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1 How Theories of Phonology May Enhance Understanding of the Role of Phonology in Reading Development and Reading Disability

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INTRODUCTION

A theory of *phonology* characterizes the systematic ways in which language communities use basic language forms (for present purposes, consonants and vowels) to encode linguistic meanings. *Phonology* contrasts with *phonetics*, the study of the physical articulatory and acoustic properties of those language forms. In most approaches, the contrast between phonology and phonetics is between the cognitive or mental, and the physical (e.g., Pierrehumbert, 1990). Phonological language forms are held to be discrete, symbolic components of a language user's linguistic competence; phonetic language forms are its continuous, articulatory, and acoustic realizations. This is not the conceptualization with which I will end this chapter, but it is one that pervades most linguistic perspectives on the sound systems of languages.

Understanding the nature of phonology is relevant to understanding reading, reading acquisition, and reading impairments. This is in part because humans are biologically adapted to spoken language, whereas reading and writing are too new (and insufficiently widespread) in human history to have shaped human evolution.

The adaptation of humans to the spoken language is evidenced by specializations of the human brain, not only for language, but, specifically, also for the spoken language, not the written language. Lieberman (1984) also suggests that the human vocal tract is adapted to speech (but see, Fitch & Reby, 2001, for another point of view). The human vocal tract differs from that of other primates in a way (a lowered larynx) that permits the production of a wide array of consonantal and vocalic gestures. The range of sounds producible by other primates is considerably more limited. A lowered larynx, other than conferring this advantage in sound production, appears maladaptive in permitting accidental choking on food; accordingly, Lieberman suggests that it must be an adaptation to speech.

That the spoken language is an evolutionary achievement of humans is also indicated by its universality. It is universal across human cultures and is nearly universally acquired within cultures. Unless children are prevented by severe hearing loss or severe mental deficiency, they learn a spoken language and learn it without explicit instruction. Literacy contrasts with the command of the spoken language in all of these respects. Many human cultures lack a writing system, and, within cultures, literacy is not universal. Children almost always have to be explicitly taught to read, and many, even when given apparently adequate instruction, fail to learn to read well.

A second reason why understanding phonology should foster understanding of reading, here particularly reading acquisition, is that the vast majority of children begin reading instruction when they are already highly competent users of a spoken language. Moreover, the language they will learn to read is typically the language they speak, albeit generally a different dialect of it. If beginning readers can learn to map printed forms of words onto the words' phonological forms, they can take advantage of their competence in the spoken language when they read.

Both of these observations, that the spoken language, but not the written language, is an evolutionary achievement of the human species and that most novice readers already know by ear the language of which they are becoming readers, suggests that reading should be "parasitic" on the spoken language (Mattingly & Kavanagh, 1972) during reading acquisition and thereafter. Research on skilled readers bears out the latter expectation. Skilled readers access the phonological forms of words very soon after seeing the printed form (e.g., Frost, 1998); this occurs among readers of writing systems that vary considerably in the transparency with which the writing system signals the pronounced form of words.

In short, a language user's phonological competence appears to provide an entryway or interface by which readers can access their knowledge of the spoken language, and, perhaps, their biological adaptation to the spoken language. Understanding phonology, then, may provide insights into reading, reading acquisition, and reading difficulties. In the following, I will offer some speculative insights that the study of phonology may provide into the latter two domains.

DIVERSITY AMONG THEORIES OF PHONOLOGY

There are, and there have been, many different theoretical approaches to the study of phonology. In some instances, new approaches emerged from the identification of deficiencies in an existing approach, for example, when generative approaches

to phonology (beginning with Chomsky & Halle, 1968) superseded descriptive (also known as structural) approaches (e.g., Gleason, 1961; Trager & Smith, 1951). However, in some cases, approaches have coexisted (e.g., autosegmental theories beginning with Goldsmith, 1976, and metrical approaches, beginning with M. Liberman & Prince, 1977), focusing on largely, but not entirely, distinct phonological domains.

In each case, issues of special interest in one approach recede in relevance or even disappear in others. For example, a central construct for descriptive linguists was that of the "phoneme," an abstract category characterized by its role in capturing the phenomenon of linguistic contrast (see section "Descriptive linguistics"). When Halle (1959) and Chomsky (1964) identified inadequacies in the outcomes of the procedural system by which descriptive linguists partitioned the phones of a language into phoneme classes, they (Chomsky & Halle, 1968) abandoned the concept of the phoneme altogether. Their generative phonology set aside the notion of contrast, focusing instead on systematic processes that hold across the lexicons of languages (see section "The generative phonology of Chomsky and Halle (1968)").

I will take the view here that the successes and failures of different theories of phonology, past and present, shed valuable light on different aspects of the phonologies of languages, which, in turn, may provide insight into reading. In the following, I will discuss three different phonological theories: descriptive linguistics, generative phonology, and articulatory phonology (e.g., Browman & Goldstein, 1986), and discuss the possible insights that an examination of them may provide on reading acquisition and difficulties in learning to read.

Descriptive Linguistics

The aim of descriptive linguists in the domain of phonology was to classify the consonantal and vocalic phonetic segments of the given languages into phonemes. Phonemes are classes of phonetic segments used by members of a language community. Community members use phonemes contrastively to distinguish words; they do not use phonetic segments within a phoneme class contrastively. Examples in English of phoneme classes are /p/, /t/, and /k/. Roughly, each of these phonemes has two variants, an aspirated variant [p^h] that occurs in stressed syllable-initial position (*pill*, *till*, *kill*) and an unaspirated version [p] that occurs elsewhere (*spill*, *still*, *skill*). There are no words of English that differ just in whether the unvoiced stop is aspirated or not. So, for example, there is no word [pɪl] that differs from [p^hɪl] in having an unaspirated [p], but otherwise differs in no other way from *pill* in its form. ([p] differs from the initial segment of *bill* in having a devoicing gesture.) Thus, the different variants or "allophones" of a phoneme do not contrast. This is different from the relation of either allophone of /p/ relative to /b/. We have word pairs such as *pill* and *bill* that differ only in the first consonant and that have different meanings. /p/ and /b/ are contrastive in English.

In descriptive linguistics, phonemes are represented in terms of their featural attributes. Figure 1.1 provides an example. In the word *tab*, the first consonant is an unvoiced, alveolar stop, the vowel is a front, low, unrounded vowel, and the

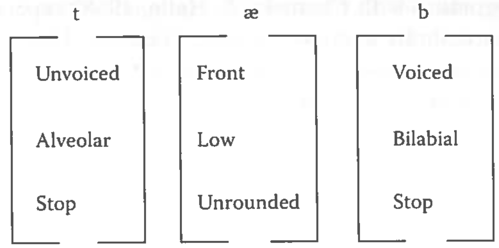

FIGURE 1.1 One way of representing word forms as sequences of consonants and vowels characterized by their featural attributes. The word is *tab*.

final consonant, /b/, is a voiced bilabial stop consonant. (There are many feature systems. I have chosen a simple one for Figure 1.1.)

In these representations, consonant and vowel phonemes are discrete from one another and are invariant in their featural attributes. Entities with these characteristics are what the letters of an alphabetic writing system represent more or less directly depending on the writing system.

When consonants and vowels are represented by feature columns, time is absent except as serial order. Therein lies a difficulty for this way of describing phonological or phonetic segments. There are some indications that time is inherent in the consonantal and vocalic segments of languages. For the present, I will present just some of the evidence. Its relevance to reading, however, may not be obvious. After all, alphabetic writing systems have the same character. Time is absent in their representations except as serial order. In the following, I will suggest that the relevance to reading has to do with the attainment of phonemic awareness. It is not always clear whether a set of features constitute one segment or two.

Ewan (1982) offers several examples of the so-called complex segments in which there is ambiguity as to whether a phonological "segment" is really one segment or two. One compelling kind of example comes from languages that will be unfamiliar to most readers. Some languages have consonants that are identified as "prenasalized stops." These are segments that begin as nasalized segments, but end as oral consonants. An example is from the language Nyanga, the disyllable /^{m}bale/. In this language, prenasalized stops have the duration of single segments. In some languages, they also have the distributional characteristics of single segments. That is, they occur in the contexts that single segments occur in. In Nyanga, they contrast with trisyllabic sequences such as /mbale/ in which the /m/ is syllabic (Herbert, 1977, cited in Ewan).

Although at least one phonologist proposed retaining the featural representation of segments, despite the existence of complex segments, by allowing a feature (here nasality) to change state within a feature column (Anderson, 1976), it violates the fundamental nature of this representation type.

Other examples come from English. English has two affricate consonants, the phone at the beginning and end of the word *church* and the phone at the beginning and end of *judge*. Like prenasalized stops, they are characterized by a dynamic

change. At onset, they have a stop-like character, but this gives way to a fricative-like character subsequently. Relatedly, two notations are used to represent these phones. In one, they are /ʧ/ and /ʤ/, respectively, whereas in the other they are /č/ and /ǰ/. One segment or two?

A final, surprising set of examples consists of the /s/-stop clusters in English. The clusters /sp/, /st/, and /sk/ appear to be sequences of two consonants. But there are reasons to question whether they are. As consonant sequences they are the only clusters in English that violate the "sonority constraint" that is commonplace in languages. The constraint is that consonants closer to the vowel nucleus in syllables must be more "sonorous" (roughly more vowel-like) than those farther away. So, if /p/ and /r/ precede the vowel in a syllable, the order must be /pr/ (as in *pram*, for example), with the continuant consonant /r/ closer to the vowel than the noncontinuant /p/. If the same two consonants follow the vowel in a syllable, the order has to be /rp/ (as in *harp*). But continuant /s/ precedes /p/, /t/, and /k/, both before (*spill, still, skill*) and after (*rasp, last, ask*) the vowel. The order violates the sonority constraint before the vowel. But if s-stop "clusters" are, in fact, single segments, then there is no violation. Fudge (1969) points out also that, in English, a statement about what consonants can occur in clusters is simpler (because no three-consonant clusters can occur) if /s/-stop clusters are considered single segments.

I will show shortly that the shortcomings of the featural representations in handling dynamic change can be overcome to a large extent by using a different representational system, that of articulatory phonology (e.g., Browman & Goldstein, 1986, 1992). However, the central message here is not that featural systems are inadequate. It is that word forms are only approximately composed of sequences of discrete consonants and vowels. Some consonants (e.g., prenasalized stops and affricates) and vowels (e.g., diphthongs) have properties of single segments and some properties of sequences of segments. There may be no right answer to the question whether affricates are single segments or else are sequences of segments. They have properties consistent and inconsistent with both solutions.

That is the nature of natural languages. The properties of languages emerge and change as people talk to one another. The properties that work (i.e., that enable communicative exchanges to succeed) have to be mostly systematic, but they do not have to be wholly formal. When phonological analyses fail to capture all of the relevant facts about a language's phonological system (e.g., when Chomsky and Halle's (1968) trisyllabic laxing rule has to predict that *obesity* should be pronounced *obehsity*), that is just a fact about living languages. There are exceptions to most of the generalizations that can be drawn about the sound systems of language.

What does any of this have to do with reading? For one thing, it offers yet another reason why achieving phonemic awareness is difficult. Phonemic awareness is difficult for children to achieve because, quite rightly, they are inclined to think about what word forms mean, not what they sound like (e.g., Byrne, 1996). If A. M. Liberman (1996) was right that speech perception is served by a brain "module," then phonemic awareness is also difficult to achieve because language users cannot introspect on the workings of the module (Fodor, 1983) that produces consonants and vowels and extracts them from spoken input. But, thirdly, it is difficult to achieve because there is sometimes no clear answer to the question of how many segments compose a word. How many segments are there in *church*? Are there three, the two affricates and the /r/ colored vowel? Are there five, because the affricates are each really two segments? Are there six, because the vowel is not /r/ colored, it is a vowel coarticulating with /r/? There may be no right or wrong answer. Because even spoken languages with very regular and consistent alphabetic writing systems will have these ambiguous segmental properties, the letters of the alphabet only can come close to mapping in a one-to-one way to the basic phonological entities of the spoken language.

The Generative Phonology of Chomsky and Halle (1968)

Analysis of the phonetic segments of a language community into phoneme classes was shown not to work in all cases by Halle (1959) for Russian and by Chomsky (1964) for English. In some cases, violation of principles used to associate phones with phoneme classes occurred. For example, a violation of the "absolute invariance condition" (that the phoneme class to which a particular phonetic segment belongs has to be determinable independently of the context in which it occurs) happens in the words *writer* and *rider* when the /d/ and /t/ phonemes are both realized as the flap [ɾ]. Because of occurrences like this, the flap appears to be an allophone of both phonemes, and the phoneme class to which the phonetic segment belongs cannot be determined independently of its context (in the example, the preceding vowel length).

This violation and others might have been interpreted as yet another indication that language forms are only almost formalizable. However, for Chomsky and Halle (1968), they necessitated a radical change in approaches to phonology, in which the concept of phoneme was banished. Although the notion of abstract cognitively represented segments, as in Figure 1.1, was retained, the property of *contrast* as the defining characteristic of those segments was abandoned. Instead, Chomsky and Halle focused their attention on distinguishing properties of words that are systematic across the lexicon from those that are idiosyncratic to a word. They proposed that lexical forms should represent just the idiosyncratic properties. Systematic properties could be generated by rules applied in the transformation of cognitively represented lexical forms to physically realizable phonetic forms. The difficulty discussed earlier that time needs to be incorporated into linguistic representations of word forms was not addressed, and so lexical representations resembling that of Figure 1.1 continued to be part of the phonology.

For example, in the English word *tab* of Figure 1.1, the fact that the initial consonant is aspirated is not indicated, because aspiration can be generated by a general rule of the language that voiceless stops are aspirated in stressed, syllable-initial position. Likewise, that the vowel is long (as compared to its length in *tap*) is not represented, because increased vowel length can be generated by a general rule that vowels are lengthened before voiced obstruents. Only properties of *tab* that are idiosyncratic to it (e.g., that the first phonological segment is /t/, the next one /æ/, and the final one /b/) are represented in the lexicon.

This approach ran into its own difficulties. One concerned determining what should count as a systematic property. Many phonological regularities are true of most relevant words but not of all of them. Chomsky and Halle had a rather low threshold for identifying a property as systematic. A consequence of pulling lots of "systematicities" from lexical representations of words is that the representations can become quite abstract. Whereas that of *tab* in Figure 1.1 is not abstracted very far from its surface pronunciation [tʰæːb], that proposed for the word *right* was /rīxt/ a representation that is both far from the actual pronunciation /rayt/, and that contains a phonological segment (the voiceless velar fricative /x/) that no longer appears in surface pronunciations in English. Considerable attention was devoted then to the issue of how to set limits on the abstractness of proposed lexical forms (see, e.g., Kenstowicz & Kisseberth, 1979).

Interestingly, the abstract lexical forms of Chomsky and Halle (1968) often conformed to the spellings of words more closely than did the surface phonetic forms (witness *right* and /rīxt/ versus the surface pronunciation [rayt]). This was notably true for words that are morphologically related, with same-spelled stems, but different surface pronunciation of the stems (e.g., such forms as *serene-serenity, divine-divinity, profane-profanity*). In turn, this led to speculation that spelling in English mapped onto lexical ("deep") phonological forms, whereas writing systems such as those for Turkish or Serbo-Croatian mapped onto shallow phonetic forms (I. Y. Liberman, A. M. Liberman, Mattingly, & Shankweiler, 1980). It also led to the conjecture (by Chomsky & Halle, among others; see also Klima, 1972) that, in some ways, English spelling is close to optimal because it maps transparently to lexical forms. However, an alternative view is that some of the systematicities that Chomsky and Halle were identifying were not alive in the language use of present-day speaker/hearers, but rather were regularities in historical sound change (e.g., /x/ was at one time pronounced in *right*). Because English has not reformed its spelling recently, spellings sometimes map more simply onto historically older pronunciations, and these were being approximated by the lexical representations of Chomsky and Halle's generative phonology. (Chomsky and Halle themselves discounted this idea, however.)

Of course, in some ways, it does not matter why English spellings frequently contain both morphological and phonological information (i.e., are "morphophonemic"). Possibly, English spellings do map onto deep representations of lexical forms. Perhaps they do not. Even if they do not, Chomsky and Halle's phonology shows that English spellings do reflect phonological (near-) systematicities across the lexicon, with the result that spellings tend to be morphophonemic. Can reader-spellers take advantage of that information?

Two fairly clear cases of an advantage of morphophonemic spellings are provided by the inflectional suffixes spelled *s* and *ed*. Even though each suffix is associated with three different pronunciations (unvoiced, voiced, and schwa-C forms), they look the same in print. This must facilitate picking them out. This facilitation comes early. Byrne (1996) trained prereading children to distinguish singular and plural spellings of words in which the plural *s* was pronounced [s]. First they learned to associate such word pairs as *book* and *books* to different pictures. Then they learned to identify each word by its spelling alone. After reaching criterion on "reading" *book* and *books* and *hat* and *hats*, they were tested for generalization to discover what the children had learned about the final *s*. They might have learned the mapping of *s* to [s], in which case they should be successful identifying which of two words was *bike* and which *bikes*, but also which of *bug* and *bus* had the pronunciation [bʌs]. Alternatively, they might have learned that *s* was the spelling of the plural morpheme, in which case they should fail on *bug-bus*, but succeed at *dog-dogs*, in which *s* is pronounced [z]. The latter was the outcome. Prereading children are disposed to expect letters to map onto something meaningful, and it can only be helpful that letters do that in the case of *s* and *ed*.

As Mann and Singson (2003) point out, there is also something that readers can learn about derivational suffixes. Some suffixes are "neutral" in that when they are added to a word, the pronunciation of the stem is unchanged. Examples are *ness* and *ment*. Others are non-neutral in that they do change the pronunciation of the stem. Examples are *ic* (compare *magic, magician)* and *ity*. Readers who know how to pronounce a base form (say, *excite*) can know how to pronounce it in a morphologically complex form with a neutral suffix (*excitement*). In addition, if they are very morphologically aware, they may learn how non-neutral suffixes change the pronunciation of base forms. Then if they know how to pronounce *magic*, they can know how to implement "velar softening" (Chomsky & Halle, 1968) and a stress shift to pronounce *magician*.

Relatedly, in a recent study of third grade children, Jarmulowicz, Hay, Taran, and Ethington (2008) measured "morphophonological accuracy" as well as phonemic and morphological awareness, to determine both the developmental pattern of their emergence and their relation to word decoding and reading comprehension. Morphophonological accuracy was assessed by having participants add a non-neutral suffix to a base form and pronounce the complex form. A model emerged from a path analysis suggesting that morphophonological accuracy emerges after morphological and phonemic awareness and that it is a strong predictor of word decoding, but affects reading comprehension only indirectly through the effect of decoding on comprehension.

Addressing the issue most directly of whether the morphophonemic spelling of English is helpful to readers seems to require a near impossible kind of experiment. Required are comparisons between readers of a variety of skill levels, some of whom are readers of English and some of whom are readers of a shallow orthography (in which such words as *heal* and *health* have different stem spellings). The problem, however, is that, unless the shallowly spelled spoken language is English, the languages are bound to differ morphologically in ways that would affect the salience of morphological information to language users for reasons unrelated to the writing system.

However, there are some less-direct indications that the knowledge of morphology and morphophonology is related to reading and spelling. First, a number of studies have shown that morphological awareness is related to reading skill (see, Carlisle, 2003, for a review), and some (e.g., Fowler & I. Y. Liberman, 1995) have shown that this is especially so for tasks involving morphologically complex words in which derivational suffixes are non-neutral. It is also known that morphological awareness grows in importance as a predictor of word recognition as phonological awareness declines. Mann and Singson (2003) found in a regression analysis predicting a z score combining word and nonword reading performance that phonological awareness explained 60% of the variance among third graders. However, it gradually declined over the succeeding grades until it explained only about 10% of the variance in sixth grade. In contrast, morphological awareness explained no variance among third graders, but it did contribute significant variance in fifth and sixth grade. Like other studies, however, this one showed that the percentage of variance explained by morphological awareness is modest, at least in the grades examined. In sixth grade it explained approximately 10% of the variance. A subsequent experiment showed that, with vocabulary and phonological awareness entered into a regression analysis, tests of morphological awareness only explained significant variance if the morphologically complex words tested had non-neutral suffixes. Mann and Singson comment that this kind of outcome has been interpreted (e.g., Fowler & I. Y. Liberman) as evidence that these tests of morphological awareness are really assessing phonological skills; however, they suggest alternatively that they may be assessing awareness of non-neutral suffixes and the morphophonological systematicities associated with their attachment to base forms.

Morphological knowledge should also help with spelling. Knowing that *equality* contains *equal*, can help spellers spell the stem correctly in the complex form. Carlisle (1987) found that this apparent spelling approach (spelling the stem in the same way in the simple and complex form) was more characteristic of typically reading fourth graders than of a group of ninth grader dyslexic readers matched to the fourth graders on spelling accuracy. However, Bourassa, Treiman, and Kessler (2006) found that both dyslexic children (aged 9–14 years) and spelling-matched typically reading children were more likely to spell both consonants of a final consonant cluster in inflected words such as *tuned* (/tund/) than in monomorphemic words such as *brand*. This implies that both groups of readers were able to take advantage of their knowledge of the base form *tune* to overcome the difficulty that final clusters can cause for young spellers.

In a second experiment, Bourassa et al. (2006) found that both dyslexic readers and typical readers were more likely to represent accurately the *t* in inflected forms such as *waiting* and the *d* in words such as *louder* than in monomorphemic words such as *daughter* and *spider*. In all of these words, the internal *t* and *d* are flapped and indistinguishable in American English. This finding, compatible with the previous one, suggests that both groups of readers can take advantage of their knowledge of stem forms such as *wait* and *loud* in spelling the morphologically complex forms. However, both groups of readers were less accurate in spelling the *t* or *d* in the complex forms than in simple forms such as *wait* and *loud*. This signifies that the children were not taking full advantage of their morphological knowledge.

In turn, this implies that morphological awareness should predict spelling accuracy. It appears that it does. For example, Deacon and Bryant (2006) gave 7–9-year-old children a spelling test like that of Bourassa et al. (2006) in which they compared their accuracy on inflected forms such as *turning* and on matched monomorphemic words such as *turnip*. As Bourassa et al. had found, children were able to use their knowledge of base forms to assist in their spelling of the morphologically complex form. In a regression analysis with age partialed out, variance in scores on the spelling test was significantly predicted by performance on a test of morphological awareness (adding inflections to base forms).

In short, the generative phonology of Chomsky and Halle (1968) draws attention to the observations that English spellings tend to map in a straightforward way to the abstract lexical phonological representations that their theory proposed for English speakers. Whether or not lexical forms have that abstract character has proven controversial. However, even so, it remains the case that English spelling preserves information about morphology more so than do shallower writing systems with more consistent spelling-sound mappings. Readers and spellers have been shown to make use of this information.

Articulatory Phonology

Browman and Goldstein's articulatory phonology (e.g., Browman & Goldstein, 1986, 1992; Goldstein & C. A. Fowler, 2003) offers a way to address the problem of time noted earlier. Conceptualizations of phonological segments as discrete and timeless collections of featural attributes do not have a good way to represent dynamic properties of phonological elements, including those of complex segments.

Articulatory phonology is revolutionary and unique in two important and related ways. First, time is inherent to phonological entities in the theory. Second, phonological forms are public things. In my view, it is ironic that in all theoretical accounts of phonology except articulatory phonology, phonological language forms are held to be categories in the mind. It is ironic because language forms are the means that languages provide to make communicative messages public. Why would language communities develop forms that are fundamentally covert, and, that, due to coarticulation in speech, remain so as talkers speak? In the view of Browman and Goldstein (e.g., 1986), phonological forms are not covert.

In articulatory phonology, uniquely, language forms are linguistically significant actions of the vocal tract. This is not to say that minds do not know something about language forms. It is to say that, just as minds know something about elephants, but elephants do not reside in knowers' minds, phonological language forms are known to language users, but do not reside in language knowers' minds. They are public actions.

In this approach to phonology, then, there is no separation between the mental (phonological) and the physical (phonetic) aspects of the spoken language as there is in other phonological theories, and hence no need for the supposition of other phonological theorists that a translation must occur between a symbolic and a physical domain of linguistic representation. Rather, the

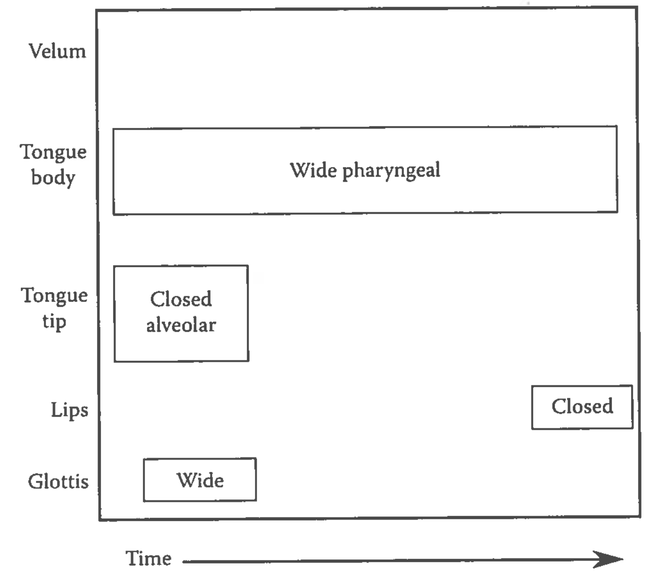

FIGURE 1.2 A gestural score for the word *tab*.

phonology–phonetic contrast (Gafos & Benus, 2006) is between a low- and a high-dimensional characterization of the same speech system.

In articulatory phonology, word forms are represented by "gestural scores." Figure 1.2 shows a gestural score for the word *tab*. A gestural score represents the linguistically significant actions, or *gestures*, of the vocal tract as they unfold over time for the production of a word. Linguistic gestures create and release constrictions in the vocal tract, and the constrictions are characterized by two parameters: constriction location and constriction degree. For the /t/ in *tab*, for example, a constriction is created at the alveolar ridge of the palate by the tongue tip. The constriction degree is complete closure. Accordingly, the constriction location is alveolar; the constriction degree is closed. Overlapping with that gesture is a gesture of the larynx in which the vocal folds open. The constriction location is glottal. The constriction degree is wide. The vocalic gesture of the tongue body spans the entire duration of the word. Its location is pharyngeal for the vowel /æ/. The final consonantal gesture at the lips begins during the vowel. Its constriction degree is closed.

In the approach of Browman and Goldstein (1992), contrast is a focus of the theory. The presence or absence of a gesture can create contrast. For example, omission of the laryngeal gesture at the beginning of the word *tab* creates the word *dab*. The laryngeal gesture is contrastive.

For present purposes, a notable characteristic of the gestural score is that segments are not in any apparent way discrete; rather, the gestures for different segments overlap in time. Nor is it obvious that the gestures of multiple-gesture segments, such as initial /t/ in *tab*, are any more cohesive than are gestures for different segments. That is, the glottal gesture for /t/ overlaps temporally both with the tongue tip gesture for /t/ and with the tongue body gesture for the vowel. Moreover, nothing in the gestural score shows that the glottal gesture somehow belongs more with the tip gesture than with the body gesture. Indeed, Browman and Goldstein (1990) wrote of phonemic segments that they are more a practical tool than they are entities that correspond to important informational units of the phonological system.

In contrast to this, in the view of Saltzman and Byrd (2000), there is evidence that coupling between the gestures of a segment (e.g., the tongue tip and glottal gestures of /t/) is stronger than that between gestures of different segments (e.g., the glottal gesture of /t/ and the tongue body gesture for the vowel). For example, they cite findings by Munhall, Löfqvist, and Kelso (1994) who show that when the lip gesture for the first /p/ in /ipip/ is perturbed during closing, lip closure occurs, but with a delay that is mirrored by a delay in the glottal opening gesture for /p/. This suggests a coupling between the lip and larynx gestures. However, the glottal gesture and therefore the period of devoicing are not terminated early to preserve its relation to the oral opening gesture for the next vowel.

However, the study by Munhall et al. (1994) had literate adult talkers as subjects. Would this finding hold for prereading children and illiterate adults? Is it possible that literacy has an impact on language users' "gestural scores" such that before a language user learns to read, the coupling inhomogeneities that reflect formation of multigesture segments are absent or at least are less marked than they are in readers of alphabetic writing systems? If so, then we might also see differences in the phonological forms of words of poor readers, which are consequences of poor reading. These would augment effects of the poor reader's hypothesized weak phonological systems (I. Y. Liberman, Shankweiler, & A. M. Liberman, 1989) in fostering a poor fit between units of spoken and written word forms.

We know that there are, in some sense, links between spoken and written word forms in memory such that skilled readers access phonological word forms when they read (e.g., Frost, 1998) and orthographic word forms when they listen (e.g., Seidenberg & Tanenhaus, 1979; Slowiaczek, Soltano, Wieting, & Bishop, 2003). This means that there is the possibility of orthographic representations having an impact on phonological representations (and vice versa).

There is also evidence that literacy affects performance on spoken language tasks in other ways. For example, Castro-Caldas, Petersson, Reis, Stone-Elander, and Ingvar (1998) found that illiterate adults had much more difficulty repeating pseudo-words than matched literate individuals.

It is well-known that there is a bidirectional causal relationship between phonemic awareness and reading. Phonemic awareness is a strong predictor of reading in the early grades (e.g., Mann & Singson, 2003, described earlier). In addition, however, literacy fosters phonemic awareness. For example, Morais, Cary, Alegria, and Bertelson (1979) found that illiterate adults performed very poorly on a task in which they were to delete or add consonants to words and nonwords, averaging 36% correct on words and 19% correct on nonwords. Matched literate participants performed the tasks more successfully (averaging 89% and 72% correct on word and nonwords, respectively).

Moreover, the kind of literacy that fosters phonemic awareness appears to be literacy in an alphabetic writing system. Navas (2004) used a deletion task and an oddity task (in which participants indicated which of three words started with a different sound) to test the phonemic and syllabic awareness of three groups of bilingual Japanese–Portuguese speakers. One group was literate only in Japanese, a syllabic and logographic system; one only in Portuguese, an alphabetic system; and the final group was literate in both languages. Individuals who were literate only in Japanese performed very poorly on the consonant deletion and oddity tasks in comparison to individuals who were literate in Portuguese.

Why does literacy in an alphabetic writing system foster phonemic awareness? Two kinds of reasons have been proposed for why prereaders lack phonemic awareness (see Fowler, 1991, for a discussion). One is that children perceive consonants and vowels when they hear words, and represent the consonants and vowels lexically, but they cannot introspect on what they know (I. Y. Liberman, 1973). The other possibility, raised by Fowler is that, initially, phonemes are not extracted from spoken input, and words in the lexicon have a more holistic representation. This is suggested by a variety of findings that she summarizes. For example, Studdert-Kennedy (1986) notes that Ferguson and Farwell's (1975) list of attempts by a 15-month old to say the word *pen* shows that the attempts characteristically retain many of the features of that word, but in a variable order. Sometimes she gets very close to the mark as in [pʰɪn]. Sometimes she misses a gesture as in [hɪn]; in this production, the bilabial constriction gesture is missing so that the devoicing gesture for /p/ sounds like word-initial [h]. That one gesture of a two-gesture segment is missing may signify that, for this child, the two gestures do not cohere into a segment. Sometimes she is farther away still as in [mãᵊ] in which the velum lowering gesture for the final nasal appears at the beginning of the word along with the bilabial constriction gesture for /p/ and persists into the vowel. However, in all cases, gestures that should be there are there; often they are improperly phased with respect to one another. In other instances, just one gesture of a two-gesture segment is preserved. This kind of evidence may signify that gestures have not coalesced into segments for this young preliterate speaker. Compatibly, perhaps, Stemberger's (1989) corpus of his two prereading daughters' spontaneous errors of speech production show twice as many feature errors ("I got that gall for Pristmas"—"I got that ball for Christmas") than whole segment errors. This contrasts with (literate) adults who show more segment than feature errors. Both of these findings may imply lexical representations in which gestures or features are present but are not organized segmentally.

Compatibly on the side of reception, Treiman and Breaux (1982) asked adults and 4-year-olds to put together which two of the three consonant–vowel–consonants were more similar. In a free sorting condition, there was a trend for adults to sort based on shared phonemes (/bɪs/ and /bun/, not /diz/), and a trend for children to sort based on global featural similarity (e.g., /bɪs/ and /diz/, not /bun/). When children and adults were trained to sort in one way or the other, children trained to sort on shared phonemes showed a significantly higher error rate than children trained to sort on featural similarity. (Adult performance was at ceiling.) In a final free sort, children who had been trained to sort on phonemes did so on under half the trials, whereas adults did so on more than three quarter of the trials. Children trained to sort on similarity did so on over half the trials on the free sort; they sorted on phonemes just a third of the time. Adults trained on similarity sorted on phonemes and similarity about equally often.

It is presumed that a segmental structure emerges in the lexicon as it grows in size (e.g., Fowler, 1991). But does it for illiterate language users? As noted earlier, they persist in their failure to exhibit phoneme awareness. How would they fare on Treiman and Breaux's (1982) sorting task? Would their feature errors outstrip their segment errors? The answers to these questions are unknown to date.* It is possible, then, that one way in which their phonological representations are weak or are unsuited for an appreciation of an alphabetic writing system is that their "gestural scores" remain unorganized or incompletely organized into segmental chunks.

CONCLUDING REMARKS

Different approaches to a linguistic understanding of phonology offer different insights into challenges presented by the task of learning to read. I have offered three. The assumption of descriptive and many generative phonologists that words are composed of discrete, countable consonants and vowels appears to be almost true. That the assumption is close to reality ensures the viability of alphabetic writing systems. But that it is not quite accurate for complex segments and other segments that undergo dynamic change over time adds to the prereader's difficulty in achieving phonemic awareness.

Articulatory phonologists do not all make the assumption even that "gestural scores" have a segmental structure. Phonetic gestures are coupled one to the other so that their phasings are appropriate. However, Browman and Goldstein (1990), as noted, did not suppose that couplings between gestures that compose conventional segments are stronger than those of different segments. There is a little evidence that they do for literate speakers. However, this leaves open the possibility that literacy itself has an impact on gestural organization.

Insights from the earliest version of generative phonology, finally, have to do with the value of the morphophonemic nature of English spelling. Chomsky and Halle (1968) derived underlying word forms that are abstract with respect to surface pronunciation by distinguishing systematic from idiosyncratic properties of words. Doing that led to a finding that the same morpheme tends to be represented phonologically identically in different lexical forms despite surface pronunciation differences. This in turn fostered an idea that there is an advantage to morphophonemic spelling. I identified some evidence for this.

* In her study of bilingual Japanese–Portuguese speakers who were or were not literate in the alphabetic writing system of Portuguese, Navas (2004) did elicit speech errors in a tongue twister repetition task. She found no difference in the relative frequency of different error types depending on literacy in Portuguese. However, she did not distinguish feature from segment errors and probably could not do so. This is because her tongue twisters were such pairs as *sopa-shapa* in which the target consonants differed in just one feature. Accordingly, an expected error such as *sopa-sapa* or *shopa-shapa* might be either a segment or a feature/gesture error.

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