Correlates of Phonological Awareness in Preschoolers With Speech Sound Disorders

Susan Rvachew
Meghann Grawburg
McGill University,
Montréal, Québec, Canada

Purpose: The purpose of this study was to examine the relationships among variables that may contribute to poor phonological awareness (PA) skills in preschool-aged children with speech sound disorders (SSD).

Method: Ninety-five 4- and 5-year-old children with SSD were assessed during the spring of their prekindergarten year. Linear structural equation modeling was used to compare the fit of 2 models of the possible relationships among PA, speech perception, articulation, receptive vocabulary, and emergent literacy skills.

Results: Half the children had significant difficulty with speech perception and PA despite demonstrating receptive language skills within or above the average range. The model that showed the best fit to the data indicated that speech perception is a pivotal variable that has a direct effect on PA and an indirect effect that is mediated by vocabulary skills. Articulation accuracy did not have a direct impact on PA. Emergent literacy skills were predicted by PA abilities.

Conclusions: Children with SSD are at greatest risk of delayed PA skills if they have poor speech perception abilities and/or relatively poor receptive vocabulary skills. Children with SSD should receive assessments of their speech perception, receptive vocabulary, PA, and emergent literacy skills.

KEY WORDS: phonological disorders, phonological awareness, speech perception

It is now well established that children with speech sound disorders (SSD) are at significant risk of concomitant delays in the development of phonological awareness (PA) and literacy skills (Bird, Bishop, & Freeman, 1995; Larrivee & Catts, 1999; Raitano, Pennington, Tunick, Boada, & Shriberg, 2004; Rvachew, Ohberg, Grawburg, & Heyding, 2003). Fortunately, these delays can be identified during the preschool period, and thus it may be possible to prevent reading difficulties among this at-risk population with interventions that are provided before school entry. However, the development of effective preventative interventions requires a better understanding of the variables that underlie the impoverishment of both implicit and explicit phonological knowledge that is observed in this population of children.

The purpose of this study was to describe the PA skills of preschool-aged children with SSD, in relation to other variables that may be associated with the emergence of preliteracy skills. Two models of the relationships among the relevant variables were tested using linear structural equation modeling. As shown in Figure 1, both models include the constructs of speech perception, articulation, receptive vocabulary,
PA, and emergent literacy knowledge. These constructs are discussed below with a focus on current hypotheses regarding the developmental links between PA and the remaining constructs.

**PA**

PA is indexed by a variety of phonological processing tasks that reveal conscious sensitivity to the sound structure of words, including the ability to match words on the basis of similarities in sound structure, as well as cognitively more difficult tasks that involve the active manipulation of specific phonological units. The child may be asked to attend to relatively large phonological units, such as syllables; intermediate units, such as onsets and rimes; or the individual phonemes contained within the onset, nucleus, or coda of the syllable. Successful completion of a PA task requires that the child have some awareness that words are made up of smaller units. Performance on these tasks reflects the level at which the child's underlying representations for words are segmented (A. E. Fowler, 1991). When task complexity is controlled, a developmental progression is observed from words, through syllables, onset rimes, and phonemes, although children’s emerging awareness of smaller units overlaps with their developing knowledge of larger units (Anthony & Lonigan, 2004; Anthony et al., 2002; Anthony, Lonigan, Driscoll, Philips, & Burgess, 2003). The relationship between these varying levels of PA and the
emergence of reading skills is complex, with rime awareness having both direct effects on reading and indirect effects that are mediated by phoneme awareness (Bryant, 2002).

As noted earlier, children with SSD can have significant difficulty with PA. Understanding the source of these difficulties requires an understanding of other variables that may account for the emergence of PA among normally developing children and children with speech and/or language delay.

**PA and Speech Perception**

*Speech perception* is the process of transforming a continuously changing acoustic signal into discrete linguistic units. Although models of speech perception vary widely in their details, most models assume a multistage process in which extraction of the acoustic details is accomplished by means of basic auditory processing mechanisms, and then the acoustic representation is transformed into phonetic units, and finally a hierarchically organized phonological representation is constructed that is subsequently used in the process of lexical access. Assumptions about the nature of the phonetic units that are recovered in the second stage are the defining features of competing models of speech perception, with motor theories positing that these units are articulatory gestures and general auditory theories positing that these units are acoustic–phonetic features organized to represent phones (Diehl, Lotto, & Holt, 2004; C. A. Fowler, 2003). A model in which the basic units of perception are acoustic–phonetic features, and the target of speech production is an acoustic product, is reflected in Figure 1 (left panel).

Speech perception and PA comprise different aspects of phonological processing. Both tasks involve accessing acoustic–phonetic and phonological representations of words. However, speech perception is dependent on detailed acoustic–phonetic representations of words, whereas PA requires segmented phonological representations of words in the lexicon. Speech perception is typically assessed with a word identification task in which the listener is presented with many tokens of the target words, with the acoustic features of the words varied in a systematic fashion, often by constructing synthetic stimuli (Nittrouer, 2002). When performing a speech perception task, the child must ignore irrelevant acoustic variation and categorize each auditory stimulus as being an exemplar of the target word or not. To be successful at this task, it is necessary to possess a detailed and efficient acoustic–phonetic representation for the target word that highlights the features that best characterize the word in relation to similar words. Notice that the child does not need to be aware of the individual segments in a word in order to successfully identify words. In fact, it has been shown that young children often perform certain speech perception tasks by attending to acoustic cues that reflect the syllable more clearly than the individual segments that comprise the syllable (Nittrouer, 2002).

Developmental changes in speech perception skills include the ability to encode quickly sufficient acoustic–phonetic detail about words, even under difficult listening conditions, and to hold that information in working memory long enough to accomplish higher level processing of the input. Nittrouer and Burton (2005) showed that this developmental course occurs as a result of the child’s experience with spoken language, which produces a gradual accumulation of knowledge about the acoustic–phonetic cues that best represent the phonological units that are important in the ambient language system. The child’s acquisition of this knowledge is reflected in the gradual sharpening of perceptual category boundaries between phonemes, a shift in the child’s attention from less to more reliable cues to phoneme identity, and a developmental improvement in the child’s ability to accurately identify words when cue redundancy has been reduced (Edwards, Fox, & Rogers, 2002; Hazan & Barrett, 2000; Nittrouer, 2002; Zlatin & Koenigsknecht, 1976). The development of language-specific speech perception begins in infancy and continues into late childhood (Hazan & Barrett, 2000).

A relationship between speech perception and PA has been revealed in many studies involving normally developing children as well as children with speech, language, or reading problems (Chiappe, Chiappe, & Siegel, 2001; Foy & Mann, 2001; Joanisse, Manis, Keating, & Seidenberg, 2000; Mayo, Scobbie, Hewlett, & Waters, 2003; McBride-Chang, 1995; Nittouer, 1996; Nittouer & Burton, 2005). Some of these studies involved sophisticated modeling techniques that yielded the conclusion that there is an indirect yet causal relationship between these variables. The model in the left panel of Figure 1 shows a relationship in which speech perception development drives the development of PA.

**PA and Articulation**

Learning to articulate phonemes is also a protracted process that begins in infancy with the production of speechlike babble and ends typically with accurate articulation of all phonemes in the language by 9 years of age (Smit, Hand, Frelinger, Bernthal, & Bird, 1990). Articulation accuracy reflects not just the ability to articulate individual segments across a variety of phonetic contexts but also the child’s underlying knowledge of all aspects of the native-language sound system.

When children fail to achieve articulation accuracy at the expected rate, the problem can sometimes be
traced to difficulties with the structural or functional integrity of the articulation system itself. More often, there is no known etiology, although it has been hypothesized that SSD may be genetically transmitted, with the underlying problem being in the cognitive–linguistic domain (Shriberg, Austin, Lewis, McSweeny, & Wilson, 1997). These children are very likely to have significant difficulty with the categorical perception of phonemes (Broen, Strange, Doyle, & Heller, 1983; Edwards et al., 2002; Hoffman, Daniloff, Bengoa, & Schuckers, 1985; Rvachew & Jamieson, 1989). Rvachew and Jamieson (1995) proposed that these children’s articulation errors are a direct reflection of inaccurate or incomplete perceptual knowledge of the acoustic–phonetic characteristics of the misarticulated phoneme categories. This hypothesis is consistent with a model of speech production in which auditory targets guide the execution of the necessary articulatory gestures (Callan, Kent, Guenther, & Vorperian, 2000). The view that speech perception leads articulation is represented in the model shown in the left panel of Figure 1.

A contrasting model, the motor theory of speech perception (Liberman & Mattingly, 1985; Studdert-Kennedy, 2002), proposes that articulatory gestures are the basic unit of both speech perception and speech production. This theory has motivated some investigations of the relationship between articulation skills and PA. For example, Castiglioni-Spalten and Ehri (2003) suggested that “articulatory gestures are closer to the heart of phonological representations than sounds” (p. 27). Carroll, Snowling, Hulme, and Stevenson (2003) proposed that the onset of PA is “a natural consequence of structuring the lexicon in terms of the subphonemic gestures within words” (p. 920). The cerebellar deficit hypothesis (Nicolson, Fawcett, & Dean, 2001) posits that an impaired cerebellar mechanism for recovering articulatory gestures from spoken language explains a congruence of difficulties with motor coordination, speech articulation, phonological processing, and reading impairment in individuals with dyslexia. This hypothesis about the cause of dyslexia explicitly states that an “articulatory problem is at the head of a causal chain” (Ivry & Justus, 2001) leading through phonological processing to dyslexia and is reflected in the model shown in the right panel of Figure 1.

PA and Receptive Vocabulary

One aspect of vocabulary development is the encoding of phonological representations for words, most likely in the form of a hierarchically organized bundle of abstract phonological units. It has been suggested that this segmentally organized structure, both at the level of individual lexical items and at the level of the lexicon as a whole, is a gradual accomplishment that takes at least 7 years to complete (de Cara & Goswami, 2003; A. E. Fowler, 1991). A relationship between PA and language skills is a highly consistent finding for children of all ages (Chaney, 1994, 1998; Cooper, Roth, Speece, & Schatschneider, 2002; Dickinson, McCabe, Anastasopoulos, & Poe, 2003; Frijters, Barron, & Brunello, 2000; Lonigan, Burgess, & Anthony, 2000; Metsala, 1999; Olofsson & Neidersoe, 1999; Sénéchal & LeFevre, 2002; Silven, Niemi, & Voeten, 2002; Storch & Whitehurst, 2002).

Longitudinal studies support the view that vocabulary development leads to improvements in PA. Metsala and Walley (1998) proposed a mechanism to account for this developmental course. Their hypothesis is that rapid growth in the size of the child’s vocabulary triggers a restructuring of the underlying representations for words in the lexicon from a holistic to a segmented form. This restructuring occurs in order to maintain the efficiency of lexical access as the size of the lexicon increases. Support for the lexical restructuring model comes from a study in which word recognition was shown to vary with the frequency of occurrence and neighborhood density of the target words (Metsala, 1997). Metsala (1999) also showed that children’s PA performance is strongly related to vocabulary size in general and to specific characteristics of the target words, such as lexical status, age of acquisition, and neighborhood density. Both models shown in Figure 1 are consistent with this perspective, with a direct link between receptive vocabulary and PA.

Comprehension and production of spoken words typically begins during the 1st year of life and expands at a rapid rate thereafter. Individual differences in a toddler’s ability to perceptually encode the fine phonetic details of speech when learning new words is correlated with both receptive and expressive vocabulary growth (Mills et al., 2004; Werker, Fennell, Corcoran, & Stager, 2002). Speech perception under conditions of reduced cue redundancy is also correlated with vocabulary size (Edwards et al., 2002). Werker et al. (2000) suggested that the ability to encode phonetic detail may be causally related to vocabulary growth. This hypothesis is reflected in the left panel of Figure 1, in which speech perception is directly related to the development of phonological representations in the lexicon and thus to receptive vocabulary.

We are aware of no studies that have specifically examined the relationship between articulation accuracy and receptive vocabulary skills, but there are several studies suggesting that prelinguistic vocalization abilities are associated with expressive vocabulary growth during the 2nd year of life (McCune & Vihman, 2001; Oller, Eilers, Neal, & Schwartz, 1999; Rvachew, Slawinski, Williams, & Green, 1999). It is clear that articulation...
deficits do not place a natural limit on the acquisition of vocabulary or other language skills, as 80% to 90% of 6-year-old children with SSD do not have a comorbid language deficit (Shriberg, Tomblin, & McSweeny, 1999). However, it has been suggested that even subtle articulation problems may influence the organization of phonological representations and the lexicon (Nicolson et al., 2001). A. E. Fowler (1991) proposed that "integrating gestures into phonetic routines serves as a mechanism for automation, providing a highly efficient representational code for encoding, storing and retrieving phonological structures" (p. 59). This hypothesis, in which the physical act of articulating speech sounds is thought to have a direct impact on the development of segmentally organized phonological representations in the lexicon, is illustrated in the model shown in the right panel of Figure 1. A direct link between speech perception and articulation is retained in this model, although in this case the basic units that underlie speech perception are thought to be articulatory gestures rather than acoustic–phonetic features.

## PA and Emergent Literacy Skills

The most current conceptualization of emergent literacy makes a clear distinction between this construct and other related but distinct constructs, such as oral language and PA skills (Sénéchal, LeFevre, Smith-Chant, & Colton, 2001). Emergent literacy skills include both conceptual and procedural knowledge about reading and writing. Conceptual knowledge includes an understanding of the functions of print and recognition of environmental print. Perhaps the most important form of procedural knowledge that is acquired by young children is the knowledge of letter names and letter sounds. Children’s acquisition of conceptual and procedural knowledge is directly linked to specific kinds of home literacy experiences (Sénéchal & LeFevre, 2002).

Linear structural equation modeling of longitudinal data has revealed that oral language skills and PA at younger ages predicts both PA and letter knowledge at later ages (Frijters et al., 2000; Lonigan et al., 2000). Consistent with these findings, the models illustrated in Figure 1 place emergent literacy knowledge as a direct outcome of PA and with no direct links between this construct and other constructs shown in the models.

## Purpose of the Study and the Proposed Model

As stated above, the purpose of the study reported herein was to describe the PA skills of preschool-aged children with SSD, in relation to other variables that may be associated with the emergence of PA. The participants were children with SSD who were receiving speech therapy when recruited to the study. Although many of these children are being followed until the end of first grade, this report describes only their performance during the test session that took place during the spring of their prekindergarten year, when they were 4 or 5 years old. This assessment provided information about emergent literacy knowledge, PA at the onset-rime level, receptive vocabulary, articulatory accuracy, and speech perception abilities. A model of proposed relationships among these variables was developed and then verified using a linear structural equation analysis of the children’s test scores.

The literature as presented above provided the basis for decisions about the grouping of individual measures to derive latent variables, the linear ordering of these variables within the model, and the proposed interrelationships among these variables. Although it is recognized that there may be reciprocal relationships among pairs of variables within the model, a linear ordering was accomplished by considering the developmental order in which the various skills emerge. Speech perception was designated as the exogenous variable in the preferred model, because a great deal of perceptual knowledge about language-specific speech sound contrasts is acquired by infants even before the emergence of first words. The infant’s ability to attend to fine phonetic detail in speech plays a role in the growth of receptive vocabulary knowledge (Werker et al., 2002). Accurate articulation of a given phoneme has been shown to be associated with categorical perception of that phoneme while it is possible for children to have accurate perception without demonstrating accurate articulation (Rvachew & Jamieson, 1989). As a consequence of the developmental dependence of these two early-appearing language skills on a prior level of perceptual knowledge, receptive vocabulary and articulation were designated as the first endogenous variables, with speech perception making an independent contribution to both domains. PA was chosen as the next endogenous variable, as it has been shown to emerge in children as young as 3 years of age (Chaney, 1992). Early forms of PA (e.g., rime awareness) appear to emerge independently of letter knowledge at an early age, although there is a close reciprocal relationship between phoneme awareness and letter knowledge in older children. Therefore, emergent literacy knowledge was positioned as the dependent variable and ultimate outcome in the model, following Lonigan et al. (2000) and Frijters et al. (2000). The fit of a contrasting model (see Figure 1, right panel) was also assessed. The alternative model comprises the same variables, but they are arranged so that articulation accuracy is the exogenous variable.
Method

Participants

The participants were 95 children who were recruited by speech-language pathologists at two pediatric hospitals located in urban centers, one in eastern Canada and the other in western Canada. Speech-language pathologists were asked to refer children who obtained a score below the 16th percentile on a standardized measure of articulation skills during their prekindergarten year. Even if the child improved his or her score to within the average range during the period between referral and our assessment, the child was retained as a participant. In addition, they were required to demonstrate normal hearing and oral–motor function prior to referral to the study (in other words, the referring clinician conducted these assessments using the test protocol that was prescribed in their particular clinical setting). We asked that the child’s primary deficit be in the area of articulation rather than language, but children with language impairment were not specifically excluded from the study. Children whose SSD was secondary to other conditions, such as sensory–neural hearing loss, Down syndrome, cerebral palsy, or cleft palate, were excluded, but suspected dyspraxia of speech was not an exclusionary criterion. All of the children were monolingual speakers of English. In addition to the 95 participants described in this report, 5 who were recruited were withdrawn from the study before the prekindergarten assessment could be completed because the child could not or would not cooperate with the test procedures.

The 95 children who completed the assessment protocol had a mean age of 57.54 months (SD = 4.33 months), with the youngest being 48 months and the oldest being 67 months. There were 62 boys and 33 girls. Socioeconomic status 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 30 (high school not completed) to 101 (professional credentials), with a mean of 54 (some postsecondary education). Eighty-seven children had received speech therapy prior to their enrollment in this study, and the remaining 8 were waiting to receive treatment at the time of the assessment.

Procedure

Most children were tested in a single 75-min session, although some were tested in two 40-min sessions. The tests were administered 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 to target, in fixed order as follows: receptive vocabulary, articulation, speech perception, PA, emergent literacy knowledge, and expressive language skills.

Speech perception. Speech perception was assessed using the Speech Assessment and Interactive Learning System (SAILS; AVAAZ Innovations, 1999), 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.

Articulation. The Goldman-Fristoe Test of Articulation—Second Edition (GFTA–2; Goldman & Fristoe, 2000) provided a measure of articulation ability during picture naming. Both percentile rank and the total number of errors were used in the analyses described below. (A detailed description of the children’s speech errors on this test was also developed, but this error pattern analysis is not reported here as these data are the focus of a manuscript in preparation.) 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 codeable consonant targets. The intraclass correlation for the PCCs determined independently by two coders of 29 randomly selected samples yielded a reliability of .95.
Language. Receptive vocabulary size was assessed using the Peabody Picture Vocabulary Test—Third Edition (PPVT–III; Dunn & Dunn, 1997). Systematic Analysis of Language Transcripts (SALT; Miller & Chapman, 1996) was used to determine the child’s mean length of utterance (MLU) from the speech samples, using the procedures recommended by the SALT program. The intraclass correlation for the MLUs, determined independently by two coders of 29 randomly selected samples, yielded a reliability of .99.

PA. Bird et al.’s (1995) PA test was administered to all participants. This test consisted of three subtests: (a) Rime Matching, (b) Onset Matching, and (c) Onset Segmentation and Matching, hereafter referred to as Rime Awareness, Onset Awareness, and Onset Segmentation and Awareness and identified by the abbreviations RA, OA, and OS, respectively. The first subtest administered to each child was RA. 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, “Dan likes things that sound like his name” and asked which he would like from “house,” “boat,” “car,” and “van.” The pictures were named for the child, and the child was required to point to the picture of the word that matched the rime of the puppet’s name. For OA, the child was shown a puppet and told that everything it owned began with the same sound. The child was told the relevant sound and then asked to select the picture whose name began with that sound. Finally, for OS, the child was again told the puppet’s name and then 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 RA, 10 OA, and 10 OS), involving the target rimes /æn, æg, æt, æp/ and target onsets /p, f, m, t, s/. The test items and administration procedures and instructions were exactly as described by 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.

Emergent literacy knowledge. The children’s emergent literacy skills were assessed using the Early Literacy Assessment, adapted from the Basic Reading Inventory (Johns, 1997). The test included three subtests: (a) Alphabet Knowledge (AK), (b) Conceptual Literacy Knowledge (CLK), and (c) Basic Word Knowledge (WK). The children were asked to name the following letters for the first subtest: O, S, V, B, W, A, x, e, t, l, n, z. For the second subtest, they were asked to look at a book with the examiner and answer questions about the reading process (“Show me the front of this book. Show me the title. Point to where I should start reading. Which way should I go? Where should I go after that? Show me one letter. Now show me two letters. Show me only one word. Now show me two words. Show me a sentence.”). The third subtest involved reading the following frequently occurring words: the, of, and, to, a, in, is, that, it,

<table>
<thead>
<tr>
<th>Test</th>
<th>M</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Pass rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speech perception (SAILS)</td>
<td>72.50</td>
<td>11.23</td>
<td>33.75</td>
<td>94.17</td>
<td>62.11</td>
</tr>
<tr>
<td>/k/ perception</td>
<td>74.00</td>
<td>14.17</td>
<td>30.00</td>
<td>100.00</td>
<td></td>
</tr>
<tr>
<td>/l/ perception</td>
<td>80.53</td>
<td>16.46</td>
<td>20.00</td>
<td>100.00</td>
<td></td>
</tr>
<tr>
<td>/r/ perception</td>
<td>66.74</td>
<td>16.26</td>
<td>25.00</td>
<td>100.00</td>
<td></td>
</tr>
<tr>
<td>/s/ perception</td>
<td>68.72</td>
<td>13.10</td>
<td>30.00</td>
<td>93.33</td>
<td></td>
</tr>
<tr>
<td>GFTA–2</td>
<td>9.29</td>
<td>11.68</td>
<td>0.50</td>
<td>59.00</td>
<td>15.79</td>
</tr>
<tr>
<td>Percentage of consonants</td>
<td>68.15</td>
<td>11.67</td>
<td>28.32</td>
<td>91.64</td>
<td>12.63</td>
</tr>
<tr>
<td>PPVT–III</td>
<td>107.18</td>
<td>12.69</td>
<td>80.00</td>
<td>138.00</td>
<td>96.84</td>
</tr>
<tr>
<td>Mean length of utterance</td>
<td>4.61</td>
<td>1.56</td>
<td>1.77</td>
<td>9.13</td>
<td>48.28</td>
</tr>
<tr>
<td>Phonological awareness</td>
<td>15.77</td>
<td>8.18</td>
<td>0.00</td>
<td>33.00</td>
<td>52.63</td>
</tr>
<tr>
<td>Rime Awareness</td>
<td>7.13</td>
<td>3.92</td>
<td>0.00</td>
<td>14.00</td>
<td></td>
</tr>
<tr>
<td>Onset Awareness</td>
<td>5.25</td>
<td>2.98</td>
<td>0.00</td>
<td>11.00</td>
<td></td>
</tr>
<tr>
<td>Onset Segmentation and Awareness</td>
<td>3.33</td>
<td>3.11</td>
<td>0.00</td>
<td>11.00</td>
<td></td>
</tr>
<tr>
<td>Emergent literacy knowledge</td>
<td>12.27</td>
<td>5.38</td>
<td>0.00</td>
<td>31.00</td>
<td>62.11</td>
</tr>
<tr>
<td>Alphabet Knowledge</td>
<td>6.28</td>
<td>3.79</td>
<td>0.00</td>
<td>12.00</td>
<td></td>
</tr>
<tr>
<td>Conceptual Literacy Knowledge</td>
<td>5.68</td>
<td>2.16</td>
<td>0.00</td>
<td>10.00</td>
<td></td>
</tr>
<tr>
<td>Basic Word Knowledge</td>
<td>0.31</td>
<td>1.30</td>
<td>0.00</td>
<td>11.00</td>
<td></td>
</tr>
</tbody>
</table>

was. Split-half reliability for total test score for 30 randomly selected test protocols was found to be .93.

Results

The mean and standard deviation of the scores obtained for each test and subtest are shown in Table 1. Kolmogorov–Smirnov tests indicated that all total test scores were normally distributed. The proportion of children who passed each test is also shown in this table. The cutoff for standardized tests was the 16th percentile for the child’s age as indicated by the test manual (GFTA–2, PPVT–III). The cutoff for the MLU at 1 SD below the mean was determined from the age-appropriate comparison group in the SALT database. The normal limit for the PCC was estimated to be 80% (Shriberg et al., 1997). The passing scores for the remaining tests were derived from a sample of 30 normally developing middle-class children whom we are following, again taking the first standard deviation below the mean as the cutoff. Some children achieved normal articulation scores prior to our assessment, as 16% of the children recruited with SSD scored above the 16th percentile on the GFTA–2, and 12.63% of the children achieved a PCC that was within normal limits. All but 3 children scored above the 16th percentile on the PPVT–III. Pass rates for the remaining tests ranged from 48% to 62%.

The correlation coefficients among these variables are shown in Table 2. We used AMOS 5 (Arbuckle, 1999) to assess the measurement model and the competing structural models. The input was in the form of raw data, and the method of estimation was maximum likelihood. Three fit statistics are reported in each case: (a) the chi-square statistic with the associated degrees of freedom and probability value (larger p values indicate better fit), (b) the comparative fit index (CFI; values closest to 1.00 indicate the best fit), and (c) the root-mean-square error of approximation (RMSEA; values less than .05 indicate a close fit).

The specific measures that were included in the model were percentage correct responses on each SAILS subtest, number of errors produced on the GFTA–2, PCC, PPVT–III standard score, and number of correct responses for each PA and emergent literacy subtest. Hierarchical multiple regression analyses showed that age and socioeconomic status did not account for significant unique variance in the outcome variables (PA and emergent literacy knowledge); furthermore, inclusion of these variables in the model itself resulted in significantly worse fit statistics. Thus, these data were not included in the data set. (This does not mean that age and socioeconomic status are not associated with PA; rather, the range of these variables was restricted by the participant selection criteria for this study, and thus these variables added nothing to the model.) Further analyses showed that the variables that were included did not vary systematically with site or year of recruitment and thus the data for the full set of 95 children was analyzed without subgrouping. Complete data were available for all variables except PCC. Eight spontaneous language samples were lost because of experimenter error, and thus PCC scores were available for only 87 participants. There are two standard strategies for

Table 2. Bivariate Pearson product–moment correlations among variables.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>/k/</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>2</td>
<td>/l/</td>
<td>.269</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>3</td>
<td>/r/</td>
<td>.355</td>
<td>.400</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>4</td>
<td>/s/</td>
<td>.446</td>
<td>.457</td>
<td>.519</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>5</td>
<td>GFTA–2</td>
<td>-.197</td>
<td>-.281</td>
<td>-.278</td>
<td>-.249</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>6</td>
<td>PCC</td>
<td>.092</td>
<td>.302</td>
<td>.270</td>
<td>.248</td>
<td>.707</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>7</td>
<td>PPVT–III</td>
<td>.155</td>
<td>.236</td>
<td>.329</td>
<td>.257</td>
<td>-.154</td>
<td>.144</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>8</td>
<td>MLU</td>
<td>.084</td>
<td>.307</td>
<td>.228</td>
<td>.177</td>
<td>-.403</td>
<td>.494</td>
<td>.194</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>9</td>
<td>RA</td>
<td>.215</td>
<td>.240</td>
<td>.236</td>
<td>.308</td>
<td>-.201</td>
<td>.143</td>
<td>.402</td>
<td>.204</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>10</td>
<td>OA</td>
<td>.152</td>
<td>.279</td>
<td>.360</td>
<td>.384</td>
<td>-.210</td>
<td>.273</td>
<td>.357</td>
<td>.194</td>
<td>.511</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>11</td>
<td>OS</td>
<td>.180</td>
<td>.186</td>
<td>.164</td>
<td>.274</td>
<td>-.279</td>
<td>.261</td>
<td>.422</td>
<td>.169</td>
<td>.418</td>
<td>.553</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>12</td>
<td>AK</td>
<td>.197</td>
<td>.267</td>
<td>.211</td>
<td>.232</td>
<td>-.092</td>
<td>.094</td>
<td>.347</td>
<td>.253</td>
<td>.234</td>
<td>.352</td>
<td>.324</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>13</td>
<td>CLK</td>
<td>.101</td>
<td>.337</td>
<td>.308</td>
<td>.389</td>
<td>-.222</td>
<td>.120</td>
<td>.364</td>
<td>.139</td>
<td>.377</td>
<td>.473</td>
<td>.429</td>
<td>.267</td>
<td>—</td>
</tr>
<tr>
<td>14</td>
<td>WK</td>
<td>.054</td>
<td>.167</td>
<td>.038</td>
<td>.163</td>
<td>-.271</td>
<td>.209</td>
<td>.094</td>
<td>.233</td>
<td>.114</td>
<td>.219</td>
<td>.281</td>
<td>.262</td>
<td>.240</td>
</tr>
</tbody>
</table>

Note. Speech perception (Speech Assessment and Interactive Learning System) subtests are labeled /k/ = cat perception, /l/ = lake perception, /r/ = rat perception, and /s/ = Sue perception. PCC = percentage of consonants correct; MLU = mean length of utterance; RA = Rime Awareness; OA = Onset Awareness; OS = Onset Segmentation and Awareness; AK = Alphabet Knowledge; CLK = Conceptual Literacy Knowledge; WK = Basic Word Knowledge.
dealing with missing data, one involving estimating the missing scores on the basis of statistical regression, and the other involving substituting the sample mean for the missing scores. Both methods were used and yielded the same result with respect to the fit of the model even though the substitution of the mean score has the potential to reduce the within-sample variance. The analyses reported herein were based on the second strategy in which the mean PCC for these 87 participants was used to replace the 8 missing PCC values.

The first step was to derive latent variables from the individual subtest scores, representing speech perception (SAILS modules cat, lake, rat, Sue), articulation (GFTA–2, PCC), PA (RA, OA, OS), and emergent literacy knowledge (AK, CLK, WK). Confirmatory factor analysis revealed that this was an appropriate measurement model: \( \chi^2(73, N = 95) = 34.53, p = .93; \text{CFI} = 1.00; \text{RMSEA} = .00 \).

The path diagram shown in the left panel of Figure 1 was developed to reflect our preferred model as described in the beginning of this article, in which speech perception is the exogenous variable. The standardized regression weights and squared multiple correlations for this model are also shown in Figure 1. The model explains 51% of the variance in PA and 93% of the variance in emergent literacy knowledge. The standardized total effect of speech perception on PA is .62, and the standardized total effect of speech perception on emergent literacy knowledge is .60. The fit statistics indicate an excellent fit to the data: \( \chi^2(61, N = 95) = 47.72, p = .83; \text{CFI} = 1.00; \text{RMSEA} = .00 \). Furthermore, all paths shown are statistically significant, and none of the standardized residual covariances exceed the desired limit of 2.0. If a path is drawn from articulation to PA, the fit of the model is not affected, but this additional path is not statistically significant. Therefore, the proposed model, in which articulation does not have a direct effect on PA, is most consistent with the observed data.

As described in the beginning of this article, some researchers privilege the role of articulatory gestures in the development of both speech perception and PA skills, suggesting that a more appropriate model might place articulation as the exogenous variable (see right side of Figure 1). In this case, 31% of the variance in PA and 88% of the variance in emergent literacy knowledge is explained. This model results in fit statistics that are less satisfactory than those yielded by the preferred model: \( \chi^2(61, N = 95) = 65.73, p = .31; \text{CFI} = .984; \text{RMSEA} = .03 \). The standardized total effect of articulation on PA is only .10, and the standardized total effect of articulation on emergent literacy knowledge is only .05. The path weight from articulation to receptive vocabulary is not statistically significant. This model results in eight standardized residual covariances greater than 2, indicating inaccurate estimation of the actual covariances among the observed variables.

The inadequacy of a model in which the inability to articulate phonemes plays a causal role in a PA deficit is further indicated by a hierarchical multiple regression analysis. This analysis showed that PPVT–III standard scores explained 23% of variance in PA test scores, \( F(1, 93) = 27.4, p < .001 \). SAILS total score explained an additional 7% of variance, a significant improvement over PPVT–III scores alone, \( F(1, 92) = 9.17, p = .003 \). On the other hand, GFTA–2 standard scores did not explain significant additional variance in PA, over and above that explained by PPVT–III standard scores alone, \( R^2 \text{ change} = .01, F(1, 92) = 1.61, p = .207 \).

The preferred model indicates that the primary determinants of PA performance in these children with SSD were speech perception and receptive vocabulary. To illustrate the relationships among these variables, we conducted a k-means cluster analysis on the basis of SAILS, PPVT–III, and PA test scores, resulting in four clusters as shown in Figure 2. Receptive vocabulary (PPVT–III) standard scores are plotted against speech perception (SAILS) scores for each individual by cluster. The figure legend shows the mean PA test score for each cluster. Clusters 3 and 4 achieved a mean PA test score within normal limits, whereas Clusters 1 and 2 scored below normal limits on average. The figure illustrates that the children who achieved the highest PA test scores had either exceptionally high vocabulary test scores or very good speech perception scores. The poorest PA performance was observed for the cluster with the lowest PPVT–III scores and the poorest speech perception performance. The contrast between Clusters 2 and 3 shows that good speech perception performance is the best predictor of PA for children whose vocabulary scores are within the average range. The small overlap between these clusters reflects the fact that some children with average vocabulary and speech perception skills achieved PA test scores that were unexpectedly low, however.

**Discussion**

Ninety-five children with SSD were assessed during the spring of their prekindergarten year when they were 4 or 5 years old, yielding information about their speech perception, articulation, receptive vocabulary, PA, and emergent literacy skills. Linear structural equation modeling was used to describe the relationships between these variables in order to understand the factors that contribute to the risk of poor PA and emergent literacy knowledge in this group. The proposed model was shown to be consistent with the observed data. Emergent literacy knowledge was almost entirely explained by
PA. In turn, PA was predicted by speech perception and receptive vocabulary. Speech perception had both a direct effect on PA and an indirect effect that was mediated by receptive vocabulary. Articulation accuracy did not have a direct effect on PA.

The results show that the emergence of PA in children with SSD is governed by the same variables that account for variations in PA among children with normally developing speech and language skills. Consistent with McBride-Chang’s (1995) research, speech perception emerged as a pivotal variable. The importance of vocabulary skills is fully consistent with results from other studies that have examined the role of language skills (Chaney, 1992, 1994, 1998; Cooper et al., 2002; Dickinson et al., 2003; Lonigan et al., 2000; Speece, Roth, Cooper, & de la Paz, 1999; Storch & Whitehurst, 2002). The findings are also consistent with the results of other studies of children with SSD in that the severity of the speech sound disorder itself did not predict PA abilities (e.g., Larrivee & Catts, 1999).

**Cautions About Linear Structural Equation Modeling**

It is necessary to highlight the limitations of linear structural equation modeling as a means of identifying causal relationships, particularly in this case in which there are not yet longitudinal data. Two difficulties are inherent to this technique. First, the statistical analyses allow one to identify models that are not consistent with the data, but it is never clear that a model that is consistent with the data is in fact the best explanation for the observed effects. The adequacy of any model that appears to fit the observed correlation matrix is entirely dependent on the adequacy of the underlying theory and on convergence with evidence from other sources. Second, any model may be subject to specification errors, such as a failure to include important relevant variables or the inclusion of variables that are not relevant to the model. The way in which these limitations influence the present study will be discussed in turn.

The proposed model was built on the premise that, given a number of variables measured concurrently, the causal relationships among those variables must at least conform to the developmental order in which the relevant skills appear. This is a logically defensible position, but the assumptions that we have made about the relationships among the relevant variables early in life require experimental confirmation and a greater number of longitudinal studies. An increasing number of longitudinal studies have recently described the emergence of PA, emergent literacy, and reading skills during the late preschool period. However, more research with infants is required. Goswami (2003) argued for “the importance
of developmental designs in dyslexia research using a neuroconstructivist framework. According to neuroconstructivism, the lowest level of impairment should be identified as early as possible, and developmental effects on higher-level cognition examined longitudinally” (p. 534). A number of exciting studies of this type are in progress, including a research program that is showing that infants with dyslexic parents process speech stimuli differently than control infants at birth (e.g., Leppanen, Pihko, Eklund, & Lyytinen, 1999) and a research program showing that an infant’s ability to attend to fine phonetic detail in speech is related to vocabulary development (e.g., Werker et al., 2002).

Turning to the possibility of specification errors, certain child and environmental variables that have been found to be important in other studies were not included in the present study. The lack of measures of the child’s literacy environment in the home, preschool, and speech therapy clinic is the most serious concern. Sénéchal and LeFevre (2002) showed that different aspects of the home literacy environment have a significant impact on vocabulary development, PA, and emergent literacy skills. It seems possible that the inclusion of measures of the child’s literacy experiences would have permitted us to understand the unexpectedly poor PA performance of some of the children who demonstrated reasonable vocabulary and speech perception skills (see Cluster 2, Figure 3).

In addition to limitations that are specific to linear structural equation modeling there are limitations that are common to any type of research. The present results may be specific to the way in which the variables were operationalized in this study and to the specific sample of children that was described. Generalizations beyond this sample can be made most confidently after replication of the findings with other samples that may be more or less similar to the original group of children. The present study adds to a number of previous studies that have shown that PA difficulties in the SSD population are not correlated with the severity of the child’s speech impairment (Larrivee & Catts, 1999; Raitano et al., 2004). This study also confirms previous findings that children with SSD are at risk for PA difficulties even when their language skills are within the normal range (Bird et al., 1995; Rvachew et al., 2003). However, none of the previous studies of PA in children with SSD included a measure of speech perception skills, and thus replication and extension of this aspect of our study would be a valuable goal for future research. An effort to test our model with a sample of children with specific language impairment might also be valuable, especially given Joanisse et al.’s (2000) suggestion that speech perception deficits are specific to children who present with dyslexia and a concomitant language disorder.

**Summary and Conclusions**

This study confirms that children with SSD are at significant risk for delayed development of PA skills. Furthermore, a linear structural equation model that fit the data exceptionally well indicated that speech perception and receptive vocabulary skills predicted PA in this population. We feel that further research in which the interaction between the child’s developing perceptual knowledge and the environmental input to the child is monitored from birth is required if we are to gain a deep understanding of the role of speech perception in the emergence of language and literacy skills. The clinical implications that follow directly from this research are that children with SSD should receive assessments of their speech perception, receptive vocabulary, PA, and emergent literacy skills. When PA is delayed, it should be targeted directly by the speech-language pathologist.

**Acknowledgments**

This research was supported by funding from the Canadian Language and Literacy Research Network and the Alberta Children’s Hospital Foundation. We are grateful to the Alberta Children’s Hospital and the Children’s Hospital of Eastern Ontario for helping us to recruit children and for providing us with the space and resources required to conduct the assessments. Many clinicians and students have been involved in this project, some of whom are acknowledged here: Dr. Robin Gaines, Jill Newman, Genevieve Cloutier, Natalia Evans, Joan Heyding, Debbie Hughes, Alyssa Ohberg, Rishanthi Sivakumaran, and Jessica Whitley. Finally, we thank the children and their parents for their participation in and support of this project.

**References**


Studdert-Kennedy, M. (2002). Mirror neurons, vocal imitations, and the evolution of particulate speech. In I. M. S. V. Gallese (Ed.), Mirror neurons and the evolution...


Received December 7, 2004
Revision received March 16, 2005
Accepted June 9, 2005
DOI: 10.1044/1092-4388(2006/006)

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