# Phonological Processes in Literacy

*A Tribute to Isabelle Y. Liberman*

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# 8 How Early Phonological Development Might Set the Stage for Phoneme Awareness

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Treiman and Zukowski's chapter provides evidence that prereaders are aware of sublexical units intermediate between the syllable and the phoneme. Whereas 4-year old preschoolers can note commonalities in sound only when a full syllable is shared (e.g., en*treat*/re*treat*), 5-year-old kindergarteners also demonstrate an ability to group words on the basis of a shared onset or a shared rime (e.g., *tr*eat/*tr*ick, s*ack*/bl*ack*). In their study, the ability to group words on the basis of a single shared segment (e.g., *br*eak/*bl*ock) does not appear before the first grade. These findings support Treiman's view, expressed in other papers (Treiman, 1985, Treiman & Danis, 1988), that syllables, onsets, and rimes constitute units of linguistic processing that are more accessible than the phoneme. In demonstrating the developmental priority of onsets and rimes, Treiman and Zukowski suggest that this initial cut may serve as a guide in focussing explicit attention on the internal structure of the syllable.

In my discussion, I explore the possibility that the developmental progression observed by Treiman and Zukowski over the preschool years may extend beyond phonological awareness to reflect more fundamental changes in phonological representation, in particular to how lexical items are stored for recognition and retrieval; that is, the child's early vocabulary may originally be represented at a more holistic level, with organization in terms of phonemic segments emerging only gradually in early childhood. This suggestion is consistent with the view adopted by Treiman in earlier papers (Treiman & Baron, 1981; Treiman & Breaux, 1982) and has been supported by a number of researchers studying early phonological development (Ferguson, 1986; Jusczyk, 1986; Menyuk & Menn, 1979; Studdert-Kennedy, 1986, 1987). Because segmental organization would seem to be an essential

substrate for the emergence of phonemic awareness, it may be that extending our investigation to basic phonological development will provide a more complete account of the ontogenesis of phonological awareness and of reading disability than has been available to date.

The traditional view of phonological development has suggested that the lexical structures of the child are organized in terms of phonemic segments well before awareness of these structures is required for alphabetic literacy. Accordingly, the difficulty in achieving awareness of phonemes was attributed to the metacognitive requirements of the task. In the first part of my chapter, I examine the consequences and limitations of a strictly metacognitive hypothesis in accounting for the emergence of phoneme awareness and in explaining individual differences in achieving success. In the second section, I introduce some recent evidence from research on early phonological development that may challenge this assumption, suggesting instead that lexical representations become increasingly segmental between 1 and 8 years of age. In the third section, I examine the implications of this new perspective for explaining phenomena of phonological awareness and reading disability that are not readily handled by the metacognitive account. Finally, I take up the issue of causality, comparing two explanations for developmental and individual differences in phonological awareness and phonological representation.

## THE METACOGNITIVE ACCOUNT OF PHONEME AWARENESS AND READING DISABILITY

Thanks in part to Isabelle Liberman, it is now an established fact that successful reading in an alphabetic system entails phoneme awareness. Whether one wishes to argue that phoneme awareness is a precursor (Bradley & Bryant, 1983; Lundberg, Frost, & Petersen, 1988), a corequisite (Liberman, Shankweiler, & Liberman, 1989; Perfetti, Beck, Bell, & Hughes, 1987), or a by-product of reading acquisition (Ehri, 1989; Morais, Cary, Alegria, & Bertelson, 1979), novel words cannot be decoded without concomitant awareness of the segmental nature of speech (see Gough, this volume). It is also a fact that phoneme awareness is not a necessary outcome of learning to speak a language: Phoneme awareness will not ordinarily develop without specific tuition and even then rarely before 5 or 6 years of age (A. Liberman, 1989). What is not known are the developmental precursors to phoneme awareness and the reasons why success is so variable. Why is it that some children fail to perform adequately on measures of phoneme awareness and fail to read, despite years of instruction, whereas others require but a cursory introduction for success?

In accounting for the absence of phoneme awareness in young children, investigators originally focussed on the explicit level of knowledge required (Gleitman & Rozin, 1977; A. Liberman, 1989; I. Liberman, 1973); that is, it was assumed that preschoolers lacking phoneme awareness should nonetheless display evidence for phoneme-level organization on other phonological tasks such as perception, production, word recognition, and memory. This assumption was based on a traditional model of phonemes and features (e.g., Chomsky & Halle, 1968) and was fueled by the findings that prelinguistic infants can discriminate virtually all phonemic contrasts (e.g., Eimas, Siqueland, Jusczyk, & Vigorito, 1971). Early research on phonological development did not contradict this assumption. On the view prevalent at that time, it was assumed that by the time word production begins, perceptual categorizations, and hence underlying representations, were equivalent to adult surface phonemic forms. Where deviations occurred in production, phonological "rules" such as reduction, deletion, or substitution were invoked to relate the production to the assumed underlying form (e.g., Smith, 1973).



Yet young children typically lack conscious awareness of phonemic segments. It is now well documented that preschoolers cannot tell you that *pat* has three separate sounds (Liberman, Shankweiler, Fischer, & Carter, 1974), produce "just a little bit" of *man* (Fox & Routh, 1976), or "say *pat* without the /p/" (Rosner & Simon, 1971). Four- and 5-year olds also appear to be unable to group words together on the basis of a single common phoneme; they fail to observe the commonality between *prince* and *plate* or *sad* and *bud* (e.g., McLean, Bryant, & Bradley, 1987; Treiman & Zukowski, this volume). To account for the discrepancy in young children between the knowledge of phonemes presumed to underlie their early perception and production abilities and the lack of knowledge exhibited in segmentation and categorization tasks, a distinction was made between implicit and explicit knowledge. It was argued that gaining access to these segments in order to count, label, or manipulate them for the purpose of reading is akin to becoming aware of the many movements that go into walking for the purpose of learning ballet. These are metacognitive tasks imposed upon an autonomously functioning system (see Rozin, 1975, for an interesting discussion of the distinction between identifying the units that guide an organism's behavior and granting that organism conscious access to those units).

Explicit awareness requires that we suspend the normal function of a behavior (here, listening to speech to gain access to meaning) to focus on its formal attributes. This ability to shift readily from one aspect of a stimulus to another, often termed *decentering*, is considered a hallmark of the Piagetian stage of concrete operations that begins between 5 and 7 years of age, just when phoneme awareness is emerging. The hypothesis that metacognitive factors may account for differences in achieving phoneme awareness was given support through a number of studies demonstrating that skill in tasks

requiring awareness of phonemes is associated with skill on other metalinguistic tasks involving awareness of morphological or syntactic structures (e.g., Fowler, 1988). Although the evidence is weaker when metacognitive ability outside of language is assessed, it has been suggested that children must attain some minimal threshold of cognitive development before they can grasp and refer to abstract concepts of word, syllable, or phoneme. For example, children who performed poorly on a Piagetian measure of concrete operations in kindergarten had more difficulty learning to read in first grade than children who did better (Tunmer, 1988).

Although general metacognitive factors do appear to play a role in allowing phoneme awareness to first develop, they are less successful in explaining why some individuals continue to experience difficulty, even after they have attained concrete operations and explicit attention has been called to the phonemic level through reading instruction (e.g., Bradley & Bryant, 1978; Pratt & Brady, 1988; Read & Ruyter, 1985). In fact, reading-disabled individuals from kindergarten to adulthood can perform nonlinguistic metacognitive tasks involving angles or figures but cannot perform the same task operations when the items to be accessed or manipulated are phoneme segments (Fowler, 1990; Lundberg, Olofsson, & Wall, 1980; Mann, Tobin, & Wilson, 1987).

Even awareness of larger linguistic units is not sufficient for phoneme awareness. As demonstrated quite clearly in the study by Treiman and Zukowski, long before children reveal awareness at a segmental level, it is evident that they are attending to the sound structure of language and making associations between words on the basis of a common syllable or portion of a syllable (see also Walley, Smith, & Jusczyk, 1986). Similarly, although extensive training efforts prior to age 5 have been successful in teaching children to segment or categorize on the basis of words or syllables, these training programs have not instilled awareness at a phoneme level, despite intensive efforts (Content, Kolinsky, Morais, & Bertelson, 1986; Fox & Routh, 1976; Treiman & Breaux, 1982). What distinguishes the younger child from the older child, or the nonreader from the successful reader, is the specific failure to access the phoneme (see also McLean et al., 1987).

Finally, it should be noted that there is not a strong association between reading and general intelligence, especially in young children who have not yet experienced the effects of reading failure. As argued by Stanovich (1988), a failure to perform in an analytic manner should cut across all domains, yet the very hallmark of specific reading disability is a failure to learn to read despite adequate intelligence. Specific deficits in phoneme awareness continue to be associated with reading difficulty even when differences in general intelligence have been controlled for (see Stanovich, Cunningham, & Feeman, 1984, for review and discussion).

In contrast to a strictly metacognitive perspective, there is growing evi-



dence that the phonological problems of poor readers often extend beyond the level of awareness (e.g., Brady, 1986, this volume; Liberman & Shankweiler, 1985; Stanovich, 1985; Wagner & Torgesen, 1987). Memory, perception, articulation, and lexical access have been implicated in reading disability; all ultimately depend on phonological representations, yet none obviously requires phoneme awareness. The best documented of these areas is verbal short-term memory: Poor readers are less able than better readers to retain strings of words, digits, or other material that can be verbally encoded. That the difficulty is fundamentally phonological is indicated both by analysis of errors produced and by the lack of difference between good and poor readers on nonverbal memory tasks (e.g., Brady, Mann, & Schmidt, 1987; Katz, Shankweiler, & Liberman, 1981; see Brady, this volume; Jorm, 1983, and Torgesen, 1978 for evidence and discussion).

There is some evidence that reading ability is also associated with naming, the ability to rapidly and accurately produce the phonological labels of items known to be in an individual's recognition vocabulary. For example, kindergarten children who perform poorly on a task involving rapid successive naming of common pictured objects presented in an array are at risk for later reading failure (Blachman, 1984; Denckla & Rudel, 1976; Wolf, 1986). Furthermore, poor readers at a variety of ages make more errors than good readers in their attempts to produce names of objects they can recognize, producing forms phonologically related to the target item. This has been interpreted as indicating that their stored lexical representations may be less precisely specified (Catts, 1986; Katz, 1986; Wolf & Goodglass, 1986).

The third area of phonological difficulty associated with reading disability concerns speech perception and production. Contrary to the expectations of a metacognitive hypothesis, several studies have found that poor readers have difficulty with the categorical perception of certain speech contrasts (Godfrey, Syrdal-Laskey, Millay, & Knox 1981; Pallay, 1986; Werker & Tees, 1987). Similarly, reading disabled children make significantly more perceptual errors than good readers when asked to repeat words presented in noisy listening conditions, although the two groups performed equivalently on a nonverbal control task (Brady, Shankweiler, & Mann, 1983). Poor readers also appear to be less able to accurately produce tongue twisters or to repeat phonologically complex or unfamiliar lexical items, suggesting that their production skills may also be compromised (Catts, 1986; Rapala & Brady, 1990; Snowling, 1981; Snowling, Goulandris, Bowlby, & Howell, 1986).

What we have learned from the literature on reading disability, then, is that a failure to gain access to phonemic segments is associated not with general metacognitive inadequacies, but with a host of other subtle phonological deficits, involving the formation, retrieval, and maintenance of phonological representations. Although the difficulties have been attributed variously to "weak," "fragile," or "underspecified" representations, arrived at via "inef-

ficient" phonological processing, there has been little attempt to further define these terms or to reconcile these individual differences within the current theory of phonological development.

## ON THE EMERGENCE OF THE PHONEME

As we noted earlier, the original concept of phoneme awareness rests crucially on the assumption that the very young child perceives, produces, and represents speech in terms of phoneme categories (Gleitman & Rozin, 1977; Liberman, 1973). More recently, however, several lines of evidence have converged to place this assumption in some doubt, suggesting that basic phonological representations undergo growth and change in the early stages of language development (Ferguson, 1986; Jusczyk, 1986; Menyuk & Menn, 1979; Studdert-Kennedy, 1986, 1987). Most critical is the suggestion that a child's first words are not, as is often assumed, represented as a sequence of independent phonemes but may instead be stored and retrieved as a holistic pattern of interacting elements, variously described as gestures, features, or articulatory routines (Ferguson & Farwell, 1975; Menyuk & Menn, 1979). According to this view, it is only with increasing pressure of the expanding lexicon that the scope of the representation needs to be narrowed, giving salience first to the syllable, and then to subsyllabic units. The implication is that the addition of a phonemic level of organization emerges only gradually in early childhood.

This view of phonological development rests on the assumption that it is not phonemes, but features, or articulatory gestures, that are the fundamental units of perception and production (Browman & Goldstein, 1986, 1989; Tartter, 1986).[1] Positing gestures as the basic components of the syllable is not only consistent with the research on infant perceptual abilities (e.g., Eimas et al., 1971; Kuhl, 1987) but also makes it possible to move smoothly from infant abilities (both perception and babbling) to first words without having to invoke phoneme representations at some intermediate point (Studdert-Kennedy, 1986). What may be changing over the course of phonological development is the ability of the child to coordinate gestures that initially

[1]Note that although I use feature and gesture interchangeably in my discussion of the literature, the idea of an articulatory feature extending throughout the syllable and existing independently of phonemes (Tartter, 1988) is different in critical respects from the distinctive feature described in Chomsky and Halle (1968). Whereas the traditional feature is a linguistic unit crucially tied to the phoneme, articulatory gestures in the Browman/Goldstein model have been defined independently of the phoneme level and explicitly refer to patterns of movement (of lip, jaw, tongue, velum, and larynx), executed with "communicative intent" and embedded within the syllable. In turn, the syllable can be defined as a unit of perception and production without reference to the phoneme.



extend the full length of the syllable into integrated subsyllabic routines that recur in many different environments (Nittrouer, Studdert-Kennedy, & McGowan, 1989). As outlined by Jusczyk (1986), the scope of the gesture may narrow first to the onset/rime distinction and only later to the level of phonemic segments, thus paralleling the developmental progression observed for awareness by Treiman and Zukowski in the chapter under discussion.

This view is also consistent with recent developments in phonological theory, where it has become increasingly evident that a number of linguistic phenomena characterizing a mature system make reference to the entire syllable and cannot be neatly tied to one or another phonemic segment. Such is the case, for example, for tone in Chinese or for intonation and stress patterns in English (cf. Clements & Keyser, 1983). The hierarchical models characterizing current phonology appear to instantiate the very levels postulated as occurring developmentally (e.g., Fudge, 1987). Examination of adult speech errors also provides support for nonphoneme syllable divisions in language processing, indicated by the finding that not all phoneme segments exchange at a similar rate. For example, syllable initial consonant clusters as in *break* or *stop* frequently move together as a unit (e.g., Treiman & Danis, 1988), as do vocalic nuclei composed of a vowel and a following liquid as in *hard* or *cold* (e.g., Shattuck-Hufnagel, 1987; Treiman, 1984).

Of course, from the perspective of acquiring phoneme awareness and reading, the important question pertains to when in early childhood the phoneme level of organization is sufficiently well developed to allow for the isolation, labeling, and manipulation of these segments. Although the bulk of the evidence for the phoneme as an emerging entity derives from studies focussing on early word production in the second year of life, the little evidence we have available suggests that the scope of gestures continues to become increasingly phonemic between 3 and 7 years of age, inviting comparison with phoneme awareness abilities over the same period. In the rest of this section, I review the kind of data from early production and then go on to discuss the evidence for growth extending to the onset of reading acquisition.

When the assumption of the phoneme as a guiding category is suspended, it appears that during the first 50 words or so the basic unit of production is the whole word shape (Ferguson, 1986); that is, children's earliest productions are represented as distinct holistic shapes, with prosodic and articulatory attributes that are not systematically related to other words. The evidence against phoneme-level representation at this stage is generally considered to include three main points. First, phonetic forms appear to be tied to particular utterances: A phonetic form observed in one word is often not generalized across words in early productions. For example, a 15-month old girl studied by Ferguson and Farwell (1985) produced [n] correctly in *no* but substituted [m] for [n] in *night* and [b] for [m] in *moo*. As noted by Nittrouer

et al. (1989), "the child does not contrast [b], [m], and [n] as in the adult language, but the three words with their insecurely grasped onsets" (p. 120). Second, production of any given utterance, the very same word in much the same context, is highly unstable, typically consisting of an almost random ordering of a few articulatory gestures (Menyuk & Menn, 1979). As a particularly compelling example of this, Ferguson and Farwell (1975) present the case of a 15-month-old girl who produced 10 different variants of the target word /pen/ in a half-hour session, which they described as an attempt "to sort out features of nasality, bilabial closure, alveolar closure and voicelessness" (p. 423). The gestures, but not the timing, seem to have been grasped at this point. The third piece of evidence suggesting a more global representation derives from observations that production of any given segment is often heavily influenced by surrounding context, much more so than in adult speech, yielding a high incidence of consonant assimilation as in [dut] or [guk] for *duck* (for reviews, refer to Ferguson, 1986; Menyuk & Menn, 1979; and Studdert-Kennedy, 1987).

As evidence that the lexical representations themselves are reorganized as phonological development progresses, Menyuk and Menn (1979) provide data showing that children retain vestiges of an earlier organization once they have learned a new pronunciation; thus representations for a given lexical item seem to involve multiple levels. This contrasts with previous models of child phonology that emphasized that a representation remains nearly constant from the initial acquisition of a word and affected segments are modified wholesale as "phonological rules" are changed. Whereas it is clear that some modifications are system wide, it seems that underlying representations may also undergo developmental change.

The evidence for continued reorganization throughout the preschool years comes from both production and perception. In one of the few direct tests of the hypothesis that basic phonological representations become less syllabic and more segmental over childhood, Nittrouer and colleagues have performed a pair of experiments examining the perception and production of the same contrast (s/sh) before two different vowels (i/u) in children at 3, 4, 5, and 7 years of age and in adult subjects. Their hypothesis was that a syllable-based phonology would result in even greater interdependence among component gestures than would a segmental phonology. In the perception study, consistent with this hypothesis, young children's identification of the initial fricative was more influenced by the syllable information carried by the following vowel segment than it was by the frequency information that is temporally constrained to the fricative; 7-year olds and adults relied more on the frequency information (Nittrouer & Studdert-Kennedy, 1987; Nittrouer et al., 1989). Corresponding effects were observed in an analysis of production: In an examination of the acoustic structure of syllables produced by these same subjects, it was observed that /s/ and /sh/ were more strongly differentiated with age before each of the vowels, whereas the extent to which the production of /s/ and /sh/ was affected by transition information extending across the syllable decreased with age. These results were interpreted to indicate that "children initially organize their speech gestures over a domain at least the size of the syllable and only gradually differentiate the syllable into patterns of gesture more closely aligned with perceived segmental components" (p. 120).



Other pairs of perception/production studies are consistent with the findings of Nittrouer et al. (1989). Zlatin and Koenigsknecht (1975, 1976) compared perception and production data on the use of voice onset time to discriminate minimal pairs such as *bees/peas*. In both sets of data, voice onset time measures reflected more discrete and less variable phoneme boundaries with increasing age. And, adult-level performance was achieved earlier for perception than for production. In a study of vowel duration as a cue to postvocalic voicing (*bip* vs. *bib*, *pot* vs. *pod*) as evident in perception and production, Krause (1982a, 1982b) also reported that "both systems demonstrate refinement and stabilization with increasing age" (1982b, p. 25). In sum, three pairs of studies have directly addressed the hypothesis that phonological representations become increasingly segmental over this period; all have observed continued greater influence of syllabic structure on phonological contrasts in children up to 8 years of age.

Further suggestion that phoneme representations are continuing to undergo change during the preschool years derives from an analysis of numerous spontaneous speech errors produced by two young girls studied between 1 and 5 years of age (Stemberger, 1989). This is a particularly interesting paradigm in light of the fact that speech errors have often been used as the most solid evidence that phonemes are, in fact, units of production and perception in adults (Shattuck-Hufnagel, 1987; Shattuck-Hufnagel & Klatt, 1979). Although Stemberger's children did produce errors involving the exchange of single phonemes (e.g., "you catch grap-hossers"), they produced proportionately fewer of these errors, and proportionately more feature errors involving subphonemic exchanges (e.g., "I got that gall for pristmas" for "ball for Christmas") than have been reported for adults. This result is consistent with the view that the phoneme may be a less cohesive unit in children than in adults. Similar findings emerged in an analysis of errors produced by children and adults in a word learning task devised by Treiman and Breaux (1982). Four-year olds were more likely to confuse labels that were "globally" similar (essentially where syllables would share features but not phonemes, e.g., *bis* and *diyz*), whereas adults tended to confuse lexical items sharing a common phoneme (e.g., *bis* and *boon*).

The apparent developmental shift in organization observed in production and perception shows interesting parallels with the development of phonological awareness over the same preschool and early school period. Highlight-

ing this parallel is increasing evidence that many young children are sensitive to the sound structure of language, but only when the tasks involve units of organization larger than the phoneme, such as the syllable or syllable onset. Children as young as 3 years can categorize words on the basis of rhyme, alliteration, and syllable structure; and yet investigators remain unable either to demonstrate or to instill awareness of phoneme segments prior to 5 years of age (Content et al., 1986; Fox & Routh, 1976; Liberman et al., 1974; McLean et al., 1987; Walley et al., 1986). Treiman and Breaux (1982) examined this parallel with a direct comparison of phonological organization and awareness. Using the same stimuli employed in their word learning task, Treiman asked a different set of children and adults to classify which two words in a triad "go together." Consistent with the results of the word learning study, 4-year olds tended to group words on the basis of overall similarity, whereas adults were more likely to apply the criterion of a single shared phoneme. With training, adults could learn to classify on the basis of overall similarity, consistent with a multiple representation hypothesis. Children, however, could not be trained to classify on the basis of a single common phoneme.

To summarize the developmental findings, Nittrouer et al. (1989) proposed:

> that the initial domain of perceptuomotor organization is a meaningful unit of one or a few syllables. As the number and diversity of the words in a child's lexicon increase, words with similar acoustic and articulatory patterns begin to cluster. From these clusters there ultimately precipitate the coherent units of sound and gesture that we know as phonetic segments. Precipitation is probably a gradual process perhaps beginning as early as the second to third year of life when the child's lexicon has no more than 50–100 words. But the process is evidently still going on in at least some regions of the child's lexicon and phonological system as late as 7 years of age. (p. 131)

## IMPLICATIONS FOR READING DISABILITY

If phoneme-level representations are continuing to develop and to be refined over the preschool years, and if developmental changes in phonological awareness reflect changes in the very nature of lexical representations, what are the implications for understanding and explaining reading disability? I should note first that such a finding would in no way alter our understanding of phoneme awareness as the immediate prerequisite to reading success. No matter how such awareness arises, it remains the case that reading an alphabetic script requires access to a phonemic organization of lexical structures. And neither would such a finding alter the long understood fact that awareness of this level of organization does not arise spontaneously in the normal course of acquiring a language.



What may be altered, however, is our understanding of how phonological development sets the stage for phoneme awareness, and why reading disability is associated with a broad array of phonological deficits. In regard to acquiring phonemic awareness, the effect of an increasingly segmental organization would seem to be straightforward. If, as the studies cited earlier suggest, the phoneme as a "crystallized perceptuomotor structure" (Studdert-Kennedy, 1987) begins its development in the second year of life and is still continuing up until at least 7 years of age, one would not expect very young children to be able to segment syllables into phoneme-sized units, or to identify "common" phonemes across a range of syllable and word contexts. Rather, the cohesiveness of these phoneme structures in production, perception, and memory may well be expected to influence the ease with which awareness of these structures is achieved, as is suggested by the general parallels that can be drawn between work on preschool phonological awareness and work on developing phonological representations. Similarly, children who, for whatever reason, are progressing more slowly with respect to these phonological abilities should experience greater difficulty in achieving phoneme awareness.

It is somewhat less obvious whether the hypothesized changes in phonological structures can explain the subtle deficits in phonological processing that have been observed in poor readers. Such a discussion requires one to consider what function a phoneme-level organization serves in memory, perception, production, and naming. One can, however, speculate that integrating gestures into phonetic routines serves as a mechanism for automation, providing a highly efficient representational code for encoding, storing, and retrieving phonological structures in verbal working memory (Baddeley, 1986; Stemberger, 1989; Studdert-Kennedy, 1987). The same advantages of a phoneme-level representation invoked by Gleitman and Rozin (1977) to justify the utility of an alphabetic orthography should apply to underlying phonological representations as well. Consider the consequences of representing lexical items in terms of thousands of English syllables that vary in the identity and precise timing of individual gestures and contrast that with a representation based upon approximately 40 phonemes whose gestural consequences have become well specified and overlearned in the course of development. As argued by Gleitman and Rozin, a syllable-level representation may be ideal for Japanese, which has 50 distinct syllables altogether, but it is not at all efficient in English, which has thousands of distinct syllable possibilities by virtue of cluster combinations and complex vowel systems and whose syllable boundaries are often obscure.

The effect of a segmental representation, then, may be to enable a child to convert (or "encode") the acoustic signal specifying a word into a sequence of discrete elements for storage and later reproduction of the correct

articulatory shape. In contrast, a syllable-level or word-level encoding, in which a greater quantity of gestural information must be specified, may more readily overload the limited storage system, particularly in the case of phonologically complex items or lengthy strings of nonsense syllables. This would lead to a more variable and underspecified output, in which only the most salient features are recalled. It is interesting that in a lexical access task involving long complicated words like *thermometer*, poor readers could typically identify overall acoustic shape (e.g., producing *tornado* for *volcano*; or *bulb* and *gulb* for *globe*), but could not provide a full specification of the word (Katz, 1986).

Because the developmental model under discussion allows representations to become augmented over time, highly familiar lexical items would eventually become fully specified, whichever method (phonemic or gestural) is employed and we would be unlikely to observe difficulties specific to poor readers. Where one would expect to find differences to be more evident is in the case of novel words or pseudowords where encoding strategies would play a larger role; or in the case of words that are phonologically complex, where specification may not yet be complete. Young children, and potentially poor readers, whose phonological representations are not segmentally organized may not be as efficient in assigning novel stimuli into a recoverable representation (i.e., for word repetition) as would be children who can readily assign a segmental structure. In fact, poor readers appear to be at a particular disadvantage when asked to repeat pseudoword stimuli (Snowling, 1981; Snowling et al., 1986), and multisyllabic words (Brady, Poggie, & Rapala, 1989). Furthermore, consistent with the developmental hypothesis under consideration, these same difficulties appear to be mirrored in younger preschool children presented with the same tasks (Brady et al., 1989).

It would seem that any task that requires reconstruction of the syllable would be aided by a segmental analysis and by refined, well-articulated prototypes of those segments to which the input must be compared. This kind of reconstruction may be required when the signal is less than optimal either because of noise (Brady et al., 1983), artificial synthesis (Luce, Feustel, & Pisoni, 1983), or dialect variation (Mattingly, Studdert-Kennedy, & Magen, 1983). As discussed earlier, poor readers do appear to have special difficulty in reconstructing lexical items presented under noisy listening conditions (Brady et al., 1983). This finding, together with the fact that poor readers are also at a disadvantage when asked to recall a single nonsense syllable after a filled interval (Dreyer, 1989), suggests that memory problems cannot be wholly explained in terms of lexical access or rehearsal strategies. Rather, both studies speak to a specific problem with encoding, in establishing the original structure of the representation.

In the developmental perspective presented, control over articulation is an important facet of developing stable, and ultimately accessible, phoneme categories (Studdert-Kennedy, 1987). Thus, one might expect to find an association between articulatory control and phoneme awareness. Poor readers should not be, and typically are not, characterized by an absolute inability to produce one or another sound. Efficiency, rather than absolute ability, seems to be implicated in a study by Brady et al. (1989) in which poor readers and young children are more prone to error than good readers and older children when asked to repeat quickly sequences they can produce in isolation (e.g., *bu blu*). If articulation is an important prerequisite to acquiring phoneme structures, then explicit instruction in monitoring articulatory cues should aid in developing more crystallized units for structures to be segmented into. It is of some interest then, that the phoneme awareness training programs that seem to be particularly effective have involved an articulation component (Lindamood & Lindamood, 1969; see Lewkowicz, 1980, for a review).



## THE QUESTION OF CAUSALITY

If, as we suggest, individual differences in phonological awareness are in large part a function of differences in underlying phonological structures, then we have succeeded in moving the question only one step back. What then accounts for individual differences in the development of these structures? Do changes in phonological representation arise spontaneously in the normal course of language learning, independent of metalinguistic demands, driven by the demands of efficiently and adequately storing large numbers of vocabulary items in terms of the fewest sets of features? Or, are phonemes themselves achieved by linguistic analysis, necessarily predicated on language play and alphabetic instruction? That is, does the conscious analytic task of imposing segments on the speech stream for the purpose of reading and writing an alphabetic script lead and shape changes in underlying representations? The answer to this question has important implications for our understanding of reading disability.

Two accounts have been put forth. On the one hand, the *phonological deficit hypothesis* suggests that chronic reading failure results from inefficient phonological processes that impede both acquiring phoneme awareness and processing spoken and written language. On this account, phonological deficits in production, perception, memory, and naming should both precede and predict reading failure and should be independent of both general intellectual factors and environmental factors. Such deficits, one might imagine, should hinder progress toward crystallized phonetic representations and thereby provide the necessary link for a number of phonological prob-

lems associated with reading disability. In support of the phonological deficit hypothesis are prospective studies unconfounded with other variables (e.g., inclusion of readers in the initial sample) that suggest that individual differences in memory and lexical access may presage reading disability (e.g., Jorm, Share, MacLean, & Matthews, 1986). A compelling piece of evidence derives from a recently completed study by Scarborough (1990). In that study, reading disability at 7 years of age was significantly related to performance on basic measures of language structure at 2½ years of age (MLU, syntactic complexity, naming). Reading ability was not related to mother's educational level or reading ability, or to the child's receptive vocabulary at age 2 or age 7. Although the language performance of the would-be poor readers lagged significantly behind the progress of would-be good readers from comparable families, the poor readers' language skills were not sufficiently delayed as to be characterizable as "language delayed" on standardized measures. This finding serves to keep reading disability separate from, though on a continuum with, language disability.

Alternatively, the *orthographic hypothesis* suggests that phoneme awareness tasks, and potentially other phonological measures associated with reading failure, depend not on underlying phonological representations, but on orthographic representations derived as a function of reading experience (Ehri, 1989). Proponents of this view suggest that those phonological tasks on which poor readers fail may be handled more efficiently by reference to the orthographic representation; that is, some of the phonological deficits associated with reading failure may result directly from a lack of experience with the orthographic code, rather than from deficits in the phonological representations relied on in speaking and listening (Derwing, Nearey, & Dow, 1986; Faber, in press; Tunmer, 1988). Even if we do not rely strictly on orthographic representations in all phoneme awareness and phonological processing tasks, there are many reasons to think that metalinguistic factors may play a role in developing a phonemic representation. In support of such a hypothesis, a recent study by McLean et al. (1986) found that individual differences in phoneme awareness in 3- and 4-year old children were strongly associated with the ability to recite nursery rhymes, independent of parental background.[2] What they proposed was that exposure to language play (epitomized here by nursery rhymes) enables the child to become aware of phonemic units. Whereas their argument applies to phonological awareness,

[2]Because the accuracy of a child's recitation of nursery rhymes was the measure of interest, the findings by McLean et al. (1986) could also be construed as supporting the phonetic deficit hypothesis. Children could be less accurate not because of lack of exposure but because of less developed linguistic ability.



it may be possible to extend it to phonological representations as well, with language play aiding in the construction of the relevant units of phonology. Indeed, an important role for language play has been hypothesized by child phonologists in order to account for further refinements in word representations in toddlers beyond the 50-word stage (Ferguson & Macken, 1983; Jusczyk, 1986; Macken & Ferguson, 1983).

Although it may well be that metalinguistic experience in general, and orthographic experience in particular, may aid us in refining our phonological representations, these findings need not commit us to the view that phonemes are arbitrary or epiphenomenal in nature. The standard arguments continue to apply, including evidence from linguistic description, speech error analysis, and the ease with which we come to use an alphabet code, once awareness has been achieved (e.g., Gleitman & Rozin, 1977; Studdert-Kennedy, 1987). Recall, for example, that the speech errors produced by Stemberger's young children did include phoneme exchanges, although these occurred relatively less frequently than in adult production. One must also be able to account for the fact that many Japanese children not explicitly taught an alphabetic system eventually do "discover" phoneme categories (Mann, 1987). What is changed in this account is only that phoneme-level representations, implicit as well as explicit, may not come for free but rather must emerge over time, in the course of lexical expansion, language play, and, potentially, orthographic experience.

Of course, if changes in representation, like the acquisition of phoneme awareness, can be aided by a catalytic prompt (most notably, reading instruction), then a fundamentally more optimistic story can be told. It suggests that successful training in phoneme awareness may have important repercussions throughout the phonological system. Although the evidence of considerable growth in segmental organization during the preschool years points to a developmental trend towards segments independent of reading experience, there is reason to believe that such a trend can be given a nudge. Note, for example, the remarkable findings of phonological coding in memory in deaf children who have been taught to read (Hanson, this volume). Clearly these students did not derive segmental representations through canonical language development; it is possible, however, that the extensive articulation training provided the deaf may aid in forming these representations.

In sum, whereas a traditional view of phonological awareness sharply distinguishes between a phonological and environmental accounts of reading disability, the developmental perspective presented here can comfortably handle both: Biological predispositions of the language system may be shaped by linguistic experience. Whether segmental awareness affects phonological representations, or vice versa, or whether there is a complex interplay between the two (as seems to be the case for phoneme awareness

and reading), finding a close correspondence between the two may increase our understanding about reading disability.

## SUMMARY

I have hypothesized in this chapter that developmental changes in phonological representation may set the stage for acquiring phoneme awareness, and hence, for reading acquisition. I have further suggested that a failure along this same dimension may be responsible for the finding that poor readers are characterized by deficient phonological representations as evident in diminished short-term memory, inability to encode phonological structures under stressed conditions, and underspecified lexical representations.

A great deal of work remains both to track the development of phonological representation over the preschool and early school years, and to assess the impact of these changes on memory, analysis, and other tasks. Nonetheless, we are left with a sense that the phonological representations upon which analysis depends are not a preset immutable part of language. Indeed, as suggested here, it is possible they may be influenced by increased vocabulary, word play, phonological awareness, and literacy. Once phonological representation is taken out of the realm of the invariant, it becomes possible to do productive research on the relationship between, and development within, awareness and representation. It allows us to be both more specific about what a phonological deficit consists of and more optimistic about remediating reading disability.

I conclude this discussion by applauding Treiman for her thorough and systematic chronicling of the emergence of phoneme awareness and for her efforts to relate awareness and underlying representations. Where many have indicated a lack of phoneme awareness, Treiman, like Liberman before her, has pressed on to ask the more positive question of what units of sound are salient for the young child. Treiman's further refinement of this developmental progression within the context of modern phonology sets the stage for a more explicit account of growth and change in phonological representation than has been available to date, enriching our understanding of phonological processing and phonological development.

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