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When Theories of Speech Meet the Real World

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Two theories of speech—one quite conventional, the other much less so—account very differently for the biological advantage of speech over writing/reading. The guiding assumption of the more conventional theory is that the elements of speech are sounds, and that these are served by processes of motor control and auditory perception that are in no way specialized for language. Accordingly, there must be a cognitive stage, beyond action and perception, where the motor and auditory representations are somehow invested with linguistic significance. On the conventional view, then, the sounds of speech are just like the letters of the alphabet. Neither has more than an arbitrary relation to language, hence the difference between them is trivially a matter of which of the equally large gaps between signal and message needs to be bridged. On the less conventional theory, the ultimate constituents of speech are not sounds, but articulatory gestures. Having evolved exclusively in the service of language, they form a natural class, a phonetic modality. Being phonetic to begin with, they do not require to be made so by cognitive translation. And that, very simply, is the advantage of speech over writing/reading. Speech has the corollary advantage that it is managed by a module biologically adapted to circumvent limitations of tongue and ear by automatically coarticulating the constituent gestures and coping with the complex acoustic consequences. But a result is that awareness of phonetic structure is not normally a product of having learned to speak: The module “spells”—that is, sequences phonetic segments—for the speaker and recovers the segments for the listener, leaving both in the dark about the way that is done; the gestural representations are immediately phonetic in nature, precluding the cognitive translation that would bring them to notice; and coarticulation destroys all correspondence in segmentation between acoustic and phonetic structures, making it that much harder to demonstrate the alphabetic nature of speech at the acoustic surface. Accordingly, special difficulty in becoming literate might be caused by a weakness of the phonetic module, for that would produce primary representations of a fragile sort, with the consequence that they would be that much harder to bring to awareness—as is required if they are to serve writers and readers as the units of an alphabetic script—and also that much less able to bear the weight of working memory.

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Theories about the production and perception of consonants and vowels—that is, speech in the narrow sense—are commonly tested against the results of carefully controlled experiments. But those theories just as commonly ignore the equally telling considerations that arise, not from experiments, but from significant facts about language that lie in plain sight, visible to all who bother to look. I do not aim to rehearse those here, or to review attempts by a few of my colleagues and me to cope with their implications (Lieberman, 1996; Lieberman & Mattingly, 1985; Mattingly, 1991; Studdert-Kennedy, 1996), but only to invite attention to a single fact that is, perhaps, the most obvious, the most neglected, and the most immediately relevant to a matter of great practical importance.

The obvious real-world fact that I want theory to wrestle with is the profound difference in naturalness and difficulty between two ways of communicating language—the one, by speech; the other, by an alphabetic transcription. Speech is plainly a product of biological evolution, part of the most important of our species-typical characteristics. Universally among normal human beings, it is responsible for deploying the phonetic units that serve as the basis for the combinatoric strategy that forms an indefinitely large inventory of words. Accordingly, it is a critical component of the generativity that distinguishes language from all other forms of natural communication. Because speech is genetically determined, the necessary and sufficient conditions for acquiring it are but two: membership in the human race and exposure to a mother tongue. In contrast, using an alphabet is not the species-typical behavior itself, but only a more or less accurate way of describing it. On that account, the historical development of an alphabetic description must be reckoned a triumph of ethology, so it is fair to say that all who use an alphabet properly have had, in effect, to master that branch of science. But why is a similar accomplishment not required of speakers and listeners? How is it that they can manage just by virtue of being certifiably human? It begs the question to say, as I already have, that the one behavior is a product of biological evolution, the other an intellectual achievement. Rather, we must capture the critical property of that which evolved, for only then can we answer the question that is truly central to the understanding we seek: What did evolution do for speech that gave it such a biological advantage over writing/reading? A theory of speech—or, more broadly, language—can avoid that question, as most do, but it cannot avoid implying an answer; and if that answer does not sit comfortably with the priority of speech, then the scientists should consider that they have got hold of the wrong theory.

Theories of speech divide neatly into two categories according to the view each takes of the biological specialization for language and the length of its task-specific reach. Moving from the top of the language hierarchy downward, the more conventional theories hold that the specialization stops short of the primary acts and percepts of speech, taking those to be no part of language but only its conveniently available vehicles (Crowder, 1983; Diehl & Kluender, 1989; Fujisaki & Kawashima, 1970; Kuhl, 1981; Lindblom, 1991; Massaro, 1987; Stevens & Blumstein, 1978; Sussman, 1989; Warren, 1993). Thus, the perception of speech is supposed to be no different from perception of other sounds. All depend on the same general processes of the auditory modality, processes that occupy a common domain, employ a common mode of signal processing, and evoke in a common perceptual register a common set of distinctly auditory primitives. On that view, a stop consonant and, say, a whistle differ at the level of primary perception only in the weights that are assigned to the auditory primitives they have in common. Being made of the same auditory stuff, they are equally remote from language. Because the conventional theory takes both to be products of a process that cuts across the widest possible variety of behaviors, serving linguistic and nonlinguistic functions alike, it deserves the epithet "horizontal."

As for speech production, it commonly gets short shrift on the horizontal view, figuring hardly at all in its theoretical calculations, except as the articulatory maneuvers are required to be relatively easy to make but able nevertheless to provide sounds that fit the language-independent properties of the ear. Accordingly, the acts of speech are no less ordinary—that is, no more immediately phonetic—than its percepts. It follows, then, that the necessarily invariant and commutable units of speech must be sounds that exploit the possibilities of ordinary auditory perception, so the alphabetic character of the combinatoric strategy has got to be manifest at the acoustic-auditory surface. In that case, speech is necessarily an acoustic-auditory alphabet.

In advance of any experiments, the horizontalists should therefore wonder why learning to read is so cognitively taxing by comparison with speech, since it would appear, as they see it, to be only a matter of moving from one alphabetic rendition of language to another. And if, as the horizontalists assume, the processes and structures of speech production are no part of the biological specialization for language, having been selected simply to produce sounds that are congenial to the ear, then how is it that people who cannot spell a single word—lacking even the awareness that words *can* be spelled—nevertheless find, each time they speak, that producing perfectly spelled phonetic structures is dead easy?

It seems equally clear that the horizontalists should also be troubled by the strong asymmetry between production and perception that is seen on

their view, for that makes it hard to take into account that normal human beings are both speakers and listeners. Surely, there is an urgent need to be explicit about the nature of the common linguistic representation that such role switching requires, not to mention the correspondingly urgent need to explain how, in the evolution of speech, changes on the one side of the communication link were matched by appropriate changes on the other. Taken together with the even more apparent need to explain how the parties to the linguistic exchange came to agree about which signals count for language and which do not, these matters add up to what has been called the requirement for parity (Lieberman, 1996; Lieberman & Mattingly, 1989; Mattingly & Lieberman, 1988), a requirement that has apparently escaped the notice of the horizontalists, as it has, indeed, of psycholinguists generally. It is, however, nonetheless important, not only for understanding the nature of speech, but also for our narrower purpose, which is to know how the bond between production and perception in speech is different from that which links writing and reading.

But I will, for the moment, ignore production and its relation to perception in favor of the one-sided preoccupation with perception that characterizes the horizontal theorists, thus clearing the way for an evaluation of their guiding assumption. Recalling that assumption, which is that the sounds of speech evoke percepts of a generally auditory sort, we can conceive that it might well have been the end as well as the beginning of the horizontalists' theory, but only if they had been willing to suppose that the morphologic and syntactic computations of language can be carried out on auditory representations. It is of interest, then, that no horizontal theorist has been willing to make that assumption, not explicitly in any case. They apparently agree, if only tacitly, that hierarchically organized formal structures of a distinctly linguistic sort are interposed between the physical signal and the message, and that the phonetic structures at the base of the hierarchy are no less distinctly linguistic than those higher up. Perhaps they also agree that such interposed structures are essential to the combinatoric strategy and therefore to the boundless diversity of utterances that language comprises. But whether for that reason or for some other—we can't know because the horizontalists don't say—they do appear to grant that the basic commutable segments of language must be specifically phonetic, that ordinary auditory units won't do. Accordingly, they accept that the primary auditory percepts must be given a phonetic cast if they are to gain entry into language and there take up their specifically linguistic roles. Acting on that acceptance, the horizontalists commonly assume a second stage, beyond primary perception, where things auditory are, by some cognitive process, remade into things phonetic.

Thus, the horizontal view shows apprehending phonetic structure to be a two-stage process, a matter of perceiving one thing and then translating it

into something else. Perhaps the horizontal theorists see things that way because they are in the grip of an ancient bias that requires of a primary percept that it have a dedicated end-organ receptor. Since phonetic units have no such receptor, the theorists fall back on auditory percepts, which do.

That kind of thinking was made explicit by Berkeley (1709), when he undertook to account for visual perception of depth. After observing, in effect, that there is no appropriate end organ, he suggested that the primary percept is evoked by receptors in the muscles that control convergence of the eyes, and that those percepts are then translated into depth by a process of learned association. Thus, like the horizontalists, Berkeley assumed a two-stage process, one primarily perceptual, the other secondarily cognitive. But students of vision have long since arrived at a very different understanding, which is that there is a biologically coherent system specialized to represent information about binocular disparity immediately as depth; there is no mediating primary perception of the disparity, and hence no cognitive translation from that percept to one more truly representative of the distal reality.

Putting aside, but just for the moment, the possibility that speech perception is in similar case—that distinctly phonetic percepts are evoked immediately by an appropriately specialized biology—we can surely agree that there is, in any event, no such possibility in reading. Given that the optical characters of the alphabet are arbitrarily selected artifacts, there could not conceivably be a biologically coherent system specialized to represent anything other than their very ordinary visual consequences. But the morphologic and syntactic components of language cannot operate on visual representations, so the primary percepts that are evoked by the alphabetic characters have got to be translated into language, presumably at the level of phonology. Recalling that the horizontal view of speech assumes a connection to language via a translation of the same kind, we see that, apart from the difference in the relevant receptors and effectors, the two processes are exactly parallel, requiring the same kind of cognitive step to endow their ordinary auditory and visual percepts with phonetic significance. Why, then, should the one be so much easier and more natural than the other?

Indeed, the horizontal view is the worse confounded, because it not only fails to explain how nature made speech so easy, but clearly implies, to the contrary, that she might better have given the nod to writing/reading. Consider that print is the clearer signal; the hand, the more versatile effector; and the eye, the more accommodating receptor. Indeed, the tongue and the ear would seem singularly inappropriate for dealing with the closely ordered strings of discrete segments that a generative phonology requires. That requirement arises if, as is the case with phonologic systems, all utterances are formed by combining and permuting a small number of segments, for

in that case, the strings of those segments must frequently run to great lengths. It is therefore necessary to produce and perceive them at high rates, not just so the job can be done in good time, but because they have got to be organized into the larger units at higher levels of the linguistic hierarchy. If speech were an acoustic-auditory alphabet, the sounds (and percepts) would require discrete gestures, and, given a tongue that operates in its sluggish nonlinguistic mode, the phonologic units would be delivered too slowly, and language as we know it would hardly be possible. And even if the tongue could manage, the ear would have difficulty simply resolving the resulting drumfire of acoustic segments and correctly perceiving their order. It is easy to imagine, then, that if psycholinguists had been asked by nature to advise about how to implement a generative phonology, they would likely have urged her to avoid the tongue and the ear in favor of the hand and the eye. But now, considering the success of speech, and taking out of its original sexist context Samuel Johnson's tribute to the dog that walks on its hind legs, we should wonder, not that nature managed to do it so well, but that she managed to do it at all. For speech is easier than writing/reading despite, not because of, the language-independent properties of the tongue and the ear that nature had to work with.

Earlier, I suggested that our inquiry comes down to the question: What evolved? Now I would emphasize that the answer given by the horizontalists is very clear and, for our purposes, not very helpful. For at the level of acts and percepts, they assume, as I said earlier, that nothing evolved. It is, to them, as if language had simply appropriated ordinary modes of action and perception and turned them to its special purposes. But is that not exactly what the inventors of alphabetic writing systems did when, having discovered the phonologic structure of words, they agreed that certain optical shapes would be chosen for use in language, and then assigned, quite arbitrarily, to its phonologic units? Surely, speech does not rest on similar agreements among our ancestors about which auditory percepts would be converted to language, and which units of language they would be converted to. Nor is it any more plausible to suppose that speech developed just because people fell to using sounds that were easy for a general motor system to make and for an auditory system to hear (Lindblom, 1991), for it would still remain to say who decided which easy acts and percepts were to be connected to which phonologic units. At all events, development of a writing system, which was certainly not a matter of biological evolution, was similarly constrained to find optical shapes that are easy to draw and also easy to perceive. Therefore, we are not much enlightened about the evolution of speech to be told that our ancestors managed, quite naturally, to find a mutually constraining combination of least effort and greatest perceptual salience.

Given all the foregoing considerations, I think the horizontal view must find it very hard to rationalize the biological advantage of speech over writing/reading, I would therefore turn to a view that reveals a specialization for language extending across all levels of the system, not excluding the primary acts and percepts at the very bottom (Lieberman, 1996; Lieberman, Cooper, Shankweiler, & Studdert-Kennedy, 1967; Lieberman & Mattingly, 1985). On that vertical view, the psycholinguist sees a distinctly phonetic way of doing things, not in the dark and deep recesses of the cognitive machinery, but up nearer the light, among the nuts and bolts of action and perception. Such a vertical theory has been around for some time, having been developed, not to explain the advantage of speech over writing/reading, but to take account of a variety of considerations, including some that arise from the kinds of experiments that I have, for the purposes of this paper, forsworn. I will not here present or defend the vertical view of speech in detail, but only as much of it as is relevant to understanding what it means to say that speech is biologically primary.

The first assumption of the vertical view is that the constituents of speech are not sounds, but distinctly phonetic gestures of the articulatory organs. A gesture is a change in the cavities of the vocal tract—a closing or opening, a lengthening or shortening, a widening or narrowing. Those gestures are the end products of more central motor patterns, something like Turvey's "coordinative structures" perhaps (Turvey, 1990), that provide the physical bases for the commutable segments of the phonology. By lending themselves to overlapping and merging (coarticulation) by a specialized phonetic module, they make possible the rapid production and perception of the commutable units that a generative phonology requires. Having been selected in the evolution of language to serve a specifically phonetic function, the constituent gestures form a natural class; they are phonetic by their very nature, requiring no cognitive translation to make them so. And that, precisely, is the crucial difference between speech and writing/reading: Speaker and listener deal immediately with pieces of language, not, as in the case of writers and readers, with arbitrary stand-ins; thus, the former are on the most intimate terms with language, while the latter must make do with an acquaintance at one remove. Once said, that conclusion must humble any theorist who presumes to explain the difference between speech and writing/reading, for it seems the merest common sense. A verticalist like me is left then with little more than the claim that his theory explains why the common sense is also the right sense. Better that, however, than mistakenly finding it wrong.

As for the comparison of speech production and writing, the speaker is not required to know how to spell a word in order to give it an accurately spelled structure, because the phonetic module spells it for him, automati-

cally selecting and coordinating the relevant gestures. But the module has no way to perform a comparable service for alphabetic characters, except as it is properly informed by the cognitive processes that are cultivated as one learns to be literate.

Nor is it necessary for the listener to understand the vastly complex relation between acoustic signal and the phonetic structure it conveys. Having been introduced into the signal by the processes of coarticulation, those complications are automatically dealt with by the phonetic module, for it is specialized not only to produce the gestures, but to recover them from the sounds in which they are encoded, and to represent them immediately to the listener. Meanwhile, the parallel transmission of information that is caused by coarticulation effectively circumvents the difficulty the ear would have in resolving the brief and rapidly sequenced sounds that must characterize a combinatoric system at the acoustic surface. As for perceiving the order of the segments, the listener is not required to do that by taking account of temporal sequence; rather, he or she relies on the phonetic module to exploit the fact that coarticulation reliably marks the sequential order of the segments by systematic changes in the acoustic shape of the signal. These last considerations do not go to the heart of our comparison of speech and writing/reading, but they do pertain to the fact that the eye is not so limited as the ear in rate of segment perception, which is, of course, why alphabets can be optical but not acoustic. So, in this respect, too, the eye had a natural, language-independent advantage over the ear, an advantage that the evolution of speech was able to match.

The requirement for parity is met in very different ways by speech and by writing/reading. In speech, the link between production and perception, as well as their tie to language, is organic. The speaker produces and the listener immediately perceives the same distinctly phonetic gestures. But the movements of the writer are not so directly in tune with the percepts of the reader. Rather, the two are connected to each other and to language only indirectly and secondarily, via their arbitrary and separate connections to its phonologic units.

There are at least two other facts about speech and literacy that we should look to theory to explain. One has to do with conscious awareness of the phonologic structure that speech implements, an awareness that is essential to proper use of an alphabetic script. We know, on the one hand, that people can be aware of that structure, for if they could not, then alphabetic transcriptions would not be possible. But we also know that such awareness does not normally come for free with mastery of speech. Thus, human beings had been speaking for thousands of years before they made the momentous discovery, referred to at the beginning of this essay, that speech can be taken apart into consonants and vowels. Why did it take them

so long to understand what it was they did when they spoke? And why, as numerous studies have shown, is the awareness of phonologic structure normally lacking in preliterate children (Liberman, 1973; Liberman, Shankweiler, Fisher, & Carter, 1974; for reviews, see Blachman, 1988; Routh & Fox 1984)? The vertical view suggests two reasons. The more important derives from the most fundamental assumption of the theory, which is that the immediate motor and perceptual representations in speech are inherently phonetic, hence perfectly suited for such further linguistic processing as is required. Unlike the visual percepts evoked by the letters of the alphabet, the primary percepts of speech do not have to be converted into something different from what they very naturally are. So, passing right through to the rest of the language apparatus exactly as they came out of the phonetic module, they don't get attention because they don't need it.

Awareness is lacking, and rather hard to come by, for yet another reason, which is that coarticulation smears the information for each phonetic segment broadly through the signal and overlaps it grossly with information for other segments. A result is that there is no direct correspondence in segmentation between the units of the phonology and any possible division of the signal. The fact that speech sounds cannot be divided into segments that correspond to the phonologic segments makes it that much harder to demonstrate those segments to the would-be reader—that is, to show him or her directly what the letters of the alphabet stand for.

We should also want a theory of speech to enlighten us about the very great difficulty that some children have in learning to read. On the horizontal view, the difference between speech perception and reading is that the one is auditory, the other visual. We are led, therefore, to assume that the problem of the reading-disabled child is most likely to be found in processes of an auditory or visual sort. It follows, then, that when reading-disabled children are found to have difficulties in perceiving speech, the horizontalists hew to their belief that phonetic perception is only a translation of auditory representations, and so assume that the fault lies with the primary processes of audition. So compelling, indeed, is this assumption that some researchers who find these speech-perception difficulties are in no way inhibited from laying the blame on the auditory system—specifically, on its ability to process “rapid acoustic changes”—even though they have not provided the nonspeech controls necessary to rule out the possibility that the effects are, in fact specifically phonetic (Kraus et al., 1996; Tallal, Miller, and Fitch, 1993; but see Studdert-Kennedy & Mody, 1995). In only one such study have the appropriate controls been provided (Mody, Studdert-Kennedy, & Brady, 1997). There it was found that reading-disabled children who had difficulty perceiving stop consonants cued by rapid acoustic changes (i.e., formant transitions) had a perfectly normal ability to perceive exactly the

same rapid changes when, having been removed from a phonetic context, they were presented as sinusoids and perceived as nonspeech. Another class of theories ignores speech altogether and lays the blame squarely on vision (Geiger & Lettvin, 1988; Orton, 1937; Pavlides, 1985; Stein, Riddell, & Fowler, 1988). Neither kind of theory assumes that the problem is specifically phonetic. And that, of course, is exactly what the vertical view, with its specialized phonetic module, allows (Lieberman, Shankweiler, & Lieberman, 1989). Being a genetically determined component of the larger specialization for language, the phonetic module presumably differs from child to child in its efficiency. But that is likely to pass unnoticed in ordinary linguistic exchanges, if only because phonologic awareness is not required there, but also because so much support is offered to speaker and listener by the redundancies that pervade the natural speech system. In reading, however, where phonologic awareness becomes a necessity, an imperfect phonetic module would presumably produce percepts of less clarity than is needed to make that awareness easy to achieve. So beginning readers with relatively poor phonetic systems should find it harder to appreciate the alphabetic principle. We should expect, too, that a weak phonetic module would adversely affect the working memory for phonetic structures that is essential to the syntactic process. That would, of course, impair the reader's ability to comprehend sentences, the more so because the slowness in decoding words that is characteristic of poor readers would put working memory under stress greater than that which even a normal system could easily bear. As for the adult dyslexics who manage, one way or another, to decode words, their reading might nevertheless be impaired, because a still sluggish phonetic module could presumably not produce the translation from print to phonetic representation with the extraordinary speed that highly skilled adult readers exhibit (Lukatela & Turvey, 1994a, 1994b; Lukatela & Turvey, 1997).

In sum, I have meant to promote the argument that the vertical view of speech accounts in a seemingly plausible way for the biological advantage of speech over writing/reading, but also for the difficulties that the latter processes must overcome. It is, of course, possible that the vertical view and the several notions it comprises will one day fall. But if they do, they will not bring down with them the conclusion that a theory of speech always implies a theory of writing/reading, in return for which a theory of writing/reading must rest on a theory of speech. It would, I think, be mutually advantageous for two communities of psycholinguists—the one concerned with speech, the other with writing/reading—if they were to accept that simple idea, and act accordingly.

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