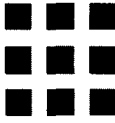




Research



Longitudinal Predictors of Implicit Phonological Awareness Skills

Susan Rvachew

McGill University, Montreal, Quebec, Canada

Purpose: The purpose of this study was to examine the longitudinal predictive relationships among variables that may contribute to poor phonological awareness skills in preschool-age children with speech-sound disorders.

Method: Forty-seven children with speech-sound disorders were assessed during the spring of their prekindergarten year and again at the end of their kindergarten year. Hierarchical multiple regression analysis was used to examine relationships among the children's prekindergarten and kindergarten performance on measures of speech perception, vocabulary, articulation, and phonological awareness skills in order to verify a proposed developmental ordering of these variables during this 1-year period.

Results: Prekindergarten speech perception skills and receptive vocabulary size each

explained unique variance in phonological awareness at the end of kindergarten. Pre-kindergarten articulation abilities did not predict unique variance in phonological awareness a year later. Prekindergarten speech perception skills also explained unique variance in articulation skills at the end of kindergarten.

Conclusions: Maximizing children's vocabulary and speech perception skills before they begin school may be an important strategy for ensuring that children with speech-sound disorders begin school with age-appropriate speech and phonological awareness abilities.

Key Words: speech disorders, speech perception, phonological disorders, articulation, phonological awareness

The identification and treatment of phonological awareness is an important part of pediatric speech-language pathology practice (American Speech-Language-Hearing Association, 2001), in large part because of the direct link between the development of phonological awareness and the acquisition of reading and spelling (Stanovich, 2000). However, phonological awareness is also a fundamental aspect of oral language development. When a child taps out the syllables in a word, or matches pictures of words on the basis of shared rime, or deletes the onset from a word, the child must access underlying phonological representations in the lexicon. The child's performance reflects the child's conscious awareness of the smaller linguistic units from which the phonological representations of words are constructed. Difficulty performing these tasks appears to be a core deficit for many children with dyslexia, specific language impairment, and/or speech-sound disorders (Snowling, Bishop, & Stothard, 2000). Understanding the way in which phonological awareness develops during the preschool period may help us to more effectively facilitate oral language development during this period and prevent literacy problems later in life.

Much recent research has been concerned with identifying the correlates of phonological awareness development in young children (e.g., Lonigan, Burgess, & Anthony, 2000). Three of several known correlates are vocabulary, speech perception, and articulation skills. Each of these variables will be discussed in turn below.

Language ability in general and vocabulary size in particular have consistently been found to be concurrent and longitudinal predictors of phonological awareness (e.g., Chaney, 1992; Cooper, Roth, Speece, & Schatschneider, 2002; Dickinson, McCabe, Anastasopoulos, Peisner-Feinberg, & Poe, 2003; Garlock, Walley, & Metsala, 2001; Metsala, 1999; Metsala & Walley, 1998; Olofsson & Neidersoe, 1999; Walley, Metsala, & Garlock, 2003). The relationship between vocabulary development and phonological awareness emerges at a very young age (Silven, Niemi, & Voeten, 2002). These researchers used a variety of laboratory-based measures of the child's lexical knowledge (at age 1 year), semantic complexity of multiword utterances (at age 2), and phonological awareness (at ages 3 and 4). On the basis of linear structural equation modeling of these data, Silven et al. reported that "children who, as infants, were fast in mapping meanings into word-sized

units, could, 3 years later, direct their attention to common sound patterns in words and more accurately reflect on them" (p. 1149).

Speech perception (sometimes called input phonology) is usually assessed using a forced-choice word identification procedure or a mispronunciation detection task. These phonological processing tasks are distinct from phonological awareness tests in that the child does not have to segment words into smaller units, and performance on these tasks does not reflect the maturity of segmental phonological representations. Rather, speech perception abilities reflect the specificity of the child's acoustic-phonetic representations for words (for a discussion of these levels of representation, see Beckman & Edwards, 2000; Edwards, Fourakis, Beckman, & Fox, 1999; Munson, Edwards, & Beckman, 2005a, 2005b). Speech perception abilities are a strong concurrent correlate of phonological awareness skills (McBride-Chang, 1995; Nittrouer, 1996; Nittrouer & Burton, 2005). It has been suggested that speech perception may be associated with the emergence of rime awareness but not phoneme awareness (Carroll, Snowling, Hulme, & Stevenson, 2003; Foy & Mann, 2001); however, this hypothesis is not supported by other findings (e.g., McBride-Chang, 1995). Even if confirmed, this hypothesis does not negate the importance of speech perception as a potential causal variable, however, because awareness of large units at a younger age is directly related to the emergence of phoneme awareness at later ages (Anthony et al., 2002).

A relationship between phonological awareness and articulation accuracy (sometimes called output phonology) has also been reported for children who do not have speech or language disorders (Carroll et al., 2003; Foy & Mann, 2001). A relationship between articulation skills and phonological awareness is further suggested by the consistent finding that children with speech-sound disorders have significant difficulty with phonological awareness, relative to children who do not have a speech or language impairment (Larrivee & Catts, 1999; Rvachew, Ohberg, Grawburg, & Heyding, 2003; Webster & Plante, 1992).

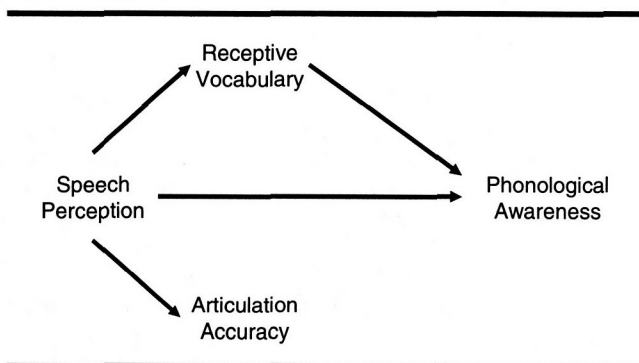
The purpose of the present study was to illuminate the nature of the relationships among these three potential predictor variables (vocabulary, speech perception, and articulation) and the outcome variable (phonological awareness) within the context of a specific population, children with speech-sound disorders. The phonological awareness skills of children with speech-sound disorders are of clinical interest because these children are at risk for delayed development of phonological awareness (Bird, Bishop, & Freeman, 1995; Raitano, Pennington, Tunick, Boada, & Shriberg, 2004; Rvachew et al., 2003; Webster & Plante, 1992; Webster, Plante, & Couvillion, 1997). These difficulties with phonological awareness are associated with poorer reading skills for children with speech-sound disorders in comparison with children with typically developing speech and language skills, especially if the speech-sound disorder is persistent and/or associated with a concomitant language disorder (Larrivee & Catts, 1999; Nathan, Stackhouse, Goulandris, & Snowling, 2004). These children form an interesting group from the research per-

spective because the vocabulary, speech perception, and articulation skills of these children vary more widely than in children with average speech and language skills. For example, we have observed (e.g., Rvachew et al., 2003) that the range of error scores on a standardized test of articulation accuracy can be three times greater for 4-year-olds with speech-sound disorders than for 4-year-olds with typical speech development. Furthermore, ability levels across these three variables are dissociable among children with speech-sound disorders. In other words, typical children by definition produce few speech perception or production errors. Children who produce many speech production errors can have very good speech perception abilities but often demonstrate chance-level or below-chance-level responding on a speech perception task. The distribution of vocabulary, speech perception, and articulation test scores among this population supports the use of regression analyses and modeling techniques for understanding the potential causal relationships among these variables.

Understanding the nature of the relationships among these variables should help us to design effective programs for remediating speech and language delays during the preschool period and preventing delayed emergence of phonological awareness skills. The literature, as it stands, is not fully helpful in this regard. For example, the well-established correlation between vocabulary size and phonological awareness might imply that interventions designed to increase vocabulary knowledge will ensure age-appropriate phonological awareness skills. However, this is a problematic assumption, particularly in the current context because many children with speech-sound disorders (and all of the children described in this report) demonstrate average or better vocabulary skills. Furthermore, children with speech-sound disorders show poor phonological awareness relative to children without speech delay even when differences in vocabulary size are controlled through matching of subjects (Rvachew et al., 2003). Therefore, preschool intervention programs may have to target other skills that are associated with phonological awareness and/or vocabulary development in order to be effective. For example, if weak vocabulary knowledge is caused by deficiencies in speech perception skills, it may be necessary to target both speech perception and vocabulary when the goal is ensuring optimal language development and preventing delayed emergence of phonological awareness. If the child has poor phonological awareness skills despite good vocabulary knowledge, it may be more efficacious to target speech perception skills than vocabulary size itself. Similarly, the correlation between articulation skills and delayed phonological awareness suggests that effective treatment of the articulation problem will have a beneficial effect on phonological awareness, but this may not be the case if the relationship between articulation and phonological awareness is mediated by another variable such as speech perception skills.

In an effort to better understand the nature of the relationships among these variables, Rvachew and Grawburg (2006) described the performance of 95 preschool-age children with speech-sound disorders on multiple measures of articulation accuracy, speech perception, language, and

FIGURE 1. A proposed model of concurrent relationships among speech perception, receptive vocabulary, articulation, and phonological awareness skills, adapted from a linear structural equation model of test scores obtained from 5-year-old children with speech-sound disorders, described in Rvachew and Grawburg (2006).



phonological awareness. A linear structural equation model was developed to test hypothesized relationships among these variables, as shown in Figure 1. This model was found to have excellent fit to the data. The model suggests that speech perception has a direct effect on the development of phonological awareness as well as an indirect effect that occurs because speech perception skills support vocabulary learning, which in turn supports the emergence of phonological awareness. According to the model, there is no direct effect of articulation on phonological awareness. These findings must be interpreted with caution, however, because the results are based on concurrent relationships. Furthermore, ordering of the variables within the model was based on assumed developmental order of emergence, with speech perception showing substantial development during the 1st year of life, vocabulary knowledge and articulation skills emerging during the 2nd year, and phonological awareness not evident much before the 4th year. Longitudinal data are required to confirm the proposed developmental links.

All of the hypothesized relationships shown in Figure 1 are a matter of current debate. Some researchers propose that speech perception development during the 1st year supports later word learning (Werker & Curtin, 2005), while others assume that perceptual learning during the 1st year is not relevant to vocabulary development during the 2nd year (Brown & Matthews, 1997). Some developmental models propose that prior acquisition of perceptual knowledge about acoustic-phonetic categories is necessary for articulatory learning (Callan, Kent, Guenther, & Vorperian, 2000), whereas other hypotheses posit that articulation drives perceptual learning (Studdert-Kennedy, 1987, 2002; Vihman & Nakai, 2003). Similarly, phonological awareness is seen as emerging from speech perception by some theorists (Manis et al., 1997) and from speech production by others (Fowler, 1991).

Longitudinal data will provide better support for the hypothesized relationships than the concurrent data reported in Rvachew and Grawburg (2006). For example, a concurrent correlation among speech perception and phonological awareness does not indicate whether speech perception skills will lead to improvements in phonological awareness. Nei-

ther does the concurrent correlation help the clinician decide whether it is advisable to include a speech perception intervention in a treatment program designed to facilitate the emergence of phonological awareness. However, if it can be shown that speech perception skills contribute to growth in phonological awareness skills over time, a stronger basis for perceptually based approaches to intervention is provided. Such a finding would support efforts to further test the hypothesis that these variables are causally related through experimental manipulations in future studies.

For the present study, kindergarten performance on tests of speech perception, vocabulary, articulation, and phonological awareness was obtained from a subset of the children described as preschoolers in Rvachew and Grawburg (2006). Hierarchical multiple regression analyses were used to identify the direction of effect between each pair of variables shown in Figure 1. Subsequently, this model was amended to reflect the best prekindergarten predictors of phonological awareness skills at the end of the kindergarten year, as revealed by the multiple regression analyses.

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 a speech-sound disorder 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 speech delay 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) prior to referral to the study, and (d) native speaker of English. Children whose speech-sound disorder was secondary to other conditions such as sensory-neural hearing loss, Down syndrome, cerebral palsy, or cleft palate were excluded.

The parents of 66 children volunteered their children for participation in this longitudinal study. Sixty-one of these children successfully completed all of the assessment procedures in the prekindergarten year. Forty-seven children returned for the follow-up assessment at the end of the kindergarten year (6 children were lost to follow-up during this interval, and 8 children were enrolled in another study involving a phonological awareness intervention that was administered after the prekindergarten assessment but before the kindergarten follow-up).

This report describes the performance of the 47 children who completed both assessments. During the prekindergarten assessment, their mean age was 57.53 months ($SD = 3.8$ months), with the youngest being 48 months and the oldest being 67 months. During the kindergarten assessment, their mean age was 69.77 months ($SD = 4.11$ months), ranging from 61 to 79 months. There were 28 boys and 19 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 31 (high school not completed) to 101 (professional credentials), with a mean of 54 (some postsecondary education).

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 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, and phonological awareness skills. (A speech sample was also recorded at the end of the test session, but the analyses of these samples will not be discussed in this report.) These tests were administered for the first time during the spring or early summer of the child's prekindergarten year and again during the spring or early summer of the child's kindergarten year.

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.

Speech perception. Speech perception was assessed using the Speech Assessment and Interactive Learning System (SAILS; AVAAZ Innovations, 1994), 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 Bird et al. (1995) phonological awareness test (PAT) was administered to all participants. 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." The child was then told, "Dan likes things that sound like his name" and was asked which thing Dan 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 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 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 rime awareness, 10 onset awareness, and 10 onset segmentation), involving the target rimes /æɪn, 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.

Data analysis. The data analysis was directed at testing the plausibility of the hypothesized relationships among variables, as shown in Figure 1. For example, it was hypothesized that speech perception contributes to the development of articulation skills, or more specifically, speech perception is proposed as a necessary (although not sufficient) cause of articulation ability. If this hypothesis is true, speech perception development must precede the acquisition of articulation accuracy in time. Hierarchical multiple regression analysis was used to identify the most likely developmental order among each pair of variables. This analysis allows one to determine the relationship between pre-kindergarten speech perception and kindergarten articulation, after first partialing out the variance in kindergarten articulation that is explained by prekindergarten articulation. In other words, this analysis is a means of asking whether speech perception skills prior to kindergarten entry explain some of the growth in articulation skills during the kindergarten year that is not explained by the child's level of articulation ability prior to kindergarten. If speech perception skills at the prekindergarten assessment are correlated with changes in articulation accuracy between the pre-kindergarten and the kindergarten assessments, after controlling for prekindergarten articulation, the hypothesis that speech perception causes articulation is plausible (proof of the hypothesized causal relation requires experimental confirmation, as will be discussed in more detail below).

TABLE 1. Participant age and test scores during the prekindergarten and kindergarten assessments.

Variable	Prekindergarten		Kindergarten	
	M	SD	M	SD
Age (months)	57.53	3.80	69.77	4.11
Speech perception (SAILS percentage correct)	68.88	13.09	81.83	5.12
Receptive vocabulary (PPVT-III standard score)	108.34	11.36	110.79	10.31
Receptive vocabulary (PPVT-III raw score)	72.40	14.32	91.62	14.53
Articulation (GFTA-2 percentile)	11.69	13.86	19.21	20.02
Articulation (number of errors on the GFTA-2)	35.79	14.67	18.68	12.15
Phonological awareness (PAT raw score)	17.00	6.40	27.17	5.27

Note. SAILS = Speech Assessment and Interactive Learning System; PPVT-III = Peabody Picture Vocabulary Test-III; GFTA-2 = Goldman Fristoe Test of Articulation-Second Edition; PAT = Bird et al. (1995) phonological awareness test.

As described in the introduction, other researchers would hypothesize that articulation skills lead speech perception development. Therefore, this alternative explanation was tested by determining the correlation between prekindergarten articulation and kindergarten speech perception, after first controlling for variation in kindergarten speech perception that is explained by speech perception skills prior to kindergarten entry.

This analysis was repeated for each relationship hypothesized in Figure 1 in order to identify those pre-kindergarten variables that are plausible causes of phonological awareness skills at the end of kindergarten. Subsequent to these analyses, a model of the relationship between speech perception, receptive vocabulary, and articulation skills prior to kindergarten, and phonological awareness skills at the end of kindergarten, was developed.

Results

The means and standard deviations for the children's scores on each of the tests administered is shown in Table 1,

specifically SAILS percentage correct, PPVT-III standard score, PPVT-III raw score, GFTA-2 percentile, GFTA-2 raw score, and number of correct responses out of 34 on the PAT. During the prekindergarten and kindergarten assessments, all children obtained a PPVT-III score that was average or greater (i.e., a standard score of 85 or greater). The percentage of children scoring below normal limits on the GFTA-2 was 79% and 62% during the prekindergarten and kindergarten assessments, respectively.

All remaining analyses involve SAILS percentage correct and raw scores on the PPVT-III, GFTA-2, and PAT. The correlations among these variables are shown above the diagonal in Table 2. In these analyses, SAILS percentage correct score corresponds to the speech perception variable, PPVT-III raw score corresponds to the receptive vocabulary variable, number of errors on the GFTA-2 corresponds to the articulation variable, and number of correct responses on the PAT corresponds to the phonological awareness variable.

Identifying Direction of Effect Between Variables

Table 3 shows the results of the analyses that assessed the developmental relationship between the variable pairs speech perception and receptive vocabulary, speech perception and articulation, receptive vocabulary and phonological awareness, articulation and phonological awareness, and speech perception and phonological awareness. Two analyses were conducted for each pair of variables. In one analysis, the dependent variable was the first variable in kindergarten and the predictors were the first variable in prekindergarten followed by the second variable in pre-kindergarten. If the second variable was associated with a significant change in explained variance, the second variable in the pair accounts for some amount of developmental change in the first variable. Then, in another analysis, the order of the variable pairs was reversed so that the second variable in kindergarten was the dependent variable and the predictors were the second variable in prekindergarten followed by the first variable in prekindergarten.

The first two analyses shown in Table 3 are concerned with the relationship between speech perception and receptive vocabulary. Prekindergarten speech perception explains 21% of variance in kindergarten speech perception,

TABLE 2. Correlations among measures of speech perception (SAILS), receptive vocabulary (PPVT-III), articulation (GFTA-2), and phonological awareness (PAT) skills during the prekindergarten (PK) and kindergarten (K) assessments.

Variable	1	2	3	4	5	6	7	8
1. SAILS PK	—	.49*	-.33	.44	.45*	.40	-.47*	.52*
2. PPVT-III PK		—	-.18	.50*	.32	.75*	-.35	.52*
3. GFTA-2 PK			—	-.45*	-.36	-.06	.65*	-.38
4. PAT PK				—	.57*	.36	-.40	.50*
5. SAILS K					—	.14	-.41	.39
6. PPVT-III K						—	-.29	.52*
7. GFTA-2 K							—	-.54*
8. PAT K								—

*Pearson correlation coefficients associated with $p < .002$, two-tailed.

TABLE 3. Results of hierarchical multiple regression analyses conducted to identify predictive relationships among pairs of variables from the prekindergarten to the kindergarten year.

Dependent variable	Independent variable	R^2	ΔR^2	ΔF	p
Speech perception (SAILS) versus receptive vocabulary (PPVT-III)					
SAILS K	SAILS PK	.207	.207	11.73	.001
	PPVT-III PK	.219	.012	00.69	.410
PPVT-III K	PPVT-III PK	.564	.564	58.32	.000
	SAILS PK	.566	.002	0.20	.660
Speech perception (SAILS) versus articulation (GFTA-2)					
SAILS K	SAILS PK	.207	.207	11.73	.001
	GFTA-2 PK	.254	.048	2.81	.101
GFTA-2 K	GFTA-2 PK	.428	.428	33.64	.000
	SAILS PK	.503	.075	6.65	.013
Receptive vocabulary (PPVT-III) versus phonological awareness (PAT)					
PPVT-III K	PPVT-III PK	.564	.564	58.32	.000
	PAT PK	.565	.000	0.03	.870
PAT K	PAT PK	.249	.249	14.90	.000
	PPVT-III PK	.349	.100	6.78	.013
Articulation (GFTA-2) versus phonological awareness (PAT)					
GFTA-2 K	GFTA-2 PK	.428	.428	33.64	.000
	PAT PK	.443	.015	1.17	.285
PAT K	PAT PK	.249	.249	14.90	.000
	GFTA-2 PK	.278	.030	1.81	.185
Speech perception (SAILS) versus phonological awareness (PAT)					
SAILS K	SAILS PK	.207	.207	11.73	.001
	PAT PK	.373	.166	11.67	.001
PAT K	PAT PK	.249	.249	14.90	.000
	SAILS PK	.363	.114	7.88	.007

a significant amount as would be expected. Prekindergarten receptive vocabulary explains an additional 1% of variance in kindergarten speech perception skills, an amount that is statistically insignificant. The reverse analysis shows that prekindergarten speech perception does not explain growth in receptive vocabulary skills between the prekindergarten and kindergarten assessments either, after controlling for prekindergarten receptive vocabulary. This finding was contrary to expectations. Although these variables are correlated with each other (see Table 2), one does not appear to explain change in the other during this time period.

The next set of analyses show that articulation skills prior to kindergarten did not predict unique variance in speech perception skills at the end of kindergarten, after controlling for prekindergarten speech perception skills. On the other hand, speech perception skills prior to kindergarten predicted about 8% of variance in articulation skills at the end of kindergarten, after controlling for articulation skills prior to kindergarten. These results suggest that speech perception leads growth in articulation skills in developmental time, as hypothesized.

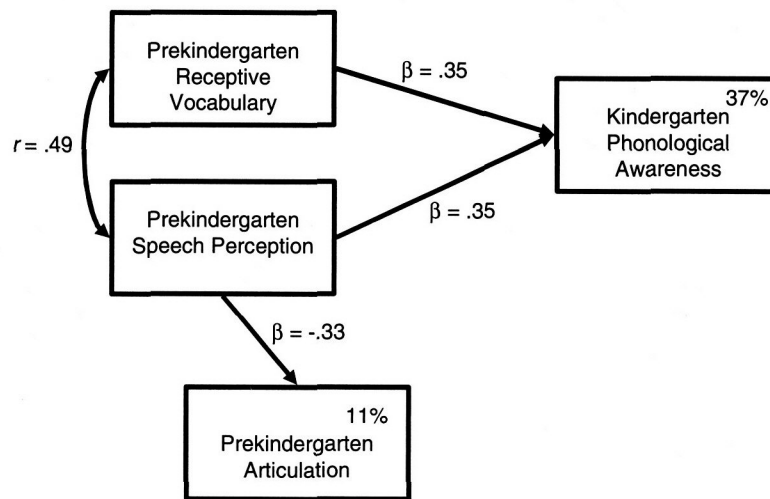
The analyses involving receptive vocabulary and phonological awareness show that phonological awareness prior to kindergarten was not related to growth in receptive vocabulary knowledge during the kindergarten year. Receptive vocabulary prior to kindergarten explained

about 10% of variance in phonological awareness at the end of kindergarten, after controlling for prekindergarten phonological awareness. The predicted relationship from vocabulary size to phonological awareness skills was therefore supported.

Phonological awareness skills prior to kindergarten did not predict significant unique variance in articulation skills at the end of kindergarten, after controlling for prekindergarten articulation skills. Neither did articulation accuracy prior to kindergarten predict significant unique variance in phonological awareness at the end of kindergarten, over and above that explained by prekindergarten phonological awareness performance. Therefore, there appears to be no direct relationship between these variables, as predicted.

The final set of analyses indicated that phonological awareness prior to kindergarten accounted for 17% of variance in speech perception skills at the end of kindergarten after controlling for phonological awareness prior to kindergarten. At the same time, speech perception skills prior to kindergarten explained 11% of variance in phonological awareness skills at the end of kindergarten after taking prekindergarten speech perception into account. Thus, a reciprocal relationship between speech perception and phonological awareness during the prekindergarten assessment and speech perception and phonological awareness during the kindergarten assessment is suggested.

FIGURE 2. Observed longitudinal relationships among speech perception, receptive vocabulary, and articulation, when measured prior to kindergarten entry, and phonological awareness, measured at the end of the kindergarten year.



Prekindergarten Predictors of Kindergarten Phonological Awareness

The analysis described above leads to the conclusion that the predicted relationships shown in Figure 1 should be amended slightly as shown in Figure 2. Figures 1 and 2 are similar except that a curved arrow between speech perception and receptive vocabulary in Figure 2 replaces the one-way straight arrow shown in Figure 1. The curved arrow indicates that these two variables are correlated but that a causal relationship between the two has not been established.

The model shown in Figure 2 reflects the predictive relationships between speech perception, receptive vocabulary, and articulation skills prior to kindergarten and phonological awareness at the end of kindergarten (PAT K), as revealed by the analyses reported above. Prekindergarten speech perception and prekindergarten receptive vocabulary are shown as correlated predictors ($r = .49$, derived from the simple correlations shown in Table 2). Multiple regression analysis shows that, together, these two variables explain 37% of variance in kindergarten phonological awareness, $F(2, 44) = 12.8, p = .000$. Prekindergarten speech perception explains 11% of variance in prekindergarten articulation, $F(1, 45) = 5.49, p = .024$ (see the simple correlation of $-.33$, shown in Table 2, which when squared yields .11). However, prekindergarten articulation does not explain any additional variance in kindergarten phonological awareness, over and above the 37% that is explained by speech perception and receptive vocabulary performance prior to kindergarten entry.

In summary, these sets of analyses revealed the following relationships: (a) speech perception and receptive vocabulary were correlated, but the exact nature of this relationship is not clear; (b) together, prekindergarten speech perception and receptive vocabulary explain significant variance in phonological awareness in kindergarten, as well as significant variance in the growth of phonological awareness

skills over this 1-year period; (c) there is also a reciprocal relationship between speech perception and phonological awareness at least during the kindergarten year; (d) prekindergarten speech perception explains variance in kindergarten articulation skills and explains variance in improvements in articulation accuracy during this 1-year period; and (e) despite a significant concurrent correlation between prekindergarten articulation and phonological awareness skills, prekindergarten articulation does not explain variance in the growth of phonological awareness abilities during the kindergarten year.

Discussion

One goal of providing speech and language services to young children should be to ensure that children begin school with a good foundation for academic success. This includes maximizing the child's speech and language development and promoting the emergence of age-appropriate early literacy skills. However, it may be difficult for speech-language pathologists who are working with preschool-age children to address phonological awareness directly in all of their treatment programs. The child may be so young that phonological awareness activities are not developmentally appropriate. The speech or language problem may be so severe that diverting resources from speech and language therapy to phonological awareness activities may not be advisable. However, the results of this study suggest that a comprehensive approach to the child's oral language abilities may lead naturally to improvements in the child's phonological awareness skills.

Figure 2 illustrates the linkages between the variables explored in this study. Receptive vocabulary skills were directly linked to improvements in phonological awareness. Speech perception skills were associated with improvements in both phonological awareness and articulation accuracy.

Articulation skills were not directly linked to improvements in phonological awareness, however. The clinical implications of these relationships will be discussed in turn below.

Vocabulary

A direct link between receptive vocabulary and phonological awareness was observed even though the children in this study all presented with PPVT-III scores that were within the average range. Concurrent and longitudinal correlations between vocabulary knowledge and phonological awareness are a consistent and frequent research finding (e.g., Chaney, 1992; Cooper et al., 2002; Dickinson et al., 2003; Garlock et al., 2001; Metsala, 1999; Metsala & Walley, 1998; Olofsson & Neidersoe, 1999; Walley et al., 2003). Experimental studies that examine the specific impact of vocabulary interventions with young children on the later emergence of phonological awareness would help to confirm that there is indeed a causal relationship between growth in the size of the lexicon and the emergence of phonological awareness skills.

Maximizing children's vocabulary development is important for the development of decoding abilities and later reading comprehension (Snowling et al., 2000; Storch & Whitehurst, 2002). Dialogic reading and focused stimulation procedures have been shown to be effective strategies for improving children's vocabulary knowledge. For example, Lonigan and Whitehurst (1998) taught parents and child care workers to use dialogic reading techniques with 3- and 4-year-old children from low-income homes who were enrolled in Head Start programs. Dialogic reading is an interactive style of reading that involves asking the child increasingly sophisticated questions about story material. Readers are also taught to repeat or expand on the child's answers and to promote a turn-taking style of interaction with the child during storybook reading. Significant positive impacts of this intervention were observed for measures of receptive and expressive language skills after 6 weeks, in comparison with a control group that did not experience this intervention at home or at their child care centers. This intervention also has a positive impact on children's narrative skills (Zevenbergena, Whitehurst, & Zevenbergenc, 2003). Promoting the use of these techniques by parents and child care workers could be an effective strategy for improving language skills and promoting the emergence of early literacy skills (Girolametto, Pearce, & Weitzman, 1996; Girolametto, Weitzman, & Greenberg, 2003).

Speech Perception

The results of the present study suggest that there may be a causal relationship from speech perception skills to phonological awareness, but this hypothesis has not yet been experimentally confirmed with intervention studies. Certainly, many programs for teaching phonological awareness have been found to be effective even though these programs do not have a specific focus on speech perception abilities (Ehri et al., 2001). The replicated findings of a correlation between speech perception and phonological awareness

among children with average language skills (e.g., McBride-Chang, 1995), children with specific language impairment (e.g., Joannis, Manis, Keating, & Seidenberg, 2000), and children with speech-sound disorders (e.g., Rvachew & Grawburg, 2006) suggests that speech perception interventions could enhance the effectiveness of phonological awareness interventions. In a nonexperimental study, children who received a program that focused on speech perception, rime matching, and onset matching activities resulted in age-appropriate phonological awareness skills in children with speech-sound disorders after only 8 weeks (Grawburg & Rvachew, 2006). Randomized control trials with appropriate control conditions are required to test this hypothesis specifically.

The findings of this study also support the hypothesis that speech perception development may be causally related to articulation accuracy. These results suggest that a speech perception intervention should improve the success of interventions designed to improve articulation accuracy, and in fact, this has been verified in experimental studies. For example, Rvachew (1994) showed that articulation therapy alone did not lead to improvements in either perception or production of an unstimulable target sound. However, a speech perception intervention improved both speech perception skills and the child's response to articulation therapy. In an earlier study (Jamieson & Rvachew, 1992), it was shown that a speech perception intervention alone resulted in changes in articulation accuracy for a stimulable phoneme, even when no articulation therapy was provided. In a more recent randomized clinical trial, a speech perception intervention in which children were taught to identify correctly and incorrectly pronounced words containing one of eight difficult consonant phonemes (SAILS; AVAAZ Innovations) was added to the children's regular speech therapy program. Children who received the SAILS intervention made twice as much progress toward improved articulatory accuracy than did children who received their regular speech therapy program without the addition of this speech perception intervention (Rvachew, Nowak, & Cloutier, 2004). A 1-year follow-up of children who received this experimental intervention revealed that 50% of them achieved age-appropriate articulation accuracy before first grade, while only 19% of the children in the control condition started Grade 1 with age-appropriate speech.

Articulation

In this study, articulation accuracy was not directly related to improvements in phonological awareness skills. The lack of a direct relationship between articulation and phonological awareness has also received support from experimental studies. Wise, Ring, and Olsen (1999) compared different approaches to teaching phonological awareness to older children with reading difficulties. One approach promoted the children's awareness of the articulatory movements that are used to produce different sounds and taught them to associate specific articulatory gestures with letters. Another approach involved representing sounds in words with markers and learning to delete, add, or switch sounds within words. Some children received an intervention that combined

both approaches. They found that articulation awareness activities offered no unique benefits in terms of phonological awareness and reading outcomes. Castiglioni-Spalten and Ehri (2003) conducted a similar comparison with kindergarten children and also did not find any advantage in the articulation awareness approach for several measures of phonological awareness and spelling. Nor was there any group difference for reading words accurately, although an advantage to the "mouth training" group over the "ear training" group was reported for a post hoc analysis in which incorrect readings of words were scored as correct under certain conditions. No experimental investigations of this type have been conducted with children with speech-sound disorders, so this is a possible direction for future research.

This study confirmed that articulation accuracy prior to kindergarten does not explain unique variance in phonological awareness at the end of kindergarten, after controlling for prekindergarten vocabulary size and speech perception skills. However, persistence of speech delay into the school-age period has been identified as a risk factor for problems with phonological awareness and reading acquisition (Nathan et al., 2004; Raitano et al., 2004). Ensuring that children begin school with age-appropriate articulation skills has implications for social and academic success later in life. The results of this study confirm that speech perception abilities are important to the acquisition of articulation accuracy, a finding that was not unexpected given the results of previous experimental studies.

It may seem strange to conclude that there is no direct relationship between articulation abilities and the development of phonological awareness even though significant concurrent correlations between these variables were observed, and other studies have shown that children with poor articulation skills tend to have difficulties with phonological awareness. The explanation lies in the observed linkage between speech perception and phonological awareness. These results are strongly suggestive of a direct, causal link between speech perception and phonological awareness. These results further suggest that the phonological awareness difficulties experienced by children with speech-sound disorders occur because these children are very likely to have difficulties with speech perception (Broen, Strange, Doyle, & Heller, 1983; Edwards, Fox, & Rogers, 2002; Rvachew & Jamieson, 1989). This proposed causal relationship requires experimental confirmation with intervention studies. Recently, we attempted just such a randomized control trial, but the speech perception intervention did not lead to superior growth in phonological awareness skills over a 6-month period, relative to the growth in phonological awareness skills that was observed during the same period in a control group (Rvachew et al., 2004). Unfortunately, however, the control condition targeted vocabulary knowledge and verbal reasoning. It is possible that both interventions were equally effective because vocabulary size is correlated with phonological awareness. Further investigation with a more appropriate control condition is required to test the hypothesis that improving children's speech perception skills will facilitate improvements in their phonological awareness skills.

Phonological Awareness

As discussed above, attention to children's oral language, speech perception, and articulation skills should lead naturally to the emergence of phonological awareness skills. This is not to say, however, that direct teaching of phonological awareness is not advisable for children with speech-sound disorders. Notice that, in this study, prekindergarten phonological awareness explained only 25% of variance in kindergarten phonological awareness. Prekindergarten speech perception and vocabulary skills also contributed to growth in phonological awareness skills during the kindergarten year, but no combination of variables examined in this study explained more than 37% of variance in kindergarten phonological awareness. An important variable not assessed in this study was the children's access to explicit teaching of phonological awareness and emergent literacy skills by their parents, speech-language pathologists, or kindergarten teachers. Most likely these experiences accounted for the greatest amount of growth in prereading abilities during the kindergarten period.

Given that the children are experiencing delays in their oral language and phonological abilities, the improvement in phonological awareness skills that may emerge from appropriate speech and language interventions may not be fast enough to ensure age-appropriate phonological awareness abilities before the onset of formal reading instruction. As reported elsewhere, about one third of the children enrolled in this study began first grade with phonological awareness skills that were below the average range, despite having access to speech-language therapy prior to school entry (Rvachew, Chiang, & Evans, 2006). There is good reason to fear that delaying the onset of phonological awareness intervention until after the onset of reading instruction may have harmful long-term effects on reading abilities (Harm, McCandliss, & Seidenberg, 2003). Furthermore, it has been shown that access to specific instruction from parents about sounds and sound-letter relationships has a beneficial effect on the acquisition of reading over and above the benefits of exposure to storybook reading (Senechal & LeFevre, 2002).

A number of nonexperimental studies have demonstrated the successful application of explicit phonological awareness interventions for children with speech-sound disorders. Major and Bernhardt (1998) combined a nonlinear phonology approach to the remediation of preschoolers' speech-sound disorders with a metaphonological intervention that targeted rhyming and alliteration skills. Follow-up assessments 3 years later revealed good speech outcomes for 7 of 12 children and good literacy outcomes for 10 of 12 children (Bernhardt & Major, 2005). Gillon (2000) described an intensive phonological awareness intervention that led to greater improvements in phonological awareness and reading skills than traditional speech-language therapy approaches. More recently, Gillon (2005) has shown that phonological awareness and speech intelligibility can be simultaneously improved in children with speech-sound disorders even when they are as young as 3 years. Hesketh, Adams, Nightingale, and Hall (2000) successfully integrated phonological awareness activities with activities designed to

eliminate phonological processes. However, they reported that this program was not more effective for the improvement of phonological awareness skills than articulation therapy alone. Their study highlights the urgent need for randomized clinical trials that explore different combinations of procedures in order to isolate the most effective and efficient practices to use with children who are at risk for literacy problems as a consequence of speech and language delays.

Conclusions

This study found that speech perception and vocabulary skills in 4-year-olds are associated with the development of phonological awareness abilities during the kindergarten year. The findings emphasize the importance of addressing speech perception and vocabulary skills alongside effective remediation of speech production deficits. The findings also point to gaps in our knowledge that require further research. In particular, replication of these findings with another sample of children with speech-sound disorders would be valuable, especially given the small size of the current sample. Furthermore, there is an urgent need for randomized clinical studies of different approaches to the treatment of phonological awareness delays. Notwithstanding this need for further research, this study highlights the potential that speech-language pathologists have for preventing literacy deficits and other academic delays by maximizing children's oral language development during the preschool period.

Acknowledgments

This study was supported by a grant from the Canadian Language and Literacy Research Network. We are also grateful for the support of the Speech-Language Departments of the Alberta Children's Hospital and the Children's Hospital of Eastern Ontario, and we thank Ms. Jill Newman and Dr. Robin Gaines in particular for their assistance with subject recruitment. Thanks are also extended to the participants and their parents for their time and cooperation in this study. The many students involved in the collection and processing of data are also acknowledged, in particular Genevieve Cloutier, Natalia Evans, Meghann Grawburg, Joan Heyding, Debbie Hughes, Alyssa Ohberg, Alysha Serviss, Rishanthi Sivakumaran, and Jessica Whitely.

References

- American Speech-Language-Hearing Association.** (2001). Roles and responsibilities of speech-language pathologists with respect to reading and writing in children and adolescents. *ASHA Supplement*, 21, 17–28.
- Anthony, J. L., Lonigan, C. J., Burgess, S. R., Driscoll, K., Phillips, B. M., & Cantor, B. G.** (2002). Structure of preschool phonological sensitivity: Overlapping sensitivity to rhyme, words, syllables, and phonemes. *Journal of Experimental Child Psychology*, 82, 65–92.
- AVAAZ Innovations.** (1994). *Speech Assessment and Interactive Learning System (Version 1.2)* [Computer software]. London, Ontario, Canada: Author.
- Beckman, M. E., & Edwards, J.** (2000). The ontogeny of phonological categories and the primacy of lexical learning in linguistic development. *Child Development*, 71, 240–249.
- Bernhardt, B., & Major, E. M.** (2005). Speech, language and literacy skills three years later: A follow-up study of early phonological and metaphonological intervention. *International Journal of Language and Communication Disorders*, 40, 1–27.
- Bird, J., Bishop, D. V. M., & Freeman, N. H.** (1995). Phonological awareness and literacy development in children with expressive phonological impairments. *Journal of Speech and Hearing Research*, 38, 446–462.
- Blishen, B. R., Carroll, W. K., & Moore, C.** (1987). The 1981 Socioeconomic Index for Occupations in Canada. *Canadian Review of Sociology and Anthropology*, 24, 465–487.
- Broen, P. A., Strange, W., Doyle, S. S., & Heller, J. H.** (1983). Perception and production of approximant consonants by normal and articulation-delayed preschool children. *Journal of Speech and Hearing Research*, 26, 601–608.
- Brown, C., & Matthews, J.** (1997). The role of feature geometry in the development of phonemic contrasts. In S. J. H. M. Young-Scholten (Ed.), *Focus on phonological acquisition* (pp. 67–112). Amsterdam: Benjamins.
- Callan, D. E., Kent, R. D., Guenther, F. H., & Vorperian, H. K.** (2000). An auditory-feedback-based neural network model of speech production that is robust to developmental changes in the size and shape of the articulatory system. *Journal of Speech, Language, and Hearing Research*, 43, 721–738.
- Carroll, J. M., Snowling, M. J., Hulme, C., & Stevenson, J.** (2003). The development of phonological awareness in preschool children. *Developmental Psychology*, 39, 913–923.
- Castiglioni-Spalten, M. L., & Ehri, L. C.** (2003). Phonemic awareness instruction: Contribution of articulatory segmentation to novice beginners' reading and spelling. *Scientific Studies of Reading*, 7, 25–52.
- Chaney, C.** (1992). Language development, metalinguistic skills, and print knowledge in 3-year-old children. *Applied Psycholinguistics*, 13, 485–514.
- Cooper, D. H., Roth, F. P., Speece, D. L., & Schatschneider, C.** (2002). The contribution of oral language skills to the development of phonological awareness. *Applied Psycholinguistics*, 23, 399–416.
- Dickinson, D. K., McCabe, A., Anastasopoulos, L., Peisner-Feinberg, E. S., & Poe, M.** (2003). The comprehensive language approach to early literacy: The interrelationships among vocabulary, phonological sensitivity, and print knowledge among preschool-aged children. *Journal of Educational Psychology*, 95, 465–481.
- Dunn, L. M., & Dunn, L. M.** (1997). *Peabody Picture Vocabulary Test—III*. Circle Pines, MN: AGS.
- Edwards, J., Fourakis, M., Beckman, M. E., & Fox, R. A.** (1999). Characterizing knowledge deficits in phonological disorders. *Journal of Speech, Language, and Hearing Research*, 42, 169–186.
- Edwards, J., Fox, R. A., & Rogers, C. L.** (2002). Final consonant discrimination in children: Effects of phonological disorder, vocabulary size, and articulatory accuracy. *Journal of Speech, Language, and Hearing Research*, 45, 231–242.
- Ehri, L. C., Nunes, S. R., Willows, D. M., Schuster, B. V., Yaghoub-Zadeh, Z., & Shanahan, T.** (2001). Phonemic awareness instruction helps children learn to read: Evidence from the national reading panel's meta-analysis. *Reading Research Quarterly*, 36, 250–287.
- Fowler, A. E.** (1991). How early phonological development might set the stage for phoneme awareness. *Haskins Laboratories Status Report on Speech Research*, SR-105/106, 53–64.
- Foy, J. G., & Mann, V.** (2001). Does strength of phonological representations predict phonological awareness in preschool children? *Applied Psycholinguistics*, 22, 301–325.

- Garlock, V. M., Walley, A. C., & Metsala, J. L. (2001). Age-of-acquisition, word frequency, and neighborhood density effects on spoken word recognition by children and adults. *Journal of Memory and Language*, 45, 468–492.
- Gillon, G. T. (2000). The efficacy of phonological awareness intervention for children with spoken language impairment. *Language, Speech, and Hearing Services in Schools*, 31, 126–141.
- Gillon, G. T. (2005). Facilitating phoneme awareness development in 3- and 4-year-old children with speech impairment. *Language, Speech, and Hearing Services in Schools*, 36, 308–324.
- Girolametto, L., Pearce, P. S., & Weitzman, E. (1996). Interactive focused stimulation for toddlers with expressive language delays. *Journal of Speech and Hearing Research*, 39, 1274–1283.
- Girolametto, L., Weitzman, E., & Greenberg, J. (2003). Training day care staff to facilitate children's language. *American Journal of Speech-Language Pathology*, 12, 299–311.
- Goldman, R., & Fristoe, M. (2000). *Goldman-Fristoe Test of Articulation—Second Edition*. Circle Pines, MN: AGS.
- Grawburg, M., & Rvachew, S. (2006). *Phonological awareness intervention for children with speech sound disorders*. Manuscript submitted for publication.
- Harm, M. W., McCandliss, B. D., & Seidenberg, M. S. (2003). Modeling the successes and failures of interventions for disabled readers. *Scientific Studies in Reading*, 7, 155–182.
- Hesketh, A., Adams, C., Nightingale, C., & Hall, R. (2000). Phonological awareness therapy and articulatory training approaches for children with phonological disorders: A comparative outcome study. *International Journal of Language and Communication Disorders*, 35, 337–354.
- Jamieson, D. G., & Rvachew, S. (1992). Remediation of speech production errors with sound identification training. *Journal of Speech-Language Pathology and Audiology*, 16, 201–210.
- Joanisse, M. F., Manis, F. R., Keating, P., & Seidenberg, M. S. (2000). Language deficits in dyslexic children: Speech perception, phonology, and morphology. *Journal of Experimental Child Psychology*, 77, 30–60.
- Larrivee, L. S., & Catts, H. W. (1999). Early reading achievement in children with expressive phonological disorders. *American Journal of Speech-Language Pathology*, 8, 118–128.
- Lonigan, C. J., Burgess, S. R., & Anthony, J. L. (2000). Development of emergent literacy and early reading skills in preschool children: Evidence from a latent-variable longitudinal study. *Developmental Psychology*, 36, 596–613.
- Lonigan, C. J., & Whitehurst, G. J. (1998). Relative efficacy of parent and teacher involvement in a shared-reading intervention for preschool children from low-income backgrounds. *Early Childhood Research Quarterly*, 13, 263–290.
- Major, E. M., & Bernhardt, B. (1998). Metaphonological skills of children with phonological disorders before and after phonological and metaphonological intervention. *International Journal of Language and Communication Disorders*, 33, 413–444.
- Manis, F., McBride-Chang, C., Seidenberg, M. S., Keating, P., Doi, L. M., Munson, B., et al. (1997). Are speech perception deficits associated with developmental dyslexia? *Journal of Experimental Child Psychology*, 66, 211–235.
- McBride-Chang, C. (1995). What is phonological awareness? *Journal of Educational Psychology*, 87, 179–192.
- Metsala, J. L. (1999). Young children's phonological awareness and nonword repetition as a function of vocabulary development. *Journal of Educational Psychology*, 91, 3–19.
- Metsala, J. L., & Walley, A. C. (1998). Spoken vocabulary growth and the segmental restructuring of lexical representations: Precursors to phonemic awareness and early reading ability. In J. L. Metsala & L. C. Ehri (Eds.), *Word recognition in beginning reading* (pp. 89–120). Mahwah, NJ: Erlbaum.
- Munson, B., Edwards, J., & Beckman, M. E. (2005a). Phonological knowledge in typical and atypical speech-sound development. *Topics in Language Disorders*, 25(3), 190–206.
- Munson, B., Edwards, J., & Beckman, M. E. (2005b). Relationships between nonword repetition accuracy and other measures of linguistic development in children with phonological disorders. *Journal of Speech, Language, and Hearing Research*, 48, 61–78.
- Nathan, L., Stackhouse, J., Goulandris, N., & Snowling, M. J. (2004). The development of early literacy skills among children with speech difficulties: A test of the "critical age hypothesis." *Journal of Speech, Language, and Hearing Research*, 47, 377–391.
- Nittrouer, S. (1996). The relation between speech perception and phonemic awareness: Evidence from low-SES children and children with chronic otitis media. *Journal of Speech and Hearing Research*, 39, 1059–1070.
- Nittrouer, S., & Burton, L. T. (2005). The role of early language experience in the development of speech perception and phonological processing abilities: Evidence from 5-year-olds with histories of otitis media with effusion and low socioeconomic status. *Journal of Communication Disorders*, 38, 29–63.
- Olofsson, A., & Neidersoe, J. (1999). Early language development and kindergarten phonological awareness as predictors of reading problems. *Journal of Learning Disabilities*, 32, 464–472.
- Raitano, N. A., Pennington, B. F., Tunick, B. F., Boada, R., & Shriberg, L. D. (2004). Pre-literacy skills of subgroups of children with speech sound disorders. *Journal of Child Psychology and Psychiatry*, 45, 821–835.
- Rvachew, S. (1994). Speech perception training can facilitate sound production learning. *Journal of Speech and Hearing Research*, 37, 347–357.
- Rvachew, S., Chiang, P., & Evans, N. (2006). *Characteristics of speech errors produced by children with and without delayed phonological awareness*. Manuscript submitted for publication.
- Rvachew, S., & Grawburg, M. (2006). Correlates of phonological awareness in preschoolers with speech-sound disorders. *Journal of Speech, Language, and Hearing Research*, 49, 74–87.
- Rvachew, S., & Jamieson, D. G. (1989). Perception of voiceless fricatives by children with a functional articulation disorder. *Journal of Speech and Hearing Disorders*, 54, 193–208.
- Rvachew, S., Nowak, M., & Cloutier, G. (2004). Effect of phonemic perception training on the speech production and phonological awareness skills of children with expressive phonological delay. *American Journal of Speech-Language Pathology*, 13, 250–263.
- Rvachew, S., Ohberg, A., Grawburg, M., & Heyding, J. (2003). Phonological awareness and phonemic perception in 4-year-old children with delayed expressive phonology skills. *American Journal of Speech-Language Pathology*, 12, 463–471.
- Senechal, M., & LeFevre, J. (2002). Parental involvement in the development of children's reading: A five-year longitudinal study. *Child Development*, 73, 445–460.
- Silven, M., Niemi, P., & Voeten, M. J. M. (2002). Do maternal interaction and early language predict phonological awareness in 3 to 4 year olds? *Cognitive Development*, 17, 1133–1155.

- Snowling, M. J., Bishop, D. V. M., & Stothard, S. E.** (2000). Is preschool language impairment a risk factor for dyslexia in adolescence? *Journal of Child Psychology and Psychiatry, 41*, 587–600.
- Stanovich, K. E.** (2000). *Progress in understanding reading: Scientific foundations and new frontiers*. New York: Guilford Press.
- Storch, S. A., & Whitehurst, G. J.** (2002). Oral language and code-related precursors to reading: Evidence from a longitudinal structural model. *Developmental Psychology, 38*, 934–947.
- Studdert-Kennedy, M.** (1987). The phoneme as perceptuomotor structure. In D. M. A. Allport, W. Prinz, & E. Scheerer (Eds.), *Language perception and production* (pp. 67–84). London: Academic Press.
- 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 of brain and language: Advances in consciousness research* (Vol. 42, pp. 207–227). Amsterdam: Benjamins.
- Vihman, M. M., & Nakai, S.** (2003, August). *Experimental evidence for an effect of vocal experience on infant speech perception*. Paper presented at the 15th International Congress of Phonetic Sciences, Barcelona, Spain.
- Walley, A. C., Metsala, J. L., & Garlock, V. M.** (2003). Spoken vocabulary growth: Its role in the development of phoneme awareness and reading ability. *Reading and Writing: An Interdisciplinary Journal, 16*, 5–20.
- Webster, P. E., & Plante, A. S.** (1992). Effects of phonological impairment on word, syllable, and phoneme segmentation and reading. *Language, Speech, and Hearing Services in Schools, 23*, 176–182.
- Webster, P. E., Plante, A. S., & Couvillion, M.** (1997). Phonologic impairment and prereading: Update on a longitudinal study. *Journal of Learning Disabilities, 30*, 365–376.
- Werker, J. F., & Curtin, S.** (2005). PRIMIR: A developmental framework of infant speech processing. *Language Learning and Development, 1*, 197–234.
- Wise, B. W., Ring, J., & Olson, R. K.** (1999). Training phonological awareness with and without explicit attention to articulation. *Journal of Experimental Child Psychology, 72*, 271–304.
- Zevenbergena, A. A., Whitehurst, G. J., & Zevenbergenc, J. A.** (2003). Effects of a shared-reading intervention on the inclusion of evaluative devices in narratives of children from low-income families. *Applied Developmental Psychology, 24*, 1–15.

Received June 5, 2005

Revision received September 7, 2005

Accepted January 6, 2006

DOI: 10.1044/1058-0360(2006/016)

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