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2 Early Precursors of Reading-Relevant Phonological Skills

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INTRODUCTION

There is a great deal of evidence that phonological awareness is a prerequisite for reading an alphabetic orthography (McCardle, Scarborough, & Catts, 2001; NICHD Early Child Care Research Network, 2005; Scarborough, 1998, 2005; Walley, Metsala, & Garlock, 2003). Phonological awareness at the level of the phoneme, the aspect most relevant to learning to recognize words in print, does not develop spontaneously, but depends on specific learning and instruction (e.g., Byrne, 1998; Goswami, 2002). Other aspects of phonological awareness, such as rhyme sensitivity and the associated factor of phonological memory, do develop spontaneously in preschool children, but the nature of their relationship to phoneme awareness and reading readiness is not clear. Moreover, connections between phonological awareness in preschool and school-aged children and the early phonological sensitivities of infants and toddlers have not been systematically studied. Further, there are sizable gaps in our understanding of relationships between early preliterate phonological sensitivities, individual variation in vocabulary development, and language development more generally.

Broadly speaking, phonological awareness is the ability to reflect on the building blocks of word forms (Liberman, 1999; Mattingly, 1972). It is a species of metalinguistic awareness, other types of which include morphological, syntactic, and pragmatic awareness (Chaney, 1992; Tunmer, Herriman, & Nesdale, 1988). Performance on metalinguistic “awareness” tasks relies on at least two factors. First, the relevant level of structure (e.g., *phonemes*) must be present in the child’s cognitive organization (Fowler, 1991; Metsala & Walley, 1998; Walley et al., 2003). Second, the child must be able to consciously access those same elements of linguistic structure (Vygotsky, 1962). Certainly, at about the same time that infants’ phonological and lexical systems are beginning to develop toward an adult-like state, their domain-general memory and cognitive abilities are also beginning to take shape (Diamond, 1985; Lalonde & Werker, 1995; Tomlinson-Keasey, Eisert, Kahle, Hardy-Brown, & Keasey, 1979). Indeed, some reading researchers have suggested that the developmental progression in meta-cognitive function, apart from the details of phonological representations themselves, may be a cornerstone of phonological awareness (e.g., Tunmer et al.). From this perspective, the relationship of phonological awareness to reading readiness may have more to do with the meta-cognitive features of the skill than with phonology as such.

In this chapter we argue, as others have before us (e.g., Fowler, 1991; Walley, 1993; Walley et al., 2003), that a complete understanding of reading-relevant phonological skills, including phonological awareness, requires an account of their developmental trajectory from the earliest stages. An improved understanding of the development of these abilities should lead to more effective and earlier identification of children at risk for reading disability, and would inform the development of age-appropriate early intervention and prevention. However, investigation of these issues, especially among the youngest individuals, has been suboptimal for two key reasons. First, research targeting the emerging language skills of infants and toddlers has tended to rely on cross-sectional rather than longitudinal research designs. There are well-known problems with the use of aggregated cross-sectional data to make inferences about change over time. These include the fact that such data do not permit inferences about individual differences in rates of development, or for the examination of (potentially) changing relationships among cognitive factors within individual learners. Certainly, the tendency to rely on cross-sectional studies is not universal, and we will review a few of the promising longitudinal studies in the literature. A second limitation of research in this area stems from the relative lack of assessments for the various levels of phonologically grounded abilities with established relevance to early literacy that are appropriate for very young children (much before the age of 3 years). A related problem is the lack of measures that can be used across a wide span of development, from infancy through preschool for example. We will discuss some of the challenges to development of reliable measurement across this age span and will summarize work from our own laboratory that we believe holds the promise of addressing these challenges.

LEXICAL REORGANIZATION AND LEXICAL QUALITY HYPOTHESES

Phonological awareness has proved to be a powerful explanatory factor with regard to group and individual variation in reading achievement, but the developmental etiology of phonological awareness itself has remained elusive, including its relationship to the earliest phonological abilities of infants and toddlers. Beginning with the earliest point at which phonological awareness can be measured using conventional awareness tasks, there is individual variation (e.g., Chaney, 1992; MacLean, Bryant, & Bradley, 1987). Some have argued that this variation is linked more or less directly to differences in the developmental state of underlying phonological representations (Anthony & Francis, 2005; Carroll & Snowling, 2001; Elbro, 1996; Fowler, 1991; Storkel, 2002; Walley, 1993). While proposals differ somewhat in detail, the basic idea underlying these *lexical reorganization hypotheses*, is that the need to keep representations distinct in a growing lexicon forces phonological word forms from initial global or holistic representations toward finer-grained, ultimately phonemic, representations. An explicit assumption of these proposals is that the observable phonological sensitivities of infants (as reflections of their emerging lexical representations) are continuous with and causally related to individual differences in subsequent meta-phonological awareness; developmental and skill-related changes in the degree of meta-phonological ability are driven, at least in part, by growth of the lexicon.

The *lexical quality hypothesis*, spelled out in Perfetti and Hart (2002; Perfetti, 2007; also see Ehri, 1992; Nation & Snowling, 1998) and elaborated in Braze, Tabor, Shankweiler, and Mencl (2007) incorporates the following premises: (a) knowledge of word forms can be partial; (b) word learning is an incremental process so that the quality of representations, both phonological and semantic attributes, changes over time; and (c) activation of stored lexical representations is a graded function of (at least) the perceptual quality of speech or print tokens. Thus, the hypothesis is consonant with dynamical models of lexical representation and access (e.g., Plaut, McClelland, Seidenberg, & Patterson, 1996; Seidenberg & McClelland, 1989). Seen in this light, a further implication of the lexical quality hypothesis is that weak knowledge about one aspect of a word's representation (ranging at least over phonology and semantics, as well as orthography in literate individuals), may be compensated for if a reader/hearer's knowledge of another aspect of the word is relatively strong. Thus, during the apprehension of speech (or print) the accessibility of word knowledge is a function of both the quality of that knowledge and the quality of the signal. A key feature of this hypothesis is that poor quality representations may provide insufficient support for linguistic apprehension in the context of particularly demanding circumstances such as reading, speech perception in noise, or simply decontextualized word recognition.

Perfetti and Hart (2002) have termed this a matter of the "functional identifiability" of words. This entails that aspects of word knowledge that are accessible and usable in some contexts may be inaccessible in other, more challenging, contexts. Functional identifiability may provide the foundation for an explanation of why the same child can more easily demonstrate phoneme awareness in some contexts than in others (e.g., Byrne & Fielding-Barnsley, 1989, experiment 5, 1990, experiment 3). Similarly, it suggests an explanation for why infants are able to discriminate phoneme level detail in some situations and yet fail to use that same level of detail for distinguishing lexical items where comprehension is at issue (e.g., Stager & Werker, 1997; Swingley, 2003). Offering a different explanation, the lexical reorganization hypothesis was put forward in part to explain the developmental progression of phonological awareness, moving from lexical to syllabic to subsyllabic (onset, rhyme and ultimately phoneme) constituents. At present, it is not clear whether the lexical reorganization hypothesis can be subsumed by the lexical quality hypothesis.

In addition to phonological awareness, other reading-related abilities have been identified which, when measured in preliterate children, correlate 1 to 3 years later with reading achievement (typically indexed as decoding skill) at least as well as does phonological awareness (see Scarborough, 1998, 2005, for reviews). These include verbal memory, rapid automatized naming and vocabulary knowledge. Moreover, a few recent studies point to predictive relationships between early phonological development, as gauged by speech perception in infancy, and later language development, including vocabulary knowledge (Espy, Molfese, Molfese, & Modglin, 2004; Leppanen, Pihko, Eklund, & Lyytinen, 1999; Lyytinen et al., 2001; D. L. Molfese, 2000). It is desirable to have a unified theoretical framework able to capture empirically established connections among these constructs, and we will use the Lexical Quality Hypothesis and the Lexical Reorganization Hypothesis to structure our discussion.

Our goals for the remainder of this chapter are first, to selectively review existing work relating to the developmental progression of individual differences in reading-related phonological awareness and underlying phonological capacities (phonological memory, phonological/articulatory fluency, and efficiency of lexical access) in the age range of toddlers and early preschool-aged children; second, to discuss measures of cognitive capacities that have the greatest potential relevance to informing a theory of the development of reading relevant language skills from infancy through maturity. We will then summarize work in our laboratory that we believe holds promise for early identification of individual differences in memory for phonologically structured material and in sensitivity to aspects of phonological structure, in particular, rhyme, in toddlers and infants (Clark, McRoberts, Van Dyke, & Braze, under review; McRoberts & Braze, under review; McRoberts, McDonough, & Lakusta, 2009).

OVERVIEW OF LONGITUDINAL STUDIES OF EARLY LANGUAGE POINTING TOWARD LITERACY

Despite a consensus about the central role of phonological awareness in attaining literacy (Ehri, 2004; Ehri et al., 2001; National Reading Panel, 2000; Scarborough, 1998, 2005; also see Adams, 1990; Anthony & Lonigan, 2004; Share & Stanovich, 1995), little is known about its earliest development or the specific nature of its relationship to other phonologically grounded capacities among the very youngest preliterate children. In fact, most longitudinal studies of precursors to reading ability begin tracking children not much more than a year or so before the onset of formal education, in part because the conventional tests of phoneme awareness and other school-age associates of reading skill are too difficult for toddlers and early preschool-aged children. Because our emphasis here is on potential literacy precursors in toddlerhood and infancy, we will touch but briefly on two longitudinal studies of preschool to grade-school literacy development; both of which are notable for the relatively early initial measurement point, and for the inclusion of children at genetic risk for reading disability. The remainder of this section will survey several studies that relate speech perception in infancy to later language development.

From Preschool Language Skills to Grade-School Literacy

Scarborough (1990) tracked the development of literacy-related skills in children from 30 months to 8 years of age. In an innovative design, two groups of children were recruited according to whether or not they carried family risk of reading disability, operationalized as having a parent or older sibling with poor reading skills despite adequate IQ. In retrospective analyses, Scarborough found that at-risk children who were subsequently identified as reading disabled showed early difficulties with syntactic performance and also made more speech production errors at 30 months of age than their at-risk but non-dyslexic peers. By the third year of life they had also fallen behind in vocabulary development. By 5 years of age, these children showed deficits in phonological awareness and picture naming skills relative to both the at-risk but non-dyslexic group and the control group. There are two remarkable design features of Scarborough's seminal study. The first is the risk-group/non-risk-group aspect of the design, and the second is the early age of the initial measurement point. Other studies using similar risk/non-risk designs have followed, but few have tracked children from such an early age. An exception is the Jyväskylä Longitudinal Study; we will discuss findings from that study in a following section.

Maggie Snowling and colleagues also employed this type of design, collecting three waves of data at about 2-year intervals beginning relatively early at 45 months of age (Snowling, Gallagher, & Frith, 2003). This allowed retrospective comparisons of fairly early preliterate profiles for three groups: at-risk children who ultimately achieved reading skill in the normal range (about 40% of the at-risk sample), at-risk children ultimately diagnosed as reading disabled, and a control group. Those comparisons revealed that, at 45 months of age, at-risk children who later achieved reading skill in the normal range were indistinguishable from controls on most measures, except for an early measure of phonological awareness (rhyme), whereas the at-risk impaired group's performance was below that of the controls (and the unimpaired group) on measures of receptive vocabulary, picture naming, verbal memory, and phonological awareness. By 6 years of age, the at-risk unimpaired group lagged behind controls in verbal memory, but not other factors, while the at-risk impaired group lagged behind both unimpaired and control groups on all measures. Therefore, the results of Snowling and colleagues are consistent with those of Scarborough (1990). An important feature of the Snowling et al. study is its clear demonstration that children who were at risk for reading disability but whose reading abilities fell within the normal range, still showed real impairments in phonologically grounded capacities (verbal memory and phonological awareness) relative to the control group. From their findings, they argued that individuals who express clinically significant levels of reading disability fall in the extreme range of a multivariate continuum, rather than bearing a categorically distinct syndrome. The work of Snowling and colleagues also lent support to earlier proposals of Nation and Snowling (1998) whose research had focused on children with poor reading comprehension despite adequate decoding skill. For this population, they proposed that relative strength or weakness in semantic aspects of word knowledge can serve to moderate individual differences in lexical access via the visual route. Based on their own work, as well as on earlier results such as Scarborough's, Snowling et al. concluded that, rather than a specific consequence of phonological limitations, reading disability is a result of multi-componential deficits, whose early developmental expressions include limitations in vocabulary and grammatical skills. This proposal is very much in accord with our own conceptualization of the lexical quality hypothesis (Braze et al., 2007), and conforms well with a dynamical systems approach to lexical representation and access (e.g., Plaut et al., 1996; Seidenberg & McClelland, 1989).

Predicting Toddler and Preschool Language From Infancy

A few recent studies point to predictive relationships between early phonological development, as gauged by speech perception in infancy, and later language development. These studies have shown that both neurophysiological (Espy et al., 2004; Lyytinen, Ahonen, et al., 2004; Lyytinen et al., 2001; D. L. Molfese, 2000; D. L. Molfese & Molfese, 1997; V. J. Molfese, Molfese, & Modgline, 2001) and behavioral measures (Fernald, Perfors, & Marchman, 2006; Kuhl, Conboy, Padden, Nelson, & Pruitt, 2005; Newman, Ratner, Jusczyk, Jusczyk, & Dow, 2006) of speech perception in the first year to 24 months of life predict a variety of indices of language development in later childhood.

Electrophysiological Studies

Among the more intriguing results in the literature are reports from two longitudinal studies that demonstrate the capacity of electroencephalographic recordings from newborn infants in response to (synthetic) speech signals to predict subsequent language and literacy skills in the preschool and early grade-school years.

In the first of these, Heikki Lyytinen and colleagues (summarized in Lyytinen, Aro, et al., 2004) related both behavioral and neurophysiological measures of speech perception in infancy to reading-related skills in the early grade-school years in the Jyväskalä Longitudinal Study of Dyslexia. Following the work of Scarborough (1990) on American-English-speaking children, this project recruited two groups of Finnish children to participate in the study; those with and those without family risk for dyslexia. Starting at birth, and continuing into the grade-school years, linguistic abilities of participating children were assessed on a number of dimensions, including speech perception in infancy and many acknowledged correlates of reading achievement from early preschool into grade-school. Here, we focus primarily on the relationship of the early neurocognitive measures of speech perception and their associations with subsequent reading-relevant capacities.

As part of the Jyväskalä study, Guttorm and colleagues (Guttorm, Leppanen, Richardson, & Lyytinen, 2001; Guttorm, Leppanen, Tolvanen, & Lyytinen,

2003) measured electroencephalographic (EEG) responses of newborn infants (1–7 days old) exposed to synthetic /ba/, /da/, and /ga/ syllables. These studies identified components of the speech-evoked EEG waveform that distinguished infants at risk for reading disability from those without family risk. The most prominent of these was a pronounced right-hemisphere-positive response to /ga/ syllables from at-risk infants. A follow-up study investigated whether differences in the lateralization of these early EEG waveforms would predict language skills in the preschool years. Guttorm et al. (2005) assessed expressive and receptive language skills at 2.5, 3.5, and 5 years of age; these yielded composite scores that loaded primarily on the lexical and somewhat on the syntactic aspects of comprehension and production. Additionally, measures of verbal memory capacity were collected at 3.5 and 5 years of age. The study found that poorer receptive language skills at 2.5 years of age were associated with increases in the right-hemisphere-positive response to /ga/ syllables in infancy, and that poor verbal memory capacity at 5 years of age was negatively associated with the magnitude of the left-hemisphere-positive response to /ga/ syllables. Regression analyses confirmed that these associations held for both risk groups. The fact that the associations hold for both risk and non-risk groups is consistent with the argument of Snowling and colleagues that RD is not a discrete syndrome.

In another EEG study, Dennis Molfese and Victoria Molfese (D. L. Molfese, 2000; D. L. Molfese & Molfese, 1997; V. J. Molfese et al., 2001; also see D. L. Molfese & Molfese, 1985) identified EEG responses in infants that distinguished between those with good and poor language skills at 3, 5, and 8 years of age. Children were recruited at birth based on their family's willingness to participate and as being either full term and healthy, or as having perinatal complications that required admission to intensive care but of a nature deemed unlikely to produce long-term cognitive difficulties (V. J. Molfese et al.); family risk of reading disability was not assessed in this study. When participating infants were less than 2 days old, they were exposed to synthetically produced syllables, similar to those of the Guttorm study, while EEG responses were recorded. The Molfese stimuli parametrically combined the consonants /b/, /d/, /g/ with the vowels /a/, /i/, /u/, creating nine syllables altogether (D. L. Molfese & Molfese, 1997). Based on a measure of verbal IQ at 5 years of age, children were classified as either high (≥100) or low (<100) language skill. In a discriminant function analysis (DFA), the factors derived from neonatal EEG responses that contributed most to reliable identification of subsequent language skill category fell within two overlapping temporal windows ranging from 70 to 320 ms post-stimulus. Difference scores for the evoked responses to consonants (e.g., the evoked response to syllables beginning with /b/ minus the evoked response to syllables beginning with /g/) at bilateral temporal and right parietal recording sites were most salient in the best fitting DFA, although evoked responses to vowel contrasts also played a role. Ultimately, classification accuracy exceeded 95% for the best model (D. L. Molfese & Molfese).

By 8 years of age, a number of children from this study were observed to meet standard diagnostic criteria for dyslexia whereas two other groups of children were identified either as typically performing readers, or as garden-variety poor readers (D. L. Molfese, 2000). Again, DFA was used to test the accuracy with which 8-year-old children could be identified as typical, poor, or disabled readers based on neonatal EEG components. The best model was able to categorize children with better than 80% accuracy. A third study used hierarchical regression analysis to predict second grade reading skill in a partially overlapping sample of children (V. J. Molfese et al., 2001). In addition to neonatal EEG components, regression models included indicators of socioeconomic status, home environment, IQ, and preschool language abilities, all collected at 3 years of age. For present purposes, the most important finding was that neonatal speech-evoked brain responses were among the significant predictors of second-grade reading skill, even after controlling for measures of environment and language skill collected at age 3.

Behavioral Studies

Several recent studies utilizing behavioral measures of speech perception in infancy have also demonstrated links between early perceptual abilities and later language development. These studies point to relations between several indices of infants' speech perception and later language development, both in the late infancy/toddler period and later into early childhood.

Pat Kuhl and her colleagues (Kuhl et al., 2005; Tsao, Liu, & Kuhl, 2004) report that infants' speech discrimination performance at 7 months is related to word knowledge from 13 to 30 months of age. A developmental decrease in the ability to discriminate phonetic contrasts that are not phonemically relevant in the child's native (or ambient) language is an established feature of the perceptual abilities of infants from about 6 to 12 months of age (e.g., Best & McRoberts, 2003); concordant increases in the ability to discriminate phonetic detail that is relevant to native language phonemic contrasts are not as well established (but see, e.g., Jusczyk, Luce, & Charles-Luce, 1994). Kuhl and colleagues found that discrimination of both native and nonnative speech contrasts as assessed through a conditioned head-turn procedure predicted expressive vocabulary growth through the second and into the third year of life. Specifically, native speech discrimination was positively correlated with vocabulary growth, while nonnative discrimination was negatively correlated with growth in vocabulary.

In two experiments, Newman et al. (2006) related infants' performance on speech perception tasks in their first year of life to later language development. In the first, three tests of infants' speech preferences in the first year of life were used to predict later vocabulary development: (a) preference for passages from a novel language; (b) preference for passages containing words previously familiarized in isolation (i.e., testing infants ability to segment known words from a novel speech stream); and (c) preference for prosodic markers of syntactic structure consistent with familiarized utterances. Results showed that performance on the segmentation test, but not the other two tests, was related to expressive vocabulary at the end of the second year. In a follow-up experiment, a subset of participants was retested on a variety of language and cognitive measures at

4–6 years of age. Newman et al. reported that subjects who had been judged to be successful segmenters as infants had higher overall language quotient scores (including both syntactic and semantic abilities) and higher communicative ability scores (based on parental report). However, there was no difference on a measure of general cognitive ability, indicating that the effect was specific to language development.

Finally, Anne Fernald and her colleagues (e.g., Fernald, McRoberts, & Swingley, 2001; Fernald, Pinto, Swingley, Weinberg, & McRoberts, 1998) examined the development of infants' lexical recognition using both accuracy and speed of processing measures. One important finding from this research is that infants recognize words embedded in sentences incrementally, in the sense that meaning is rapidly extracted from the speech signal, even in advance of it being unambiguously determined. To demonstrate this, Fernald and colleagues measured infants' eye gaze shifts from a distracter picture (e.g., *doggie*) to a target picture (e.g., *baby*), beginning with the onset of a spoken target word (*baby*, in this case). The time to shift gaze to the target image, measured from the onset of the target word provides a reaction time measure of speech processing (Cooper, 1974). When presented with familiar words and target images (e.g., *doggie* versus *baby*), the shift from distracter image to target image can occur within 300 ms for 2-year-old children. This is often before the end of the target word (spoken with prosody typical of child directed speech) and has been interpreted as demonstrating rapid and incremental extraction of meaning from speech. In a subsequent longitudinal study, Fernald et al. (2006) related infants' speech processing efficiency at 25 months, operationalized as time to shift gaze to a target word, with both retrospective and concurrent measures of language development in the second year of life. Correlations between processing speed at 25 months and language measures from 12 to 25 months were generally between $r = -.35$ and $-.48$ (with shorter RTs predicting better language development). Both speed and accuracy measures of spoken word recognition at 25 months were associated with the rate of vocabulary growth between 12 and 25 months. This result provides a link between vocabulary size and the functional identifiability of known words (e.g., Perfetti & Hart, 2002).

Together, these neurobiological and behavioral studies are consistent in showing that infants' speech perception capabilities are related to both concurrent and later language development, especially the rate of expressive vocabulary growth.

STEPS TOWARD EXPLORING LINKS BETWEEN EARLY SPEECH AND SUBSEQUENT LITERACY

In the remainder of this chapter, we will describe work from our own laboratory that we believe moves toward addressing limitations in the ability to track early developmental precursors of literacy-relevant phonological memory and sensitivity to phonological structure.

Sensitivity to Rhyme in Infants and Toddlers

The first study from our own laboratory used a version of the auditory preference procedure to gauge phonological (rhyme) sensitivity in infants and toddlers (McRoberts & Braze, under review). Our study builds on the work of Jusczyk, Goodman, and Baumann (1999), who used the auditory preference procedure (Cooper & Aslin, 1990; McRoberts et al., 2009; Pinto, Fernald, McRoberts, & Cole, 1998) to investigate whether infants categorize consonant—vowel—consonant (CVC) syllables based on shared initial phonemes (consonant or consonant–vowel) or shared final vowel–consonant patterns. They found that 9-month-old infants listened longer to syllable sequences that shared initial consonant or consonant–vowel sequences when compared to sequences with unrelated initial consonant or consonant–vowel sequences. However, they did not find a listening preference for shared final vowel–consonant sequences (i.e., no preference for rhyming syllables). This indicates that 9-month-old infants' attention is drawn to syllable onset information. In turn, the results are compatible with the interpretation that relevant memory traces of CVC syllables include representations of syllable-initial consonants, but that such traces may not be sufficiently detailed to support detection of rhyme similarity (also see Swingley, 2005; Vihman, Nakai, DePaolis, & Halle, 2004).

McRoberts and Braze (under review) investigated the emergence of sensitivity to rhyme in infants and toddlers, also using an auditory preference procedure (described below). We compared childrens' looking times to contrasting sets of rhyming and non-rhyming words. Word lists from six rhyme families (/ɪŋ/, /ɛt/, /ʌn/, /æk/, /an/, /og/) were used, with the words organized into rhyming and non-rhyming sets (as shown in Table 2.1). The non-rhyming sets were made up of one word from each of the rhyming families. Thus, on each trial, children heard a list of words all from one of six rhyming families (e.g., *king*, *ring*, *sing*, *thing*), or from a list of the same words used to form the rhyming lists, but containing only one word from each of the six rhyming families (e.g., *king*, *pet*, *fun*, *pack*).

In the auditory preference procedure used in our laboratory, infants sit on a parent's lap in a small testing booth, facing a computer monitor that displays a checkerboard that serves as a fixation target. At the beginning of each trial, the checkerboard flashes to attract the infant's attention. When the infant fixates on the checkerboard, an observer monitoring the infant's gaze via a video link from a separate room presses a "looking" key on a computer keyboard, initiating the

TABLE 2.1
Examples of Rhyming and Non-Rhyming Trials

Rhyming Trials	Non-Rhyming Trials
1. king, ring, ding, sing, etc.	1. king, hat, run, cake, etc.
2. cat, sat, mat, rat, etc.	2. sat, fun, ding, bake, etc.
3. fun, sun, run, nun, etc.	3. nun, rake, mat, sing, etc.
4. rake, take, cake, bake, etc.	4. take, sun, hat, ring, etc.

trial, and continues to press the "looking" key as long as the child maintains fixation. During the trial, a digitized audio file (in this case, a series of words that either rhyme or do not rhyme) is presented via the computer. The computer also monitors and records the amount of time the "looking" key is pressed. When the "looking" key is up (i.e., the infant is not looking at the checkerboard) for more than 1 s, the trial ends; the sound file stops and the checkerboard is removed. After a brief inter-trial interval, the checkerboard returns, signaling the availability of the next trial. Trials alternate between rhyme and non-rhyme word lists. Accumulated looking times are recorded and averaged across trials to provide mean looking times for each condition.

We used this procedure to test two groups of children for rhyme preference: infants aged 8–9 months and toddlers aged 20–24 months. Each child heard 12 trials, 6 rhyming and 6 non-rhyming, in alternating order. Each child's listening times to the rhyming and non-rhyming trials were entered into a repeated measures ANOVA, with age group as a between-subjects factor and rhyme condition (rhyming, non-rhyming) as a within-subjects factor.

Results indicated a significant Age × Listening Time interaction, readily apparent in Figure 2.1. Further, toddlers listened significantly longer to the rhyming words than to the non-rhyming words, while infants showed no preference. Examination of individual listening times confirmed that almost all the toddlers listened longer to the rhyming trials, but listening times for infants did not differ consistently by trial type (i.e., half listened more to trials in one condition, half to trials in the other). These results are consistent with those of Jusczyk et al. (1999) in showing no sensitivity to word-final VC patterns at

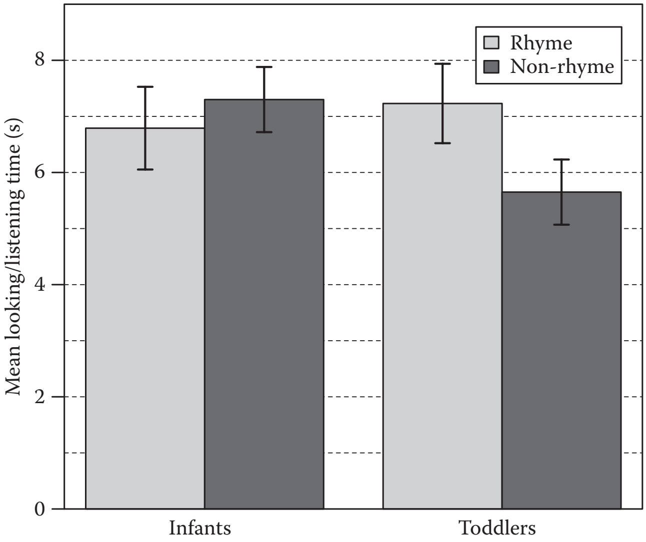

FIGURE 2.1 Mean listening times to rhyming and non-rhyming word lists by 8- to 9-month-old infants and 20- to 24-month-old toddlers.

8–9 months, but suggest that sensitivity to rhyme emerges sometime between 9 and 24 months of age.

Recently, we have begun to pinpoint the age at which rhyme preference typically emerges by testing infants and toddlers between 12 and 24 months of age. Preliminary results suggest that as infants pass 20 months of age, they show a consistent preference for rhyme. Those children who had had a rhyme preference when first tested at a younger age, continued to show a rhyme preference when retested; other toddlers who had not had a preference on initial testing showed a rhyme preference when retested after 20 months. This result holds the promise of a means to assess the early emergence of an aspect of phonological sensitivity and a possible precursor to subsequent phonological awareness abilities.

Verbal Memory in Very Young Children

Infants' emergent phonological systems and their acquisition of a lexicon are likely to be at least partially dependent on the development of memory abilities that provide both short-term and longer term retention of information from the speech signal. Although the early course of development for speech-related memory has not been extensively studied, it is clear that at least rudimentary short-term and even longer term memory for auditory stimuli, including speech, exists prenatally. Fetuses can be habituated to auditory stimuli from 36 weeks of gestation (Hepper & Shahidullah, 1992). Postnatal preferences for speech to which infants were exposed in utero demonstrate relatively long-term retention of some speech information (Decasper & Fifer, 1980; DeCasper & Spence, 1986; Moon, Cooper, & Fifer, 1993).

Both short- and long-term retention of speech information is also evident in the early postnatal period. Two-month-old infants have been shown to discriminate between sentences that differ in a single word after a 2-min post-habituation delay (Mandel, Nelson, & Jusczyk, 1996), and 6-week-old infants who heard the same nursery rhyme over a 12-day period showed evidence of retention as long as 3 days after familiarization (Spence, 1996). These studies provide evidence that infants have the ability to retain some information about speech to which they have been repeatedly exposed (habituated or familiarized) during the perinatal period. However, speech processing must eventually be done online (e.g., Fernald et al., 1998), and these indications from habituation studies fall short of demonstrating the ability to extract meaning from a speech signal in real-time.

Recent results from our laboratory move significantly in that direction by demonstrating that by 5–6 months of age infants have short-term memory for sentences they had heard just once (McDonough, 2003; McDonough & McRoberts, 2003; McRoberts et al., 2009). Using infant-directed speech (i.e., 2–4 syllables, infant-directed prosodic style) in a repetition preference paradigm, infants at 5–6 months showed a preference for immediately repeated utterances over the same utterances arranged without repetition. By 9 months, infants preferred utterances

TABLE 2.2
Examples of Repetition Conditions

I. No Repetition		II. Immediate Repetition		III. Delayed Repetition	
A	Is that funny?	A	Is that funny?	A	Is that funny?
B	Get that fishy.	A′	Is that funny?	B	Get that fishy.
C	Where do these go?	B	Get that fishy.	C	Where do these go?
D	Don't chew on that.	B′	Get that fishy!	A′	Is that funny?
E	Pick up the cup.	C	Where do these go?	D	Don't chew on that.
F	You're OK.	C′	Where do these go?	C′	Where do these go?
G	Turn the page.	D	Don't chew on that.	E	Pick up the cup.
H	Almost done.	D′	Don't chew on that.	D′	Don't chew on that.

that were repeated after two intervening utterances over both no-repetition, and immediate-repetition, conditions.

Sentence material used in this study was selected from transcripts of mother–infant interactions. The utterances were then recorded by a female speaker using prosody typical of infant-directed speech. Multiple tokens of each utterance were produced using different F0 contours identified as common in infant-directed speech (Fernald & Simon, 1984). After acoustic analysis of F0 and duration, final tokens of each utterance were selected and organized into two types of sound files.

One type was made up of non-repeated patterns (e.g., A B C, etc.; Table 2.2, No Repetition pattern). The second type was made up of repeated patterns of utterances, in which different tokens (e.g., A and A′) of the same utterance with different prosodic patterns (e.g., Almost done! and Almost done?) were arranged in repeated patterns (e.g., A A′ B B′ C C′; See Table 2.2, Immediate Repetition Pattern). For example, a series of utterances (e.g., A B C D E F G H) were arranged into two repeated trials in which four utterances were each repeated immediately (e.g., A A′ B B′ C C′ D D′, and E E′ F F′ G G′ H H′) for a total of eight utterances per trial. Later in the session, the same utterances were presented in two control trials (e.g., A B′ C D′ E F′ G H′, and E′ F G′ H A′ B C′ D). Thus, each token of each utterance served as its own control by occurring in both repeated trials and non-repeated trials.

McRoberts et al. (2009) used these stimuli to study preferences of 4- and 6-month-old infants for trials with repeated utterances versus ones without repetition. A significant Age × Repetition Condition interaction indicated that 6-month-old infants had a preference for repeated utterances, demonstrated by longer listening on trials with repetition than on trials without. The younger infants showed no preference for either condition. The fact that the 6-month-old infants detected repeated patterns despite the utterances having different prosodic patterns means they were retaining at least some information about the repeated segmental pattern, and recognized it as familiar after a single presentation. Thus, one factor involved in the emergence of a preference for verbal repetition (between 4 and 6 months of age) might be improvements in speech-related short-term memory.

The role of memory is suggested in another study (McDonough, 2003; McDonough & McRoberts, 2003) in which infants at 5, 7, and 9 months of age were tested for their detection of utterances repeated after a delay. The hypothesis was that older infants would have better short-term verbal memory, which would be seen in a preference for utterances repeated after a delay. Stimuli were prepared as described above, with two tokens of each utterance produced with different prosodic patterns typical of infant-directed speech. A third condition was added to the *no repetition* and *immediate repetition* conditions from the previous experiment. This third condition incorporated *delayed repetition* with two intervening utterances (A B C A′ D C′ E D′). The same tokens of each utterance occurred in all conditions (see Table 2.2).

Infants at each age were tested on all three repetition conditions in a single session. The results showed that 5-month-olds had a significant preference only for the immediately repeated utterances, 7-month-olds had no significant preference, and 9-month-olds had a preference only for utterances repeated after a delay of two intervening utterances. In those age groups showing a preference, 90% of 5-month-olds and 79% of 9-month-olds expressed the preferences characteristic for their age cohort. Within each of those age cohorts, there was a significant correlation between exact infant age and looking times to immediate repetition targets (r =.37) or long delay repetition (r =.21). In a follow-up experiment, 7-month-olds showed a preference for utterances repeated after a short delay of one intervening utterance (A B A′ B′ C D C′ D′, etc.) versus non-repeated utterances. Together, results from these studies point to a means of assessing individual differences in short-term memory for speech in infancy, a significant step beyond assessment of perceptual discrimination.

The experiments just described provide evidence for developmental trends in memory for verbal material. Further, they hold out hope that with an appropriately designed longitudinal study we might be able to connect the surmised developmental trajectory just described to individual differences in verbal memory in the preschool to early grade-school years. At those ages, individual differences on verbal memory measures have been associated with vocabulary acquisition (Avons, Wragg, Cupples, & Lovegrove, 1998; Gathercole & Adams, 1993; Gathercole & Baddeley, 1993; Gathercole, Service, Hitch, Adams, & Martin, 1999), other reading relevant skills, and reading itself (Lonigan, Schatschneider, & Westberg, 2008; Scarborough, 2005).

A recent study from our laboratory measured verbal working memory in preschool children between the ages of 37 and 57 months and demonstrated concurrent associations with emerging phonological awareness. Clark et al. (under review) assessed verbal memory using a novel pseudo-word repetition task and measured phonological awareness using the phonological awareness subtests of the Test of Preschool Early Literacy (TOPEL; Lonigan, Wagner, Torgesen, & Rashotte, 2007). Stimuli for the pseudo-word repetition task were built from two-syllable sequences of trochaic feet (strong–weak syllable combinations). Constituent syllables were

TABLE 2.3
Pseudo-Word Items Consisting of Two Trochaic Feet

Rhyming Items	Non-Rhyming Items
/'bog.zə'hog.zə/	/'mɔit.sə'teiv.də/
/'paif.pə'daif.pə/	/'wig.zə'fum.zə/
/'tiv.bə'kiv.bə/	/'boʧ.tə'deip.sə/

selected to satisfy two sets of constraints. First, in order to minimize articulatory challenges of pseudo-word items their segmental make-up was controlled by excluding consonant phonemes identified by Shriberg and Kwiatkowski (1994) as late acquired (/s/, /z/, /l/, /ɹ/, /ʃ/, /ʒ/, /θ/, /ð/) from items consisting of three or fewer trochees. Strong syllables were paired with weak CV syllables to build trochaic feet. Concatenated sequences of trochaic feet were used to construct two classes of pseudo-words: rhyming and non-rhyming (see Table 2.3). Trochees of rhyming items differed only in the onset of the strong syllable (e.g., /'tiv.bə'kiv.bə/), whereas non-rhyming items differed throughout the first syllable (e.g., /'wig.zə'fum.zə/). Further, because pseudo-word recall is influenced by the wordlikeness of test items (e.g., Gathercole, 1995; Treiman, Goswami, & Bruck, 1990), pseudo-words were matched on this dimension across rhyme conditions by controlling the neighborhood size and summed neighborhood frequency of the strong syllable elements (Rastle, Harrington, & Coltheart, 2002). The test set included items of both rhyme-types starting at a length of two trochaic feet and increasing to a length of six.

Pseudo-words were presented to the children in the context of learning words from a "space language" spoken by a birdlike puppet named "Glerk." Glerk, described as a recent arrival from a distant planet who wants to make friends on Earth, does not speak English, so a translator helps Glerk teach the child some words from his space language. The translator introduces the pseudo-word, a puppeteer for Glerk repeats it, and finally the participating child is asked to say the pseudo-word. (A child's repetitions were accepted as correct if at least the onset consonant in each stressed syllable was produced correctly.) The stimuli became progressively longer on subsequent items. After three consecutive repetition failures in a rhyme condition (rhyme or non-rhyme), that condition was discontinued. Testing in the alternate condition continued until the stop condition was met there. Performance on the two conditions were analyzed; the pertinent result for the present discussion was a significant correlation between pseudo-word repetition and performance on the phonological awareness task ($r = .53$). Although Clark et al. found no difference in memory for rhyming versus non-rhyming pseudo-words in this preschool-aged sample, there is a considerable body of work suggesting that rhyme interference effects do emerge in the grade-school years and that the relative magnitude of these effects is associated with reading skill (e.g., Mark, Shankweiler, Liberman, & Fowler, 1977; Olson, Davidson, Kliegl, & Davies, 1984; Shankweiler, Liberman, Mark, Fowler, & Fischer, 1979). The availability of controlled pseudo-word materials incorporating a rhyme contrast, together with a delivery protocol suited to very young children opens the door to a more thorough investigation of the earliest developmental trajectory of rhyme interference effects.

In summary, the results from these studies examining verbal memory from infancy through preschool hold the promise for measurement of this and other literacy-related constructs across an age span that encompasses preliterate development and the earliest onset of print knowledge. Of course, verbal memory is not the only prerequisite for reading. Normal oral language development, vocabulary, and phonological awareness are also prerequisites. More research is necessary to attain a complete understanding of the patterns within early language development that presage differences in these skills among preschool-aged and early school-aged children. In future work we will ask whether the language development of children as young as 6 months of age reveals the seeds of individual differences in preschool childrens' readiness for reading instruction and in school-age children's reading skills. For example, we have the tools to ask whether and how development of memory for verbal repetition in the first year of life, and sensitivity to rhyme in the second are related to similar skills in the preschool years, and even to the development of reading skills in grade-school.

CONCLUSIONS

The main goal of this chapter was to sketch evidence that a full understanding of reading-relevant phonological skills requires an account of their development from the earliest stages. We are motivated in this by our conviction that the earliest verbal abilities of infants are continuous with subsequent reading-related phonological abilities of older children. Elucidating the emergence of the phoneme as a functional unit is an important part of the ultimate goal of providing a better account of the development of reading readiness and all features of its foundation. Certainly, other aspects of phonological awareness may be relevant, possibly as stepping stones to phoneme awareness, just as other phonologically grounded capacities like verbal memory certainly play some role. Ultimately, reading readiness is likely the result of a rather definite interweaving of phonologic and cognitive abilities. The challenges of research in this area are real, but not insurmountable. By attending to lessons from both speech research in infancy and toddlerhood and literacy research in the preschool years and beyond, we believe that an improved understanding of the development of these abilities is both possible and worthwhile. The hope is that empirical and theoretical developments in this area will open the door to earlier identification of children at risk for reading failure and inform the development of age-appropriate early interventions.

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