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Growth Modeling of Phonological Awareness

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In a longitudinal study following prereading kindergartners through first grade, the variables verbal memory, IQ, and speech perception (SP) together predicted 26% of growth in and 42% of the final status of phonological awareness (PA). The correlation between initial status and growth in PA was .51, suggesting that those who begin with high PA develop that skill more quickly than those who begin with lower PA. Although those low and high in SP in kindergarten had substantially different word-decoding scores by the middle of first grade (low: $M = 6.8$ words; high: $M = 18.1$ words), this difference was no longer significant once phonological processing was controlled, suggesting that the effect of SP on word decoding is mediated by phonological processing ability.

Phonological awareness is one of the two strongest longitudinal predictors of reading in children. Its ability to predict reading is paralleled only by knowledge of the letter names and sounds of the alphabet. Indeed, phonological awareness is an even better predictor of subsequent reading success than is general cognitive ability, typically measured using an IQ score. Phonological awareness has been measured in fairly young children, perhaps as young as two years of age (Lonigan, Barker, Burgess, & Anthony, 1995), using measures of "phonological sensitivity" (Stanovich, 1991). These measures include rhyme and alliteration oddity (e.g., Bradley & Bryant, 1985). However, measuring phonological awareness in such young children is quite difficult; measuring phonological awareness in children younger than 2 years old may be impossible.

For both diagnostic and theoretical reasons, identifying precursors of phonological awareness is important. Practically speaking, distinguishing predictors of phonological awareness may help educators and researchers identify those at-risk for reading disabilities even before they begin formal reading instruction. Early identification of those who may need special help with reading skills is important to prevent such children from falling behind in all aspects of formal school instruction (Adams, 1990). Theoretically, identifying precursors of phonological awareness may help contribute to a comprehensive model of reading development (Fowler, 1991; McBride-Chang, 1995a, 1996; Walley, 1993).

The purpose of this paper is to consider factors influencing the growth of phonological awareness. We first examine possible precursors of phonological awareness in kindergarten children. In particular, we focus on simple speech perception as a potential precursor of phonological awareness and, ultimately, word recognition. General cognitive ability and verbal memory are also considered precursors to phonological awareness. Furthermore, we examine the association between initial ability in phonological awareness and growth in phonological awareness to determine the nature of the development of phonological awareness.

What Is Phonological Awareness?

All phonological awareness tasks have in common the requirement that participants recognize and manipulate the sound structure of language. For example, skill in regeneration of a word after altering it in a particular way (e.g., say 'cowboy' without saying 'boy'; say 'rasket' without saying the /s/ sound) is a frequently used phonological awareness task. At the most linguistically difficult level, phonological awareness involves the ability to recognize and manipulate phonemes (i.e., phoneme awareness), which are the individual speech sounds in language. For example, /n/, /z/, and /l/ are all separate phonemes in English. Phonological awareness, in general, is the ability to attend to and manipulate units of speech, such as the phoneme, onset and rime, syllable, or word.

Phonological awareness has been argued to be comprised of at least three component skills (McBride-Chang, 1995b). These capacities are general cognitive ability, verbal short-term memory, and speech perception.

To master a phonological awareness task, children must first understand what is required of them and be capable of

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carrying out the task. These skills collectively constitute the general cognitive ability demanded, to a certain extent, in all phonological awareness measures. Cognitive ability correlates at least moderately with phonological awareness in several studies (e.g., Wagner et al., 1987; Wagner, Torgesen, Simmons, & Rashotte, 1993).

Children must also retain in their memories the requirements of a given phonological awareness task and, perhaps most important, keep in mind the stimuli they are asked to manipulate long enough to perform the task. Typically, children are asked to remember either individual words or nonsense words. Remembering these words requires an element of verbal short-term memory (Bradley & Bryant, 1985; Wagner et al., 1993).

Finally, by definition, speech perception should be an integral part of phonological awareness. Because phonological awareness is the ability to manipulate phonemes, the simple skill of distinguishing speech sounds, one aspect of speech perception, must implicitly be required in all phonological awareness tasks. Speech manipulations and levels of linguistic difficulty influence performance on phonological awareness tasks (Adams, 1990; Stahl & Murray, 1994). Others have also suggested that speech perception may be associated with phonological awareness (e.g., Eisen, Fowler, & Brady, 1995; Flege, Walley, & Randazza, 1992; Manis et al., 1997).

Using structural equation modeling, McBride-Chang (1995b) found evidence for the simultaneous unique contributions of each of these three component capacities to a phonological awareness construct, among 136 third and fourth graders. Thus, general cognitive ability, verbal short-term memory, and speech perception all contributed independently to phonological awareness in concurrently collected data. Because the data from this study were collected concurrently, no causal relations among variables could be established. A major goal of the present study, therefore, was to test whether these component skills would contribute independently to phonological awareness over time.

One criticism of the McBride-Chang (1996) research is that all of the participants in that study were already reading, which may have confounded the results. For example, it is possible that these children used their reading ability to carry out the tests of phonological awareness. Readers frequently use pictured spelling as one strategy for performing such tasks (Stuart, 1990). Reading skill itself certainly may be influenced by cognitive ability (e.g., Stanovich, 1988) and verbal short-term memory (e.g., Mann & Liberman, 1984). Good and poor readers can be distinguished on the basis of simple speech perception as well (DeWeirdt, 1988; Godfrey, Syrdal-Lasky, Millay, & Knox, 1981; Lieberman, Meskill, Chatillon, & Schupack, 1985; Reed, 1989; Steffens, Eilers, Gross-Glenn, & Jallad, 1992; Tallal, 1980). Thus, the phonological awareness construct in the McBride-Chang (1995b) study might have been predicted from the three components largely because it involved reading itself. A second goal of the present study, therefore, was to test whether these component abilities would predict phonological awareness in prereaders.

Relations Among Speech Perception, Phonological Awareness, and Word Recognition

The concept of phonological awareness is of interest mainly because of its ability to predict word recognition skill. Several investigators have examined speech perception in relation to word reading (e.g., DeWeirdt, 1988; Godfrey et al., 1981; Lieberman et al., 1985; Reed, 1989; Werker & Tees, 1987). Invariably, good readers are more successful at discriminating speech sounds than are poor readers. Implicit in this research is the idea that speech perception may have a direct impact on word reading.

In contrast, McBride-Chang (1996) argued that speech perception may influence word reading only indirectly, through its association with phonological awareness and related phonological processing abilities. Such phonological processing skills probably include alphabet knowledge (e.g., Trieman, Weatherston, & Berch, 1994; Wagner & McBride-Chang, 1996). Thus, speech perception may contribute unique variance to phonological awareness, but not to word reading itself, once the influences of the most powerful predictors of word recognition are controlled.

Defining Speech Perception

Our operational definition of speech perception for the present study was the ability to discriminate a single pair of stop consonants, /b/ and /p/, in the words *bath* and *path*. Thus, we tried to isolate speech perception as one of the simplest linguistic tasks possible. In this paradigm, speech perception is defined as the ability to distinguish *bath* across several trials of a forced-choice experiment, where the only other alternative is *path*. Across trials, a child hears only a single word and identifies it by pointing to a picture of it. We focused on this continuum because stop consonants have been theorized to be particularly difficult for disabled readers (Tallal, 1980). Therefore, we anticipated that this continuum might reveal greater variability in performance than would other classes of continua.

Measuring speech perception this way distinguishes it substantially from phonological awareness tasks, or "phonological sensitivity" measures (Stanovich, 1991) such as "Odd One Out," in which children have to select a word, from among three to four choices, which does not belong. For example, Stanovich, Cunningham, and Cramer (1984) administered a phonological awareness task in which, for each trial, children were asked to identify one of four words presented that had a final sound that differed from those of the other three. This task taxes memory and involves multiple comparisons, aspects of phonological awareness (e.g., Yopp, 1988), which can be distinguished from speech perception (McBride-Chang, 1995a).

The way in which speech perception is conceptualized, defined, and measured has important consequences for its consideration in the literature on reading development and disability. Although we are well aware that the stop-consonant continuum used in the present study represents only one kind of speech perception, we nevertheless use this general term to communicate our commitment to distinguishing and understanding speech perception in relation to phonological awareness. (For a review of the many complex and rich levels of speech perception, see Nusbaum & Goodman, 1994.)

There were four goals of this study, which started with nonreaders who were beginnning kindergarten. These goals focused in particular on establishing the extent to which speech perception is integral to phonological awareness and reading. Speech perception is of particular interest, because its association with phonological awareness has been tested in very few studies.

The first goal of this study was to examine associations among speech perception and phonological awareness tasks. In the McBride-Chang (1995b) study of third and fourth graders, associations of speech perception tasks with phonological awareness tasks were all fairly low. It may be that in younger children, speech perception and phonological awareness tasks have higher magnitudes of association because there may be more variability among younger children in response to speech perception tasks. For example, Nittrouer and Studdert-Kennedy (1987) noted that consistency of response to fricative-vowel syllables increased with age among children ages 3, 4, 5, and 7, and adults. Thus, we present correlational analyses of the associations of speech perception with three measures of phonological awareness initially and two measures of phonological awareness taken approximately 15 months later.

Our second goal was to use hierarchical linear modeling (HLM) to examine the contributions of cognitive ability, verbal memory, and speech perception to the growth of phological awareness, assessed four times within a 15-month period. HLM allowed us to test the contributions of each of these abilities to the phonological awareness task, phoneme elision, at the conclusion of the study and the contribution to the growth rate of phoneme elision across four testing times.

A third goal of this study was to obtain a correlation between phoneme elision at the initial testing time and growth in phoneme elision. From the reading literature, there were at least three possibilities for the relation of initial status and growth of phoneme elision. First, it was possible that those who had an initial advantage in phonological awareness would capitalize on their strength and improve their skill at a faster rate than those who began with lower abilities, the so-called "Matthew effects," which have been applied to reading (Stanovich, 1986). Here, "the rich get richer" in phonological awareness skill. Second, we considered the possibility that those with lower skills would, with development, catch up to their peers, a compensatory model. Thus, those students with initially low phonological awareness might grow in phonological awareness more quickly than those who began at a higher level. Third, it was possible that a reliable pattern between initial status and growth of phonological awareness could not be discerned.

A fourth goal of the present study was to examine the extent to which initial speech perception scores were associated with differences in subsequent word reading across time in younger children. McBride-Chang (1996) previously argued that the influence of speech perception on word reading is probably indirect, through its effects on phonological awareness and other phonological processing abilities. Thus, this study considered the extent to which speech perception predicts subsequent word recognition ability, directly and also indirectly, after controlling for effects of phonological awareness and alphabet knowledge.

Method

Participants

Initially, 142 children in the first semester of kindergarten participated, 75 were female. These children were from four lower to upper middle-class public schools in the central Florida area. According to school records, all children had normal hearing. Kindergartners ranged in age from 60 to 80 months at time of testing ($M = 66.7$; $SD = 3.9$) and were without obvious physical, emotional, or cognitive difficulties. All children were tested initially between the beginning of September and mid-November, 1994. There were 100 Caucasian, 27 African American, and 15 Hispanic/Latino participants, and all were native English speakers.

From the initial testing time to the final testing time, 15 months later, the sample size dropped by approximately 28%. t-Tests revealed no significant differences between those who stayed and those who left on age, IQ (Block Design or Vocabulary Subtests), phonological awareness (phoneme elision, sound isolation, phoneme synthesis), word reading, memory, letter sound knowledge, or speech perception at Time 1..However, the two groups did differ significantly in letter name knowledge, $t(140) = 2.48$, $p < .05$, with those who dropped out ($n = 38$) scoring lower ($M = 9.5$) than did those who remained in the study ($n = 104$; $M = 13.7$).

The children's ages may have been one factor in this disappointing 28% attrition rate. Informal conversations with teachers revealed that (a) these families considered moving easier with younger children, who were not yet "firmly entrenched" in their particular schools, and (b) many of the families of the children from these schools were, as a population, fairly mobile.

We wanted to make use of as much of the data as we had available at each testing time. Sample sizes for various analyses differed because of occasional absences of the children and the overall attrition rate. Therefore, differing ns will be noted throughout the paper.

Procedure

At the initiation of the study, kindergarten teachers were asked to select students from their classrooms whom they judged to be nonreaders and to give these children's parents letters explaining the nature of the study and permission slips soliciting their children's participation. Teachers judged that approximately 70% of their students were essentially nonreaders at the beginning of kindergarten.[1]

[1] This was a longitudinal investigation of cognitive abilities contributing to future reading success as well as a study attempting to train reading-related skills to groups of children over a 16-week period. Training focused on synthesis and elision of words, syllables, and individual phonemes. However, there were no differences in the experimental and control groups' abilities in phonological awareness, word reading, spelling, or alphabet knowledge at any point in the study. Furthermore, correlations among the measures of phonological awareness, speech perception, cognitive ability, memory, and alphabet knowledge were similar for the two

Children were tested a total of four times, from September of 1994 through February of 1996. Testing was done at approximately 5-month intervals, in fall of 1994, spring of 1995, fall of 1995, and winter of 1996. The first assessment and the final assessment were fairly lengthy. The middle two assessments consisted only of four short tasks.

For each assessment, children were tested individually in a quiet room at school during regular school hours. Testers were the present author and a total (across four semesters of testing) of 25 trained undergraduate psychology majors in their junior or senior years. Only the first author administered the speech perception task and the Wechsler Preschool and Primary Scale of Intelligence (WPPSI; Weschler, 1989) Block Design. The remaining tasks were administered by several testers, under the direct supervision of the first author. Kindergartners were tested for 20–25 min each time. A variety of colorful stickers were offered as rewards for participation following each session. Measures of cognitive ability, verbal short-term memory, speech perception, phonological awareness, word reading, and alphabet knowledge were administered to all participants. The order of these tasks was random to maintain the interest of the children and to conform to time constraints. These tasks are described here.

General cognitive ability. The Block Design subtest of the WPPSI (Wechsler, 1989) was used to estimate nonverbal reasoning skill. General verbal ability in these children was measured using the Vocabulary subtest of the Stanford-Binet Intelligence Scale (Thorndike, Hagen, & Sattler, 1986). These tasks were administered during the fall of 1994 only.

Verbal short-term memory. An experimental Memory for Numbers task was administered. Children were asked to repeat back numbers orally presented by the experimenter. Digit strings increased from two to six items in a row. Three trials of each length were presented. When children missed all three trials of one length, testing was discontinued. These tasks were scored using a system that gives some partial credit for partly correct responses (Torgesen & Houck, 1980). This task was administered in the initial testing only.

Speech perception. Speech perception was measured using a forced-choice identification paradigm. Participants were asked to listen to stimuli presented on a MacIntosh computer and determine whether, at each trial, the word they heard was *bath* or *path*. These stimuli were borrowed from Miller, Green, and Schermer (1985) and differed only in voice onset time.

Stimuli were initially created by having an adult male speaker read sentences containing each word (e.g., "She did not see the bath/path."). The words *bath* and *path* were then isolated from the rest of the sentence and edited to form 13 stimuli along a voice onset (VOT) continuum. Portions of periodic energy were removed from the end of closure of /b/ in the /baeth/ segment and repeated with segments of aperiodic energy from the end of the closure of the /p/ in /paeth/ to form the stimuli. These stimuli were presented at 7, 12, 15, 19, 21, 26, 32, 35, 39, 45, 48, 53, and 59 ms of VOT, from a clear "bath" to a clear "path," respectively. Each stimulus was 418 ms in length. For example, the clearest "bath" stimulus consisted of 7 ms of /b/ and 411 ms of /aeth/, whereas the clearest "path" consisted of 59 ms of /p/ and 359 ms of /aeth/. All stimui were perceived by native speakers as unedited speech.

On an accompanying sheet, children saw pictures of a bath and a path. Children were tutored as extensively as necessary by the experimenter on identifying these words and distinguishing them. Some children had no difficulty identifying each picture, and others needed some help understanding what a path was. Following this initial tutorial, children listened to the computer pronounce the words. Once children had been trained to point to one of the two choices depending on what the computer "said" in three practice trials, they were asked to identify these sounds for the test itself. For each trial, children pointed to either the bath or the path picture, and the experimenter circled this selection on an accompanying sheet. There were 39 trials.

Averages of perceptions of these segments across many trials tend to be categorized uniformly as either "bath" or "path" and are generally not classified as ambiguous (e.g., Lieberman & Blumstein, 1988). A previous study (McBride-Chang, 1995b) administered these same stimuli to third- and fourth-grade children and showed standard categorization of this continuum. Total stimuli correctly named according to the consensus of children from this previous study (McBride-Chang, 1995b) was the measurement unit for this task. That is, all stimuli from 26 to 59 ms of VOT were categorized as correct if children identified them as "path," whereas stimuli from 7 to 21 ms of VOT were counted as correct when they were identified as "bath." This measure was administered in the fall of 1994 only. The obtained internal consistency reliability for this task was .78.

Phonological awareness. Three measures of phonological awareness were administered to all children. The first was phoneme synthesis, created based on similar measures discussed in Wagner et al. (1997). This task has children begin by blending word syllables (e.g., pen + cil). Children are eventually asked to blend onsets and rimes, and then single phonemes. This task is discontinued when five items in a row are scored incorrectly. Different numbers of points are assigned for each trial. For example, a score of two points is assigned if children respond "cat" when given the sounds /k/ + /aet/. If the child says "hat," instead, for these stimuli one point is assigned. Zero points are assigned when no synthesis occurs or children respond with "don't know." For more difficult items, up to 10 points may be assigned for a single response. This occurs when many individual phonemes must be blended together. There are 29 test items altogether, and a maximum score of 131 is possible. This test was administered in the initial testing time only.

The second phonological awareness task, phoneme elision, was also introduced by Wagner et al. (1997). This task requires children to segment sounds. Children begin by segmenting compound words (e.g., say "cowboy" without saying "boy"). They then continue segmenting syllables (e.g,. say "window" without saying "dow" and phonemes (e.g., say "rasket" without saying the /s/ sound). Again, the task is discontinued when five items in a row are missed. The task consists of 3 compound word items, 1 syllable item, and 21 phoneme items. Responses are scored as either correct or incorrect (1 or 0), and there are 25 trials. This task was administered at all four testing times.

A final phonological awareness task included in the battery was based on the sound isolation task created by Stanovich, Cunningham, and Cramer (1984). In this test, children are required to give individual sounds. Items involve first saying a word (e.g., *fin*) and

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groups. The training may have been ineffective for a variety of reasons, including the large sizes of the groups of children (up to 20 at a time), the relatively small amount of time spent on training (less than 30 min per week), and the multitrack schedules of the children, which meant that some children were always on vacation during the training sessions. It should be noted that, although the training did not appear to have any effect on the children, it is possible that this focus in some way changed the longitudinal relations among the variables considered in the present study. In particular, this training may have weakened the relations of cognitive ability, memory, and speech perception to phonological awareness over time.

then identifying the sound (always a single-consonant onset phoneme) heard in that word that is not present in a second rhyming word (e.g., in). For example, the experimenter would ask each child, "Say 'pie.' What sound do you hear in 'pie' that you do not hear in 'eye?' " The correct answer in this case would be /p/. The item-difficulty level remained constant across all 12 trials of this measure. This task was administered in the initial and final testing periods only.

At the initiation of the study, a decision was made to focus on the growth of phoneme elision across time. This decision was made based on pilot studies that showed that phoneme synthesis tended to improve fairly rapidly (and thus show minimal variance by the end of first grade) and that sound isolation items were all fairly uniform in their level of difficulty (so that children had some tendency either to master most items or to master very few of them, leading to minimal variation). In contrast, phoneme elision tends to be developmentally more difficult then phoneme synthesis and is graded in difficulty level.

Alphabet knowledge. Children were tested on their knowledge of letter names and letter sounds. Uppercase letters were presented in random order to the children. These letters were displayed in large print on a single piece of paper. Children were first asked to name the letter. They were then asked to give the sound made by each. Any spoken phoneme recognized as corresponding to the written letter in English was considered an acceptable response. For example, the letter C might be described to make either the /s/ or the /k/ sound. Thus, a maximum score of 26 was possible for each task. Letter-sound and letter-name knowledge were assessed at each testing time, but only the results of testing in the fall of 1994 are discussed here.

Word reading. Word reading was assessed using the word identification subtest of the Woodcock Reading Mastery Tests—Revised (Woodcock, 1989; Form H). This test was administered across all four testing times.

Results

Age was not significantly associated with any variable measured in the present study. Therefore, it is not included in the following analyses.

Descriptive statistics on initial and final measures and internal consistency reliabilities for all experimental tasks are given in Table 1. All tasks had adequate variability.

One question addressed by these data was the extent to which a measure of speech perception and various measures of phonological awareness were associated concurrently and longitudinally. Table 2 shows these correlations.

Speech perception was moderately correlated with each phonological awareness measure, even the two taken 15 months after initial testing.

Growth Models of Phoneme Elision

The second question addressed by the present study centered on predicting growth rate of and final status of a single measure of phonological awareness, phoneme elision. We used HLM to examine the extent to which four variables would contribute unique variance to the development of phoneme elision. Of particular interest was whether our measure of speech perception would contribute unique variance to phoneme elision once other variables had been controlled. We also used measures of IQ, both verbal and nonverbal, and short-term verbal memory to predict phoneme elision.

A linear growth model was fitted for the four times of observation of phoneme elision. The linear model was chosen from an examination of the scatterplot of the data and by comparing it with other competing models. Scatterplots revealed a fairly linear increment of phoneme elision across four time observations, although for some cases, the increment from Time 1 to Time 2 was somewhat flat. This seemed to suggest a quadratic model with acceleration occurring after Time 2. However, the fit of the quadratic model was poor; the acceleration term was basically zero, $\chi^2(126, N = 127) = -.006, p = .95$, with its standard error being 18 times the size of the coefficient. It took 156 iterations for the model to converge, whereas the linear model converged after 15 iterations. We also tried a "reduced quadratic" model, which included only the quadratic but not the linear coefficient. The fit was equally poor.

The linear model was fitted on data from 128 children,

Table 1
Descriptive Statistics on All Relevant Variables

Variable	*M*	*SD*	Range	*n*	ICR
Verbal reasoning[a]	98.2	13.9	68–164	140	
Nonverbal reasoning[a]	9.3	2.7	1–16	140	
Memory[b]	38.2	11.8	12–60	142	.85
Speech perception[b]	27.4	5.7	14–37	141	.78
Letter names[b]	12.6	9.1	0–26	142	.95
Letter sounds[b]	6.6	7.7	0–26	142	.96
Phoneme elision, T1[b]	3.8	2.7	0–12	142	.83
Sound isolation, T1[b]	2.7	4.3	0–12	141	.97
Phoneme synthesis, T1[b]	14.2	13.1	0–73	141	.90
Phoneme elision, T4[b]	8.0	4.9	0–25	104	
Sound isolation, T4[b]	8.1	4.6	0–12	103	
Word identification, T1[c]	0.1	0.4	0–3	142	
Word identification, T2[c]	1.1	2.5	0–14	128	
Word identification, T3[c]	6.0	9.6	0–53	107	
Word identification, T4[c]	12.6	13.7	0–66	104	

Note. ICR = internal consistency reliability, measured only at Time 1 (T1), for experimental measures only. T2 = Time 2; T3 = Time 3; T4 = Time 4.
[a]Standard score. [b]Raw score for experimental measure. [c]Raw score for standardized measure.

Table 2
Correlations Among Phonological Awareness Variables and Speech Perception

Variable	1	2	3	4	5	6
1. Speech perception	—					
2. Phoneme elision, T1	.31	—				
3. Sound isolation, T1	.43	.36	—			
4. Phoneme synthesis, T1	.41	.28	.42	—		
5. Phoneme elision, T4	.44	.50	.54	.40	—	
6. Sound isolation, T4	.38	.21	.41	.34	.56	—

Note. $N = 102$. Correlations above .30 were significant at $p < .05$, two-tailed. T1 = Time 1; T4 = Time 4.

most but not all of whom had observations at each of the four testing times. HLM does not require the same number of data points for all subjects (Bryk & Raudenbush, 1992). Because there were approximately 5 months between each observation, the four observation points were treated as equally spaced and coded as −3, −2, −1, and 0 from the first to the last observation. With this coding the intercept of this linear growth model was the mean phoneme elision score at the final observation when the children were in the middle of first grade. Table 3 contains the results of this linear growth model.

In Table 3, the intercept or mean of the last observation was 8.3 phoneme elision items. The slope of 1.54 indicates that, on average, children acquired 1.5 more items on the phonological awareness measure for each 5-month interval. Both coefficients are significantly different from zero. The OLS error variance of 4.5 was large, as expected, due to the small sample of data points. It indicates that the standard error of estimate at each time point is about two test items. Parameter variance associated with both the intercept and slope was large and significant, indicating variability among children in their growth trajectories. This interindividual variation in growth was to be explained by these children's initial abilities in speech perception, cognitive skills, and short-term memory.

Before considering the contributions of these predictor variables to final status and growth in phoneme elision, we did an additional analysis of the linear growth model to look at the association of initial status and growth in phonological awareness. In this case, the observation points were coded for Times 1 through 4 as 0, 1, 2, and 3, respectively. Thus, the intercept became the mean of the initial observations. The correlation between the intercept or initial status of phoneme elision and the slope or growth in phoneme elision was .51, $p < .01$. This association supported the idea that those who are skilled in phonological awareness initially tend to show more rapid growth in phonological awareness ability as well.

We then considered the extent to which the predictor variables would account for variance in growth and final status of phoneme elision. Two person-level models were fitted to account for the growth variation. Results are contained in Table 4.

In the first model, nonverbal reasoning, vocabulary, and memory, all of which were measured at the first observation time, were used to predict both the intercept and slope of growth in phonological awareness during the data collection period. For the intercept, all three predictors were positive and significant, $p < .05$. On average, children higher on these cognitive abilities that were measured at Time 1 achieved a higher level on phoneme elision 15 months later than those who were lower on these abilities initially. Nonverbal reasoning and vocabulary were significant predictors of the slope or growth rate over the data collection time; memory was not. For all three predictors, higher values initially were associated with a faster rate of growth in phoneme elision. For instance, the mean and standard deviation of vocabulary were 98.2 and 13.9, respectively. The regression coefficient of .031 associated with vocabulary showed that someone who was one standard deviation above the mean on vocabulary was expected to perform the phonological awareness task at a rate that was .43 (.031 × 13.9) faster than someone at the mean of vocabulary. This faster rate translated to acquiring 1.3 (.43 × 3) more items from Time 2 to Time 3 than an average vocabulary child and acquiring 1.7 (.43 × 4) more items on the phonological awareness task from Time 3 to Time 4 than the average vocabulary child.

Without these predictors, the variance of the intercept and of the slope were 21.24 and 1.17, respectively. After the three predictors, the residual variances were 14.98 and 0.92, respectively, for the intercept and slope. These three predictors explained 29% of the variance in the intercept [(21.243 − 14.985)/21.243 or R^2 − change = 29.46] and about 22% of the variance of the slope or growth rate (R^2 − change = 21.57). These variance reductions were significant. Further statistics not included in Table 4 showed that most of the variance reduction in the slope was parameter variance—variance in growth rate among individuals, but not total variance, which also included the OLS estimation error variance. This supports the theoretical soundness of the selection of the predictor variables that are not expected to be related to random errors.

The second model included these three predictors as well as speech perception. The purpose of fitting these two models separately was to determine how much additional variance in growth trajectory could be explained by speech perception over and above what had been accounted for by the other predictors. Variance reduction by speech perception over the first predicting model was 12% for the intercept and 4% for the slope. Both of these variance reductions were significant. These results are also presented in Table 4. Thus, all four component abilities combined, with speech perception included, predicted approximately 26% of the variance

Table 3
Linear Growth Model of Phonological Awareness

	Fixed effect			Random effect		
Measure	Coefficient	*SE*	*t*	Variance[a]	$\chi^2(126, N = 127)$	Reliability
Intercept	8.320	.453	18.359*	21.243	785*	.633
Slope	1.538	.137	11.261*	1.173	260*	.341

[a]Error = 4.552.
*$p < .05$.

Table 4
Contrasting Models of Phonological Awareness

Measure	Fixed effect: Coefficient	*SE*	*t*	Random effect: Variance	R^2 change (%)
		Unconditional model			
Intercept				21.243	
Slope				1.173	
		Conditional Model 1			
Intercept				14.985	29.46
Nonverbal reasoning	0.022	0.009	2.414*		
Vocabulary	0.141	0.030	4.758*		
Memory	0.065	0.033	1.969*		
Slope				0.920	21.57
Nonverbal reasoning	0.006	0.003	1.912*		
Vocabulary	0.031	0.010	3.158*		
Memory	0.007	0.011	0.680		
		Conditional Model 2			
Intercept				13.170	12.11
Nonverbal reasoning	0.021	0.009	2.393*		
Vocabulary	0.103	0.031	3.357*		
Memory	0.047	0.032	1.474*		
Speech perception	0.277	0.074	3.740*		
Slope				0.883	4.02
Nonverbal reasoning	0.006	0.003	1.869*		
Vocabulary	0.024	0.011	2.246*		
Memory	0.004	0.011	0.379		
Speech perception	0.048	0.025	1.896*		

Note. R^2 change is the percentage of variance reduced by the additional predictors in the current model over the previous model.
*$p < .05$, one-tailed.

in growth of phoneme elision and 42% of the variance in final status of the phonological awareness measure.

Speech Perception and Reading

There are several ways of considering the data on speech perception in relation to word reading. Because most previous studies of reading in relation to speech perception have looked at group differences (i.e., good and poor readers—DeWeirdt, 1988; Godfrey et al., 1981; Reed, 1989) and because we were interested in what the practical effects of a single speech perception task on subsequent reading might be, we looked at reading skill for those high and low in speech perception. For each time period, we divided children, based on a median split from the whole Time 1 sample, into those who were low (scoring 27 and lower) and high (scoring 28 and above) in speech perception. Results are shown in Table 5.

These differences across time were striking, with those who began with high speech perception scores having out-performed those with low speech perception scores at every time point.

Hierarchical regression was also used to examine these data among all participants. Once the Block Design and

Table 5
t-Test Comparisons of Word Recognition for Those High and Low in Speech Perception

Word identification[a]	Low *M*	Low *SD*	Low *n*	High *M*	High *SD*	High *n*	*t*	*df*
Time 1	0.04	0.26	76	0.23	0.58	65	−2.46*	139
Time 2	0.54	1.00	67	1.64	2.78	61	−2.56*	126
Time 3	3.26	9.38	54	8.83	9.14	53	−3.11*	105
Time 4	6.84	11.40	51	18.10	13.60	53	−4.57*	102

[a]Woodcock Word Identification raw score.
*$p < .05$, two-tailed.

Vocabulary subtests were used to predict word recognition, speech perception was no longer a significant predictor of word recognition at Times 1 and 2. With the addition of phoneme elision, speech perception's contribution to word identification at Time 3 was nonsignificant. At Time 4, speech perception contributed a unique 6% of the variance in word recognition after the Block Design, memory, vocabulary, and phoneme elision tasks had been used to predict it (30%, collectively), for a total of 36% of the variance explained. However, once letter naming was additionally forced into the regression equation, speech perception was a nonsignificant predictor of word recognition.[2]

Discussion

This study extends the literature on speech perception and phonological awareness in young children with four findings. First, we have shown that speech perception and phonological awareness tasks are moderately associated in young children. Second, we found that cognitive ability, verbal memory, and speech perception together predicted 26% of the growth in and 42% of the final status of phoneme elision across time for kindergartners starting out as prereaders. Third, we showed that there is a substantial association between initial status of and growth in phoneme elision in young children. Fourth, we demonstrated that the effects of speech perception on subsequent word recognition may be mediated by phonological processing abilities. We consider each of these findings in turn.

First, the relatively strong associations of speech perception to phonological awareness in these young children is noteworthy. Although others (e.g., Hurford, 1991; Manis et al., in press) have found moderate associations of measures of speech perception and phonological awareness, this is the first time, to our knowledge, that such an association has been demonstrated across time in prereaders. Thus, this study provides further evidence for a speech perception–phonological awareness link without the confound of reading experience.

The demonstration that speech perception, cognitive ability, and short-term verbal memory are predictive of growth in and final status of phonological awareness may be a second useful finding in understanding early reading development. The simplicity of these tasks makes them among the easiest to administer to very young children and clearly distinguishes them from more difficult phonological processing skills.

It should be noted that all children participating in the present study had normal hearing. Thus, the significance of speech perception for understanding phonological awareness performance lies in something other than hearing per se. Rather, it is the variability in children's perceptual skills that may contribute to differences in phonological awareness performance. Speech perception tasks may, therefore, prove to be useful early diagnostic tools in the long run for identifying those who may have phonological awareness difficulties and, perhaps ultimately, may be at-risk for reading failure.

A number of phonologically based skills may contribute to growth in phonological awareness. For example, Torgesen and Davis (1996) showed that response to training in phonological awareness was affected by several phonologically based skills. Growth in phoneme segmentation was best predicted by invented spelling and general verbal ability, and the strongest predictors of growth in phonemes synthesis were invented spelling and rapid naming of digits. Our finding that vocabulary ability contributed uniquely to growth in phoneme elision is quite similar to that reported by Torgesen and Davis (1996). Future studies should focus on isolating the best longitudinal predictors of phonological awareness as well as on the extent to which different predictors predict different kinds of phonological awareness, such as phoneme segmentation and phoneme synthesis (Torgesen & Davis, 1996).

A third issue addressed in the present study was the nature of phonological awareness development. The substantial correlation between initial status of, and growth in, phoneme elision extended the ideas of Stanovich (1986) of "Matthew effects" to prereading skills. It seems that, as with word decoding and reading comprehension, those who begin with greater phonological awareness tend to develop this awareness more quickly than those who begin with less phonological awareness. Perhaps those who are skilled in phonological awareness seek out word/sound games, such as "Pig Latin" or rhyming pairs, whereas those who have difficulty in phonological awareness actively tend to avoid such activities. Thus, it may be that as children develop, ability and practice effects interact, bringing further up those who are skilled and leaving behind those who are unskilled in phonological awareness.

The fourth theme of the present findings is that the effects of speech perception on subsequent word recognition may be mediated by phonological processing abilities. Although those who began with high and low speech perception showed markedly different word recognition over the four time periods, the effects of speech perception on word reading were not significant once initial phonological awareness and letter-name knowledge were controlled.

Overall, the results of the present study support the

[2] Our fairly conservative allowance of up to three words being read initially on the Woodcock Word Identification subtest was done to make use of as much data as were available and minimize the effects of word reading on growth in phonological awareness. However, others may be concerned that even ability to read three words may confound the reported results. Therefore, in a separate analysis, which included only those 91 students who read 0 words on the word recognition subtest at the initial testing time, we looked at the effects of speech perception on phoneme elision at Time 4. In this analysis, hierarchical regression was used. The overall equation was significant, $F(4, 86) = 10.21, p < .001$. The Block Design contributed 7% of the variance, the vocabulary subtest contributed a unique 18% of the variance, verbal memory contributed an additional 3% of the variance, and the speech perception measure uniquely contributed 4% of the variance, for a total R^2 of 32%. In contrast, when word recognition at Time 4 was predicted in this sample, speech perception did not contribute significantly once Block Design, vocabulary, short-term verbal memory, phoneme elision, and letter-name knowledge were forced into the equation.

previous hypotheses of McBride-Chang (1995a, 1995b, 1996) that speech perception may be among the important precursors of phonological awareness and that its effects on word reading may be mediated through phonological processing skills. One issue to consider with reference to a model of the development of word reading, which posits a direct link between speech perception and phonological awareness and an indirect link between speech perception and word recognition, is timing. We have shown that speech perception and phonological awareness tasks are moderately associated prior to the emergence of word recognition abilities. This association, and the relatively weak association of speech perception and word recognition in older children (e.g., McBride-Chang, 1996; Werker & Tees, 1987), further suggests that a speech perception–phonological awareness link may be a fruitful one to consider in future research.

An issue of particular concern for future studies is the idea of speech perception as a global construct. As reading researchers, we are particularly interested in estimating speech perception as a potentially important predictive variable. However, the myriad of speech measures and conceptualizations available (Elbro, 1996; Nusbaum & Goodman, 1994) and the fact that more traditional speech contrasts are not necessarily correlated (McBride-Chang, 1995b) make defining and constructing adequate measures of speech perception arduous. Tallal's (1980) finding that stop consonants are the most difficult contrasts for those who have difficulty reading may prove helpful in future studies of reading. Given that the stop consonant continuum used in the present study was moderately associated with performances on phonological awareness tasks, such contrasts may be optimal in future studies in which phonological awareness and reading are predicted.

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