shopping*; Day, 1989). The children were asked to "talk about the pictures," and, if necessary, the examiner prompted with open-ended questions, primarily "What is happening here?" and "What do you think is going to happen next?" These samples were phonetically transcribed and coded to obtain the percentage of consonants correct (PCC; Shriberg & Kwiatkowski, 1982). On average, the samples contained 412 codable consonant targets. The intraclass correlation for the PCCs was determined independently by two coders of 29 randomly selected samples (McGraw & Wong, 1996), yielding a reliability of .95. The difference between pairs of scores varied from 0 to 14%, with the exception of one outlier at 20%, yielding a median difference of 4.5%.

Mean length of utterance. Systematic Analysis of Language Samples (SALT) – Standard Version 8 (Miller & Chapman, 2005) was used to determine the child's mean length of utterance (MLU) from the speech samples that were recorded as described above, using the procedures recommended by the SALT program. The intraclass correlation for the PCCs was determined independently by two coders of 32 randomly selected samples (McGraw & Wong, 1996), yielding a reliability of .99. The difference between pairs of scores varied from .01 to .86 morphemes, with the exception of one outlier of 1.86, yielding a median difference of .18 morphemes.

Speech perception. Speech perception was assessed using the Speech Assessment and Interactive Learning System (SAILS; AVAAZ Innovations), a computer game that assessed the child's ability to identify words that were pronounced correctly and words that were pronounced incorrectly, each beginning with a commonly misarticulated consonant. The test words were organized into modules consisting of 10 to 30 tokens recorded from children and adults, and digitized at a sampling frequency of 20 kHz and a 16-bit quantization rate. Half were articulated correctly (e.g., *lake* → [lek]), and half were articulated incorrectly (e.g., *lake* → [wek]), and all were presented in random order. The recorded words were presented one at a time over headphones. The children were also presented with two response alternatives on the computer monitor, a picture of the target word, and a picture of a large X. Using the *lake* module as an example, the children were instructed to point to the picture of the lake if they heard the word *lake* and to point to the X if they heard a word that was "not lake." Test trials were preceded by a 10-trial practice block that contrasted the words *lake* and *make*. Corrective feedback was provided if necessary, and the children were required to achieve a level of at least 80% correct before proceeding to the test trials. All children in this study were presented with the test modules targeting the words *lake, cat, rat,* and *Sue* in order as written. Across the four modules, 70 items were presented in total, not including practice trials. Split-half reliability for total test score was .82.

Phonological awareness. The Phonological Awareness Test (PAT) that was developed by Bird et al. (1995) for research purposes was administered to all participants. This test was selected because (a) no verbal responses are required and thus the children's responses will reflect phonological processing rather than speech production accuracy skills, and (b) the types of tasks employed by this test have been shown to provide the best estimate of phonological awareness ability for younger children with emerging phonological awareness skills (Schatschneider, Francis, Foorman, Fletcher, & Mehta, 1999). This test consisted of three subtests: rime matching, onset matching, and onset segmentation and matching. The first subtest administered to each child was rime matching. The child listened to the name of a puppet and then selected from an array of four pictures the one whose name rhymed with the name of the puppet. For example, the child was shown a puppet named "Dan." They were then told that "Dan likes things that sound like his name" and asked which he would like from *house, boat, car,* and *van*. The pictures were named, and the child was required to point to the picture of the word that matched the rime of the puppet's name. For the onset matching subtest, the child was shown a puppet and told that everything it owned began with the same sound. The relevant sound was produced in isolation by the examiner, and then the child was asked to select the picture whose name began with that sound. Finally, for onset segmentation and matching, the child was again told the puppet's name and asked to point to the picture whose name "began with the same sound as the puppet's name." In this case, the child was given the puppet's name but not told the specific target sound. Before each of the three sections, the children were given five practice questions with feedback. The instructions were repeated and the response alternatives named for every item on the test. There were 34 test items in total across the three subtests (14 rime awareness, 10 onset awareness, 10 onset segmentation), involving the target rimes /æn, ʌg, æt, æp/ and target onsets /p, tʃ, m, t, s/. The test items and administration procedures and instructions were exactly as described in Bird et al. (1995) except that we replaced the item *settee* with *soap*. Split-half reliability for total test score for 87 randomly selected samples was .98.

Reading. During the Grade 1 assessment, reading was assessed with the Test of Word Reading Efficiency (TOWRE; Torgesen, Wagner, & Rashotte, 1999). This test comprised two timed subtests: the sight word score, which is the number of real words read correctly within 45 s, and the phonetic decoding score, which is the number of nonwords pronounced correctly within 45 s. Some of the children who were learning to read in both English and French pronounced a few nonwords using a French decoding strategy. These "French" pronunciations were counted as incorrect, as the standard English scoring guide was used to score all of the children's responses, potentially resulting in an underestimation of the reading abilities of the typically developing comparison group.

Participant grouping procedure. The 68 children involved in this study were each placed in one of three groups, reflecting their speech and phonological processing skills. Thirty-three children (20 boys and 13 girls) were identified as having SSD on the basis of GFTA–2 percentiles below 16 during the prekindergarten assessment. Thirty-five children (22 boys and 13 girls) who achieved a percentile ranking that was greater than 16 on the GFTA–2 during the prekindergarten assessment were placed in the typical speech (TS) group. The performance of children in the TS group on the SAILS and PAT tests was used to convert all children's scores on these tests to a *z* score. Specifically, the children's speech perception scores during the prekindergarten assessment were normalized with respect to the mean and standard deviation of SAILS scores obtained by the TS group (77.70 and 6.61, respectively). The children's phonological awareness performance was also normalized with respect to the mean and standard deviation of PAT scores obtained by the TS group during the prekindergarten assessment (21.54 and 4.63, respectively). These two *z* scores were averaged to yield a phonological composite score for each child. This composite score was used as the predictor of reading because, as reported in Rvachew (2006), there is a reciprocal developmental relationship between speech perception and phonological awareness. In other words, speech perception abilities at a given age contribute to growth in phonological awareness skills over time, but phonological awareness skills in turn contribute to growth in speech perception abilities over time. The 10 boys and 7 girls with SSD who achieved a composite score less than –1.00 formed the SSD-low PP group. The 10 boys and 6 girls with SSD who achieved a higher composite score formed the SSD-high PP subgroup. The mean composite scores for the SSD-low PP and SSD-high PP groups were –2.20 and –0.20, respectively.

Data Analysis

The first set of data analyses were conducted to examine between-group differences in performance on the tests administered prior to kindergarten entry and at the end of the first-grade year. First, univariate analyses of variance (ANOVAs) were conducted to compare test performance across the three groups of participants, SSD-low PP, SSD-high PP, and TS. The results of these tests were assessed against an alpha level of .05. Planned comparisons were used to compare performance between the three groups, using an overall alpha level of .05 but applying the Bonferroni correction for the three comparisons per variable.

A second set of analyses were conducted in order to examine the predictive relationship between variables assessed in the prekindergarten and first-grade reading outcomes. Specifically, Pearson product–moment bivariate correlations were examined, and then hierarchical multiple regression analyses were conducted. The outcome of these analyses was also assessed with alpha set at .05.

Results

Group Characteristics

The results of measures that were obtained for the purpose of describing the participants rather than testing hypotheses are shown in Table 1. A univariate one-way ANOVA revealed that SES did not differ significantly between groups, although there was a trend toward lower SES for the SSD-low PP group relative to the SSD-high PP group. Age was also equivalent across groups.

However, significant between-group differences were observed for language measures. All children scored within the average range for receptive vocabulary skills, but planned comparisons showed that the SSD-high PP and TS groups scored higher than the SSD-low PP group during the prekindergarten assessment. No between-group differences in receptive vocabulary skills were observed at the end of Grade 1. Planned comparisons showed that the TS group achieved a higher MLU than both SSD groups during the prekindergarten assessment. These between-group differences were no longer apparent during the Grade 1 assessment.

As would be expected given the subject selection criteria, the SSD-low PP and SSD-high PP groups obtained GFTA–2 scores that were below normal limits on average and significantly worse than the GFTA–2 scores obtained by the TS group during the prekindergarten assessment. The mean GFTA–2 percentile for the TS group is unchanged in Grade 1 relative to the prekindergarten results. However, 9% of this group scored below the 16th percentile during the first-grade assessment, whereas all of these children scored within the average range prior to kindergarten entry. In Grade 1, the SSD groups showed a large improvement in GFTA–2 percentiles relative to their prekindergarten performance, with the mean score for these groups now within the average range. Within these groups, the percentage of children scoring below normal limits in Grade 1 was 59 and 56 for the SSD-low PP and SSD-high PP groups, respectively. A detailed description of the types of speech errors produced by these children during the prekindergarten and kindergarten assessments can be found in Rvachew et al. (2007).

Prekindergarten Outcomes

Univariate one-way ANOVAs revealed significant between-group differences in articulation, speech perception, and phonological awareness performance during the prekindergarten assessment, as shown in Table 2. The results of the planned comparisons are illustrated in Figure 1 where overlapping standard error bars indicate nonsignificant differences between groups. It can be seen that both SSD groups obtained significantly worse PCCs than the TS group. However, planned comparisons indicated no significant difference in PCC when comparing the SSD-low PP and the SSD-high PP groups. Normative data indicate that the lower limit of normal performance is 72.5% at age 4 years (Austin & Shriberg, 1997). In the SSD-low PP and SSD-high PP groups, 88% and 75%, respectively, scored below normal limits. In the TS group, 4 children scored just below the normal limits, with scores between 70% and 72%.

The SSD-high PP group scored similarly to the TS group on the SAILS and PAT tests, while the SSD-low PP group scored significantly worse on these measures, a finding that

TABLE 1. Sample characteristics by subtype and assessment time.

Measure	SSD-low PP *M*	SSD-low PP *SD*	SSD-high PP *M*	SSD-high PP *SD*	Typical speech *M*	Typical speech *SD*	*F*	*p*	η^2
Prekindergarten assessment									
SES	51.94	10.23	62.97	21.45	58.52	10.22	2.55	.086	.07
Age	58.53	3.59	57.19	2.43	58.66	2.83	1.44	.244	.04
PPVT–III	103.12	6.58	113.00	11.75	112.43	11.02	5.46	.006	.14
MLU	3.76	1.39	4.59	1.31	4.99	0.97	6.36	.003	.16
GFTA–2 raw	43.18	11.45	38.44	8.03	13.97	8.54	73.16	<.001	.70
GFTA–2 rank	4.74	4.50	6.22	3.54	45.03	18.53			
Grade 1 assessment									
Age	83.35	3.20	81.50	2.68	83.23	4.19	1.44	.245	.04
PPVT–III	104.65	9.61	109.69	9.28	111.49	12.28	2.17	.122	.06
MLU	6.87	2.27	8.12	1.92	7.26	1.59	1.97	.147	.06
GFTA–2 raw	11.47	9.24	10.75	6.17	2.91	3.49	15.88	<.001	.33
GFTA–2 rank	19.21	18.36	18.28	13.98	44.37	19.76			

Note. Age is measured in months. SSD = speech sound disorders; PP = phonological processing; SES = socioeconomic status (measured as a Blishen score); PPVT–III = Peabody Picture Vocabulary Test—III (performance expressed as a standard score); MLU = mean length of utterance in morphemes; GFTA–2 = Goldman Fristoe Test of Articulation—Second Edition (both the mean raw scores and percentile ranks shown). Between-group differences were assessed with a univariate one-way analysis of variance (*df* = 2, 69).

TABLE 2. Outcome measures by subtype and assessment time.

Measure	SSD-low PP		SSD-high PP		Typical speech				
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*	η^2
Prekindergarten assessment									
PCC	61.54	10.01	65.82	10.17	83.21	6.99	45.04	<.001	.58
SAILS	59.66	8.66	77.67	6.76	77.70	6.61	39.93	<.001	.55
PAT	13.76	4.02	19.69	5.68	21.54	4.63	15.42	<.001	.32
Grade 1 assessment									
PCC	85.94	10.52	87.20	6.54	91.33	6.25	3.49	.036	.10
SAILS	80.59	7.05	87.95	4.49	84.12	6.73	5.55	.006	.15
PAT	31.59	1.62	30.81	2.20	32.31	1.60	4.12	.021	.11
Sight Word SS	100.65	5.40	102.88	8.77	104.60	13.37	0.77	.470	.02
Sight Word raw	31.12	6.74	31.56	14.79	36.54	17.86	1.01	.369	.03
Nonword SS	95.24	7.66	101.94	9.67	107.17	10.98	8.34	.001	.20
Nonword raw	8.35	4.94	11.63	7.95	18.60	10.78	8.37	.001	.21
TOWRE SS	97.53	6.54	102.94	10.20	107.17	13.03	4.37	.017	.12

Note. PCC = percentage consonants correct; SAILS = Speech Assessment and Interactive Learning System; PAT = Phonological Awareness Test; Sight Word = Sight Word Reading subtest of the Test of Word Reading Efficiency (TOWRE); Nonword = Phonetic Decoding subtest of the TOWRE.

reflects the grouping criteria. Overall, these results suggest that these groups may form two distinct subtypes of SSD rather than representing a continuum of severity levels within the SSD population.

First-Grade Outcomes

The mean scores by group for the tests of articulation, speech perception, and phonological awareness when administered at the end of first grade are also shown in Table 2. Univariate one-way ANOVAs again yielded significant between-group differences for these measures, although the effect sizes are smaller than observed during the prekindergarten assessment. During the Grade 1 assessment, mean PCC scores were within the average range for all three groups, and planned comparisons revealed no significant between-group differences at that time. Normative data indicate that the lower limit of normal performance is 86.8% at age 6 years (Austin & Shriberg, 1997). In the SSD-low PP and SSD-high PP groups, 47% and 50%, respectively, scored below normal limits in Grade 1. Within the TS group, 19% of the children fell below the average range on this test.

All groups made gains in speech perception, but significant between-group differences in SAILS scores were observed in Grade 1. However, the significant difference was between the SSD-low PP and the SSD-high PP groups. The mean score for the TS group was unexpectedly low due to a single outlier score. Across all three groups, the child with the lowest SAILS score in Grade 1 was a child who scored at the 48th percentile on the GFTA–2 prior to kindergarten but at the 16th percentile at the end of Grade 1. This child had significant difficulty with the perception and production of liquid consonants (although her phonological awareness and reading abilities were well above average).

The mean PAT score obtained by the SSD-high PP group was significantly lower than the mean PAT score obtained by the TS group. The mean PAT score obtained by the SSD-low PP group was not significantly different than the mean score obtained by the other two groups. However, these scores were very close to ceiling for all three groups.

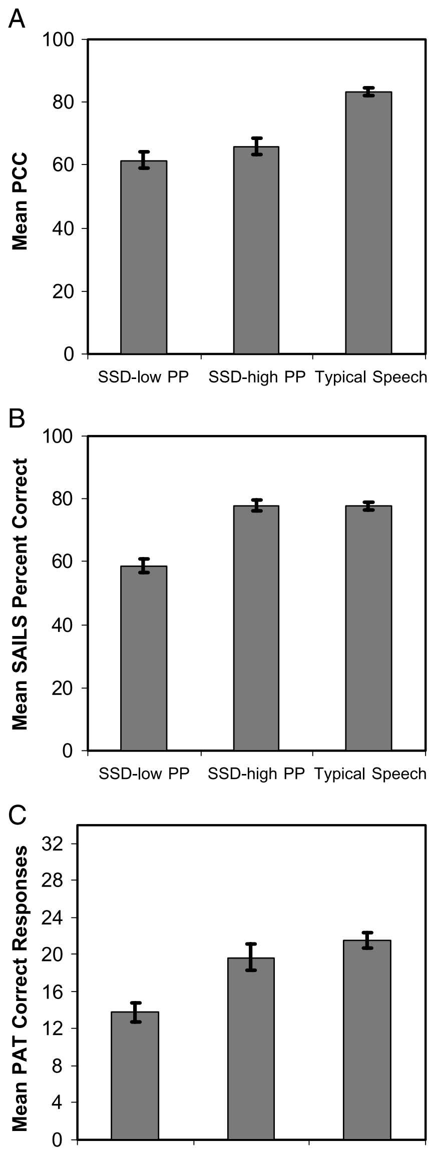
The results of the reading tests are also shown in Table 2. No significant between-group differences were observed for sight word reading. However, the SSD-low PP group scored significantly worse for phonetic decoding of nonwords than either the SSD-high PP or TS groups, resulting in a significantly lower total TOWRE score for this group as well. Although the SSD-high PP group achieved a lower mean score on the TOWRE than the TS group did, this difference was not statistically significant. Finally, it should be noted that the subtest standard scores and total TOWRE standard scores were within normal limits on average for all three groups. In fact, only 1 child (in the SSD-low PP group) scored below normal limits on this test.

Prediction of First-Grade Reading

Correlations between the Grade 1 outcome variables (sight word and nonword reading) and the prekindergarten predictors (PPVT–III, MLU, SAILS, PAT, GFTA–2, and PCC) are shown in Table 3. This table shows that receptive vocabulary (PPVT–III) and speech perception (SAILS), as measured prior to kindergarten entry, were significantly correlated with sight word reading in Grade 1. This table also shows that receptive vocabulary (PPVT–III), speech perception (SAILS), phonological awareness (PAT), and articulation (GFTA–2 and PCC) were significantly correlated with nonword decoding in Grade 1.

Hierarchical multiple regression analyses were conducted to further examine the predictive relationship between the prekindergarten measures and first-grade reading. The variables were entered into the equations in three separate blocks representing language skills (PPVT–III and MLU), phonological processing skills (SAILS and PAT), and articulation skills (GFTA–2 and PCC). As shown in Table 4, these blocks of variables were entered in different orders in order to identify those variables that explain unique

FIGURE 1. Mean scores by subtype for the prekindergarten measures of articulation accuracy (percentage consonants correct [PCC], Panel A), speech perception ability (Speech Assessment and Interactive Learning System [SAILS] percentage correct, Panel B), and phonological awareness (Phonological Awareness Test [PAT] number correct, Panel C). SSD = speech sound disorders; PP = phonological processing.



variance in the outcome variables, sight word and nonword reading.

Examining first the prediction of sight word reading, it can be seen from Table 4 that language skills predicted a significant proportion of variance, specifically 11%, when entered in the first step. Language skills also explained significant unique variance in sight word reading when entered after phonological processing or articulation. In fact, language skills explained significant unique variance in sight word reading when entered in any step. Neither phonological processing nor articulation explains significant unique variance in sight word reading when entered after language skills. Therefore, the overall conclusion is that language was the primary predictor of sight word reading in this sample.

In contrast, phonological processing skills emerged as the primary predictor of nonword decoding, accounting for 23% of variance, when entered in the first step. Phonological processing skills explained significant unique variance in nonword decoding regardless of the step at which this block was entered. Neither language nor articulation explained significant unique variance in nonword decoding when entered after phonological processing skills.

A final pair of hierarchical multiple regression analyses were conducted in order to examine the predictive power of the two phonological processing variables singly. When

TABLE 3. Pearson product–moment correlations among the Grade 1 reading outcomes and the prekindergarten predictor variables.

	1	2	3	4	5	6	7	8
1. Sight words	—							
2. Nonwords	.74	—						
3. PPVT-III	.30	.28	—					
4. MLU	−.14	.01	−.04	—				
5. SAILS	.27	.44	.34	.36	—			
6. PAT	.23	.34	.39	.18	.40	—		
7. GFTA–2	−.16	−.39	−.18	−.40	−.40	−.47	—	
8. PCC	.10	.30	.10	.53	.36	.39	−.89	—

Note. Sight words and nonwords are the sight word and decoding subtests of the TOWRE, respectively, as administered in Grade 1. Raw scores were used in each case. All correlations with an absolute value larger than .25 are significant at the .05 level.

TABLE 4. Squared multiple correlation change in fixed-order hierarchical multiple regressions to predict first-grade reading.

Steps in regression	Sight word reading	Nonword reading
1. Language	.11*	.08
2. Articulation	.03	.13*
3. Phonological processing	.05	.10*
1. Language	.11*	.08
2. Phonological processing	.07	.18*
3. Articulation	.01	.06
1. Phonological processing	.09*	.23*
2. Language	.09*	.03
3. Articulation	.01	.06
1. Phonological processing	.09*	.23*
2. Articulation	.01	.04
3. Language	.09*	.05
1. Articulation	.03	.16*
2. Phonological processing	.06	.11*
3. Language	.09*	.05
1. Articulation	.03	.16*
2. Language	.10*	.06
3. Phonological processing	.05	.10*

Note. Phonological processing = SAILS and PAT; Language = PPVT–III and MLU; Articulation = GFTA–2 and PCC in conversation. Asterisk indicates significant R^2 change.

entered first, PAT explained 12% of variance in nonword decoding by itself, $F(1, 66) = 8.71$, $p = .004$, and SAILS explained an additional 11%, $F(1, 65) = 9.27$, $p = .003$. When entered first, SAILS explained 19% of variance in nonword decoding, $F(1, 66) = 15.89$, $p < .001$, and PAT explained an additional 3%, $F(1, 65) = 2.76$, $p = .101$.

Discussion

In this longitudinal study, first-grade children who were treated for SSD prior to kindergarten entry were found to have weak nonword decoding skills, relative to the decoding skills of children with normally developing speech and relative to their own language abilities. This finding converges with the results of several other longitudinal studies, as will be discussed further below. This study adds to the findings of previous research by demonstrating that preschool measures of phonological processing skills (specifically speech perception, rime awareness, and onset awareness measured at age 4 years) predicted significant variance in nonword decoding abilities 2 years later. A further unique finding is that these preschool measures of phonological processing can be used to differentiate two distinct subgroups within this sample. The SSD-low PP subgroup demonstrated significantly poorer speech perception, phonological awareness, and nonword decoding skills than the TS comparison group. The SSD-high PP subgroup achieved scores on these measures of phonological processing that were indistinguishable from those of the TS comparison group, despite having speech impairments that were equally as severe as those observed in the SSD-low PP group.

This study joins three other published longitudinal investigations of the early reading skills of children with a preschool history of SSD. Bird et al. (1995) recruited children in kindergarten and followed them for 2 years. Larrivee and Catts (1999) assessed their sample at the end of kindergarten and again 1 year later. Nathan et al. (2004) followed children between the ages of 4;6 (years;months) and 7;0, overlapping the follow-up period of the current study. Each study involved small samples of children, but collectively 132 children with SSD are described. When comparing the reading skills of children with SSD with the reading skills of their typically developing peers, the effect sizes are consistently negative, as shown in Table 5. The consistency of this finding lends confidence to the conclusion that these children are indeed at risk for delayed acquisition of reading skills. However, there is considerable heterogeneity in the observed effect sizes. Therefore, it is clear that there are variables that mediate the relationship between speech production accuracy and RD. Investigation of potential mediating variables may help to explain two paradoxes that are apparent in this literature: First, not all children with SSD have difficulty with phonological processing, and second, not all children with phonological processing deficits develop reading disabilities.

One explanation for the first paradox is that the SSD population is composed of distinct subtypes that are differentiated by distinct etiologies (see Pennington, 2006, for further discussion of possible causal models). The dissociation of phonological processing skills and articulation accuracy that is seen in Figure 1 provides some support for this hypothesis. Some of these children have clear difficulties with phonological awareness, whereas others do not, a difference that is not explained by differences in articulation accuracy or language skills.

TABLE 5. Effect sizes from four studies that compared the reading skills of children with SSD to that of their peers with normally developing speech.

Sample	SSD *n*	Control *n*	Effect size
Bird et al. (1995)[a]			
SSD, language impairment	13	13	−1.45
SSD	18	18	−1.38
Larrivee & Catts (1999)[b]			
SSD, mixed language skills	30	27	−1.14
Nathan et al. (2004)[c]			
SSD, language impairment	19	19	−1.01
SSD	19	19	−0.36
Current study[b]			
SSD	33	35	−0.62
SSD-low PP	17	35	−1.17
SSD-high PP	16	35	−0.49

Note. The effect size reported is Hedge's *g,* which is Cohen's *d* with Hedge's correction for small sample sizes (Strube, 1998).

[a]Outcome variable was sight word reading.
[b]Outcome variable was a composite of sight word and nonword reading.
[c]Outcome variable was a composite of letter knowledge, sight word, and nonword reading.

It has been suggested that these children's phonological awareness difficulties reflect inefficiencies in the formation of phonological representations of words. Immaturity of phonological representations has been attributed to imprecision in the children's articulatory gestures (Carroll, Snowling, Hulme, & Stevenson, 2003; Fowler, 1991; Nicolson, Fawcett, & Dean, 2001; Raitano et al., 2004). This impression has been reinforced by the use of phonological processing tasks that involve spoken responses (e.g., nonword repetition, phoneme deletion). In the current study, phonological processing measures were selected to specifically avoid verbal responses on the part of the children. Modeling of the concurrent and longitudinal relationships between articulation accuracy, speech perception, and phonological awareness skills in these children (Rvachew, 2006; Rvachew & Grawburg, 2006) shows that phonological awareness skills are mediated by speech perception, and not articulation accuracy. Research employing event-related responses, behavioral measures of speech perception, and various priming paradigms confirms this finding in children with SSD and/or dyslexia (Boada & Pennington, 2006; Lyytinen et al., 2004; Munson, Baylis, Krause, & Yim, 2006).[1]

[1]The conclusion that phonological awareness skills reflect speech perception difficulties remains controversial because some studies have found that measures of "input phonology" are not correlated with phonological awareness or reading abilities (e.g., Carroll et al., 2003; Chaney, 1994; Nathan et al., 2004). The discrepant findings can be explained by the use of tasks that do not tap the specificity of acoustic-phonetic representations for words. For further discussion of levels of representation and appropriate assessment procedures, see Boada and Pennington (2006), Munson, Edwards, and Beckman (2005), Rvachew (2007), and Rvachew and Jamieson (1989).

The second paradox, involving varying levels of reading ability in children with phonological processing deficits, may be explained by complex interactions among risk factors and protective factors in individual children (Pennington, 2006). One such protective factor may be language skills. Language development has direct and indirect effects on reading acquisition. Indirect effects occur because rapid growth in vocabulary size triggers the gradual segmentalization of underlying phonological representations for words, thus supporting the emergence of decoding skills (Metsala & Walley, 1998). Direct effects occur because strong oral language skills provide essential support for the development of reading comprehension, especially at supralexical levels (Share & Leikin, 2004; Storch & Whitehurst, 2002). Another protective factor may be the nature of environmental supports for reading acquisition provided by parents, teachers, and speech-language pathologists. Many studies have shown that phonological awareness programs in the kindergarten classroom have an impact on reading acquisition (Ehri et al., 2001). Other studies have described positive impacts of speech therapy and phonological awareness interventions on the development of phonological awareness skills in children with SSD (Bernhardt & Major, 2005; Gillon, 2000, 2002, 2005; Hesketh, Adams, Nightingale, & Hall, 2000).

Pennington (2006) suggested that multifactorial research designs involving techniques such as confirmatory factor analysis and path analysis should be used to examine the dynamic interactions between various etiological and cognitive factors during development. Systematic application of different combinations of interventions targeting speech perception, speech production accuracy, vocabulary, and/or phonological awareness would also help to disentangle the complex developmental relationships among the risk and protective factors that may explain individual differences in reading acquisition.

Despite the need for further research to illuminate the precise nature of this developmental process, the clinical implications of the findings to date are clear. Longitudinal studies of children with SSD indicate that they achieve lower levels of reading performance than their normally developing peers, even when the children present with language skills within the average range, and regardless of the severity of their speech impairment. This study suggests that children who have phonological processing difficulties can be identified prior to school entry by an assessment of the children's speech perception and implicit phonological awareness skills. Efforts to ensure normalization of phonological processing, speech production, and language skills in these children prior to school entry are important. Continued monitoring of reading development and the provision of appropriate interventions when required would be a prudent course of action for a child with a preschool history of SSD, especially if the child shows evidence of phonological processing difficulties and fails to achieve age-appropriate speech and language skills prior to the onset of formal education.

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Contact author: Susan Rvachew, Communication Sciences and Disorders, McGill University, 1266 Pine Avenue West, Montréal, Quebec, Canada, H3G 1A8.
E-mail: susan.rvachew@mcgill.ca.