There May Be Nothing Peculiar to Perceiving in a Speech Mode

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ABSTRACT

The speech mode is thought to be a peculiar manner of perceiving, uniquely geared to the extraction of linguistic features from the acoustic signal. Results from several different experimental paradigms were thought to converge on the psychological reality of the speech mode and on the auditory-phonetic distinction. All of these results, however, occur for musical sounds identified as plucked or bowed notes from a stringed instrument. Thus, at present there appears to be no empirical evidence for the existence of a special speech mode for processing linguistic features. The concepts of a speech mode and an auditory-phonetic distinction should be reexamined. This paper takes a small step in that direction.

I. INTRODUCTION

“To speak of ‘perception in the speech mode’ is to imply, of course, that speech and its perception are somehow special (Liberman, 1970b, p. 238).” To say that there may be no peculiarity to perceiving in a speech mode is to imply that that view may have to be revised, at least with regard to its usual referents. For the past fifteen years many have extolled the singularity of speech perception. Today, however, empirical support for that view seems to be disappearing. This paper tells part of the story why.

Let me preface this account, however, by stating that speech will remain special. Speech perception in the broad sense, as an integral part of language perception, is endemic to humans and a foundation for much that is human—
literature, technology, science, culture. Sign language, its only legitimate contender, is not endemic and has many thousandfold fewer adherents. The perception of sign follows its own rules; and many of those are quite different from speech (Bellugi & Klima, 1975; Klima & Bellugi, 1976). Moreover, speech has shaped the vocal tract in a peculiar fashion (Lieberman, 1975); sign, as we know it, is a recent invention and has not shaped the hand.

Speech perception in the broad sense can be analyzed at many levels: phonetic, phonological, feeding into morphological, lexical, syntactic, semantic, and pragmatic tiers of the language hierarchy. It seems a good bet that no other system, not even that of music, can match it. But the speech mode has been defined more narrowly: The “concern is not with abstract matters of meaning and syntax, but with the very concrete sounds of speech and their raw perception as the phonetic and phonemic segments that we all know as consonants and vowels (Liberman, 1970b, p. 238).” Indeed, most effort has been directed towards the phonetic level of perceptual analysis and how it differs from the auditory level (Cutting, 1974b, 1976; Pisoni, 1973; Studdert-Kennedy, Shankweiler, & Pisoni, 1972; Wood, 1974, 1975a). This distinction was first made in 1969 by Studdert-Kennedy (1974).

Twenty years of research have yielded many results indicative of speech perception at the phonetic level. Many were thought peculiar to perception in the speech mode. From this collection of results, Wood (1975a, p. 16), for example, selected six thoughts to converge on the psychological reality of the auditory-phonetic distinction. Of this list, three appear to converge on the same processes involved in hemispheric specialization; thus the list reduces to four. These four results are important because many, including me, had taken them to be the empirical basis for the peculiarity of perception in the speech mode. They are: (a) categorical perception; (b) boundary shifts due to selective adaptation; (c) left-hemisphere effects due to cerebral specialization; and (d) asymmetric interference with redundancy gain in speeded classification tasks. Although this list seemed apt just a few years ago, none of these results is peculiar to speech. In fact, they all occur for a single set of musical sounds. Thus, the empirical base for a peculiar speech mode has been weakened, and certain aspects of speech should be assessed anew. What follows is a small step in that direction.

II. CATEGORICAL PERCEPTION

Categorical perception was the first empirical buttress supporting the speech mode (Liberman, Harris, Hoffman, & Griffith, 1957). Called by Wood (1975a) the “phoneme boundary effect,” categorical perception is a complex concept involving the intersection of results from identification and discrimination tasks involving synthetic stimuli generated in equal increments along an acoustic dimension (Studdert-Kennedy, Liberman, Harris, & Cooper, 1970). Several
criteria must be met. First, labeling functions for identified groups must be clear-cut. Second, the discrimination functions must be distinctly nonlinear, with "peaks" (regions of high performance) surrounded by "troughs" (regions of near-chance performance). Third, the location of peaks must occur at identification boundaries and troughs within identified groupings of stimuli. Finally, there should be good agreement between observed discrimination functions and those predicted on the basis of absolute categorization. These four criteria reduce to the notion that the ability to discriminate the sounds is essentially no better than the ability to label them.

Consider a set of seven stimuli, each with two formants, or resonance bands of energy. Such an array can be seen in schematic form in the top left panel of Fig. 1. These particular items were among those used by Mattingly, Liberman, Syrdal, and Halwes (1971). Stimuli 1 through 3 are identified as /ba/ nearly all the time, Stimuli 5 through 7 as /da/, and Stimulus 4 is identified as /ba/ about 40% of the time, and as /da/ 60%. Identification functions for /ba/ and /da/ responses are shown in the lower left panel. A discrimination function is overlaid
on the identification functions. Performance for within-category comparisons, such as Stimulus 1/Stimulus 3 and Stimulus 5/Stimulus 7, is relatively poor (the troughs), and performance for the between-category comparison of Stimulus 3/Stimulus 5 is relatively good (the peak). Performance for other comparisons is intermediate. These patterns reveal the anatomy of categorical perception. The phenomenon is important because “categoricalness is a property of language generally; active-passive and singular-plural, for example, do not admit degree (Mattingly et al., 1971, p. 132).” Thus, the grammars of speech and language share binary features as well as other factors (Liberman, 1970a).

Glottocentrically, many have called all that is not speech by a handy term—nonspeech. There have been several demonstrations that categorical perception does not occur for certain nonspeech sounds. First was a study by Liberman, Harris, Kinney, and Lane (1961), who inverted the spectra of categorically-perceived speech syllables around a center frequency of about 1300 Hz. Categorical perception was not obtained. Similar results were reported by Mattingly et al. (1971). They isolated the second formants and second-formant transitions of the stimuli shown in Fig. 1, and found more continuous perception than for the full syllables from which they were taken. Such results are interesting; they demonstrate that the integrity of the speech signal must not be violated for speech to be perceived as speech. However, there are no appropriate nonspeech control stimuli to be fashioned from the spectral surgery of speech syllables. Not only do such manipulations deny the perceiver a chance to perceive in a speech mode, they also deny the stimulus ecological integrity. It is clear that the notion of modes of perception must be separated from the notion of naturalness of the stimuli. This distinction is crucial because in vision, for example, Biederman (1972) found that scenes carved up in an arbitrary manner are processed differently from intact scenes, yet his analysis concerned global stimulus properties not perceptual modes. Should the analysis of speech be different?

Mattingly et al. (1971, p. 132) noted categorical perception to be “unusual, if not unique” to speech perception. Recent evidence, however, suggests it is more usual than previously thought. In vision, it has been demonstrated for critical flicker fusion (Pastore, 1976), and to a lesser degree for hue (Bornstein, 1975; Lane, 1967). Elsewhere in audition it has been demonstrated for (a) the perception of onsets in noise-buzz sounds (Miller, Weir, Pastore, Kelly, & Dooling, 1976), (b) the perception of onsets in two-component tones (Pisoni, 1977), (c) the perception of sinusoids varying in intensity before a constant referent (Pastore, 1976), and (d) the perception of musical intervals (Locke & Kellar, 1973).

Rise time is a second musical dimension that is categorically perceived (Cutting, 1977; Cutting & Rosner, 1974, 1976). An array of sawtooth sounds differing in rise time can be identified as plucked or bowed notes from a stringed musical
FIG. 2. Oscillograms of two sawtooth wave stimuli from an array of musical sounds that yield results once thought peculiar to the perception of stop consonants.

instrument. Like the binary oppositions in speech, the plucked versus bowed distinction is natural, at least in the sense that it stems from simple mechanical action of easily fashioned materials. Two stimulus items are shown in oscillographic form in Fig. 2. These 10- and 70-msec rise time musical sounds, along with seven other stimuli, were generated on a Moog synthesizer. They varied only in rise time, by 10-msec increments from 0- through 80-msec. Rapid rising items (with 0- through 30-msec rise times) sound like a plucked string, and more slowly rising items (50- through 80-msec rise times) sound like a bowed string. The item with 40-msec rise time is ambiguous between the two. The perception of these sounds meets all the criteria for categorical perception suggested by Studdert-Kennedy et al. (1970), plus several new criteria. For example, like stop consonants (Pisoni, 1973), plucked and bowed sounds yield no decay of within- and between-category information as a function of delay interval between items in a discrimination pair (Cutting, Rosner, & Foard, 1976). Vowels, on the
other hand, yield such decay and also demonstrate a more “continuous” type of
perception. These results suggest that the nature of the memory code for stops
and for plucked and bowed sounds may be the same, both differing from that
for vowels.

Another set of issues in categorical perception centers on the extent to which
it is learned (See Lane, 1965; Pisoni, 1976). For example, are the peaks in the
discrimination function acquired or innate? Ten years after this question first
arose (Liberman et al. 1961), it was answered conclusively by Eimas, Siqueland,
Jusczyk, and Vigorito (1971). They demonstrated that one-month-old infants
discriminated speech sounds in a manner functionally identical to adults. That is,
for example, while infants would discriminate Stimulus 3 from Stimulus 5 of
Fig. 1, a /ba/-/da/ comparison, they would not discriminate Stimulus 1 from 3
(both /ba/) or Stimulus 5 from 7 (both /da/) pairs that differ acoustically to the
same degree. Thus, the distinctiveness between /ba/ and /da/, and between other
such stop consonant pairs, appears not to be acquired; it is already present in
the young infant.

One might suppose that the innateness of speech perception separates it from
the perception of nonspeech sounds. For example, the young infant might not
be able to discriminate between major and minor chords, just as a number of
adults cannot. If so, the distinctiveness of the tonal modes would appear to be
acquired through learning. While there are no firm data on this dimension as yet,
the infant can discriminate between plucked and bowed sounds, but not within
plucked or bowed categories, a pattern just like adults (Jusczyk, Rosner, Cutting,
Foard, & Smith, 1977). Thus, the perception of this musical distinction is innate
to the same degree that the perception of stop consonant distinctions is innate.

One aspect of categorical perception, however, may prove unique to speech:
Speech is multidimensionally categorical, whereas all nonspeech sounds examined
thus far appear to be categorical along but a single dimension. This factor may
be more than a quibble, because the rapid transmission rates of speech may be
attributable, in part, to categorical perception along multiple dimensions. For
example, the initial phoneme in the syllable /ba/ is /b/ not /d/, a difference in
place articulation that is categorical; it is /b/ not /p/, a difference in voicing that
is categorical; and it is /b/ not /m/, a difference in manner that is also categorical.
Thus, three categorical decisions may be made for the same segment, for an
acoustic shape that occurs in less than 100 msec. Liberman, Mattingly, and Tur-
vrey (1972) estimated that the transformation of acoustic signal into phonetic
message is akin to the reduction of signal load from 40,000 bits/sec to 40 bits/sec,
a thousandfold savings for memory. Multidimensional categorical perception
may be an important way of achieving such coding rates efficiently.

Nevertheless, simple categorical perception is not peculiar to speech. In fact,
it may not be peculiar to humans (Kuhl & Miller, 1975; Morse & Snowden, 1975),
although the data are still equivocal (Sonnott, Beecher, Moody, & Stebbins, 1976;
Waters & Wilson, 1976) and incomplete. What is unequivocal is that, whereas
categorical perception is central to speech perception, it cannot be used to bulwark the speech mode as a peculiar form of auditory perception.

III. BOUNDARY SHIFTS DUE TO SELECTIVE ADAPTATION

A second empirical buttress for the speech mode, at least according to Wood (1975a) and others, dealt with the boundary shift and its underlying mechanisms in selective adaptation. Borrowed and modified from vision research (Blakemore & Campbell, 1969), the adaptation paradigm is built on the foundation of categorical perception. Consider again the /ba/-/da/ array shown in Fig. 1. If Stimulus 7 (/da/) were presented several dozen times in succession, and the listener asked to identify each of the seven members of the stimulus array — and if this procedure were repeated many times — the postadaptation identification function would typically shift towards the /da/ end of the array, as shown in the top right panel of Fig. 1. This shift reflects a change in the tuning of the perceptual apparatus, and it was first reported by Eimas and Corbit (1973). It occurs not only for identification, which could reflect simply a criterion shift in responses, but also for discrimination, as shown in the lower right panel. This second type of shift suggests a change in sensitivity, not simply criterion. The shift in sensitivity is crucial for the argument that opponent-process detectors are differentially fatigued during adaptation.

The perceptual shift was first thought to reflect adaptation of phonetic feature detectors. That view, however, was modified (Cutting & Eimas, 1975), then changed altogether to one that accounted for adaptation in terms of auditory property analyzers (Pisoni & Tash, 1975; Tarter & Eimas, 1975). The latter view seems prudent and more plausible since similar shifts occur for plucked and bowed sounds (Cutting, 1977; Cutting et al., 1976), which are not phonetic in the accepted sense of that term. Thus, in the auditory domain the effects of adaptation are not exclusive to speech.

Wood (1975a), however, did not suggest that adaptation shifts were peculiar to speech. After all, they occur in vision. He stated, rather, that there is a difference in the “relative effectiveness of various speech, speech-like, and non-speech stimuli in producing systematic phoneme boundary shifts (p. 16).” Thus, whereas shifts might occur for certain speech continua that are categorically perceived, and also for certain nonspeech continua, cross-adaptation effects from nonspeech to speech were thought unlikely. Recently, however, Diehl (1976) demonstrated that a plucked sound produces an adaptation effect on a /ba/-/wa/ continuum, a speech array varying in the duration of formant transitions. This adaptation effect was as potent as that for /da/, a syllable not a member of the adapted array, but one that shares some features with /ba/. Thus, like categorical perception, the boundary shift in a speech array due to selective adaptation is not peculiar to perception in the speech mode.
IV. LEFT-HEMISPHERE EFFECTS DUE TO CEREBRAL SPECIALIZATION

The left hemisphere of the human brain is specialized to perceive and produce language. The perception of certain speech sounds, particularly the stop consonants, is one aspect of language processing for which the left hemisphere has a clear advantage over the right (Student-Kennedy & Shankweiler, 1970). This was a third result buttressing the existence of a special speech mode. In a typical experimental paradigm a pair of syllables is presented, one to the right ear and one to the left ear at the same time. Most listeners report the item presented to the right ear more easily than the one to the left. This result reflects two facts: the prepotency of the crossed-pathway connections from ear to cortex, and the effect of hemispheric specialization for speech. A second paradigm, used by Springer (1973), is a reaction-time task in which the listener presses a telegraph key when she hears a target syllable. A random ordering of many syllables is presented to one ear, white noise to the other, and the stimulus-to-ear configuration counterbalanced over several blocks of trials. Springer found a reliable 14-msec advantage for stimuli presented to the right-ear/left-hemisphere system.

The left hemisphere, however, is specialized for more than speech, and right-ear (Darwin, Howell, & Brady, this volume) and right-side (Morais, this volume) advantages accrue for many different reasons. Certain complex auditory stimuli (Halperin, Nachshon, & Carmon, 1973; Papcun, Krashen, Terbeek, Remington, & Harshman, 1974), certain acoustic properties of speech stimuli (Cutting, 1974a, 1974b), and certain musical stimuli for certain listeners (Bever & Chiarello, 1974; Gordon, 1975) appear to be processed best by the left hemisphere. Recently, Blechner (1977) used the same type of paradigm as Springer did and found that plucked and bowed sounds presented to the right ear, with noise to the left, were responded to more rapidly than those presented in the opposite configuration. Interestingly, the magnitude of the right-ear advantage was the same as for speech sounds — a 13-msec significant difference. Thus, the third of four results that I and others thought peculiar to speech perception is also found for the musical sounds. Wood’s (1975a) other two measures of laterality — differential ear advantages for temporal-order judgment of dichotically presented stimuli, and unilateral differences in averaged evoked potentials — may or may not occur for the musical sounds. The experiments have not been done.

V. ASYMMETRIC INTERFERENCE WITH REDUNDANCY GAIN

Wood’s (1975a) final converging operation on the auditory-phonetic distinction is the differential interference between auditory and phonetic dimensions of the same stimulus during speeded classification tasks. Since he also found redundancy gain for the same stimuli when they were presented in a perfectly correlated
manner (Wood, 1974), that result may be added to bolster this fourth buttress of the speech mode.

Imagine a set of four stimuli: /ba/ at a relatively high fundamental frequency; /ba/ at a low fundamental; /da/ high; and /da/ low. When classifying each item in a random sequence of these stimuli, frequency variation interferes with place decisions, but place variation has no effect on frequency. Moreover, when these dimensions are correlated (such as /ba/ low vs /da/ high) the stimuli can be responded to more rapidly than in any other condition. To account for these results, a hybrid parallel-serial model has been proposed (Wood, 1975a, 1975b). These results and others in tasks of speeded classification are developed more fully by Garner (1974, 1976).

The same pattern of results, however, has been found for nonlinguistic stimuli both in vision (Pomerantz & Sager, 1975) and in audition (Pastore, Ahroom, Puleo, Crimmins, Golowner, & Berger, 1976). More importantly, it occurs for plucked and bowed sounds as well (Blechner, Day, & Cutting, 1976). The stimulus set consisted of a plucked sound at a relatively high intensity, a plucked sound at a low intensity, a bowed sound at a high intensity, and a bowed sound at a low intensity. These stimuli yielded not only the same pattern as the speech sounds, but reaction-time differences of the same magnitude. Thus, at least with regard to these four rigorously determined patterns of results, the speech mode now appears to be without empirical support.

VI. THE SPEECH MODE AND THE AUDITORY-PHONETIC DISTINCTION

The notion of a peculiar speech mode is, to a degree, counterintuitive. Why should speech require a special mode of processing and other events not? The answer, of course, is that it seemed a necessary theoretical construct; now these results seem to question its necessity, although the broader observations of Liberman, Cooper, Shankweiler, and Studdert-Kennedy (1967), for example, remain unimpeached. There remains some small chance that all these parallels between the perception of stop consonants and plucked and bowed sounds are without real importance. It may be that underlying the complex of categorical perception, shifts due to selective adaptation, right-ear advantages, and asymmetric interference — all of which are logically, and in many cases empirically demonstrated to be, independent of one another — are two, perhaps more, possible modes of perception. My response to this possibility is twofold. First, the chance of so many parallels occurring by chance seems vanishingly small, and a single set of mechanisms accounting for both sets of results is more parsimonious than two sets, one for speech and one for music. Second, the results with plucked and bowed sounds are not the only ones that cause one to question the notion of a special speech mode. Other results indicative of speech perception, revealed in certain memory paradigms (Crowder, 1971) and in certain masking-like paradigms (Dorman, 1974; Dorman, Raphael, Liberman, & Repp, 1975), appear to be
accounted for in terms of nonlinguistic processes (Cutting & Dorman, 1976; Darwin & Baddeley, 1974; Pastore, Ahroon, Wolz, Puleo, & Berger, 1976; Remez, 1977). There are still other results in speech perception one could cite in defense of a speech mode, but in my opinion they are irrelevant to the separation of auditory from phonetic processes.

Since certain nonspeech results appear to go against the notion of a peculiar speech mode, they might be considered *counter*-counterintuitive. Counter-counterintuition is, of course, what might have been intuitive all along. The results from the plucked and bowed sounds, in particular, suggest reevaluation of two important concepts: the speech mode and the auditory-phonetic distinction. The second concept must be addressed first, for it has bearing on the first.

A. The Auditory-Phonetic Distinction

As I see it, there are two possible resolutions to the current quandary. The first runs contrary to Wood's (1975a) claim. These four results may not actually converge on the psychological reality of the auditory-phonetic distinction. Instead, they may converge on something else. Perhaps they reflect two different tiers of auditory analysis, or perhaps two different memory codes, one an input and the other an output from short-term memory. Perhaps phonetic processing is more abstract, or simply different, and not tapped by these four experimental situations. The second resolution, on the other hand, is consonant with Wood's analysis. These results may indeed reflect auditory versus phonetic processing. To render this view plausible, however, "phonetic" processing must be said to occur outside of speech as well as within. The Greek word *φωνή* has at least three translations — voice, sound, and speech — even though linguistic tradition reserves it, *phone*, for a sound of speech. If a definition of the term *phonetic* were expanded to include sounds outside speech, or to include "voices" of musical instruments, we could say that none of these results need be reinterpreted: Many auditory-phonetic differences occur within the speech domain, some outside of speech, but the constellation of results still converges on the distinction. Such a view may be more than whimsy, since the pluck-bow distinction appears to be akin to at least one consonantal-vocalic distinction, that of hard versus soft vocal attack (Hirose & Gay, 1973). This distinction separates */a/ (beginning with a glottal stop) from */a/ In addition, it is allied to that which separates */tsa/ as in CHOP from */sa/ as in SHOP, an affricate-fricative distinction. Finally, like speech, the musical distinction does have articulatory reference, although that reference is extralaryngeal, even extracorporeal.

It seems likely that one of these two interpretations is correct, yet they both have problems. The first appears to have a severe pragmatic constraint: If these four experimental results do not reflect differences between auditory and phonetic processes, I, personally, am at a loss to propose what kind of experi-
ments would properly reveal phonetic processes as different from auditory processes. I think it unlikely that the reality of phonetic processes is so tortuous as to be beyond these already pretzel-shaped paradigms. For this reason I favor the second account — phoneticlike (if not phonetic) distinctions occur for natural events throughout the auditory domain. I realize there are problems in this view. For example, in linguistics the term phonetic connotes many meanings not even vaguely touched on (at least thus far) by the plucked and bowed sounds and their results. In addition, the redefinition of a particular type of process is unlikely to solve substantial problems in our understanding of auditory perception in general, and speech perception in particular. However, this new view can guide our thinking. Studdert-Kennedy (1975, p. 14) noted that between the auditory and phonetic processes there lies a gap. In this gap is the none-too-well-understood mapping of acoustic property onto phonetic feature. In my view, the plucked and bowed sounds allow us to peer into the perceptual network and observe one of these mapping processes, and to do so outside the domain of speech. Perhaps because no nonspeech sounds (yet) appear to be multidimensionally categorical, we cannot (yet) peer farther into the system to observe the compilation of a “phonetic” feature matrix and subsequent remappings onto “phonological” processes that might occur for nonlinguistic sounds. I think this line of reasoning and experimentation should be pursued. The observation of speechlike processes outside of speech is important; the more processes shown to be common to the perception of speech and nonspeech sounds, the more unified can be a general theory of the perception of complex, naturally occurring auditory events.

B. The Speech Mode

Both interpretations of the data reported here appear to speak against the peculiarity of a speech mode. The first interpretation, that the results have no bearing on the auditory-phonetic distinction and the perception of phonetic features, suggests that speech researchers have simply been unable to gather evidence for a peculiar speech mode. The second interpretation, that phoneticlike processing can occur outside of speech, is almost equally damning. At the same time, however, it seems much more interesting. It suggests that if a speech mode exists, it is not so peculiar as once thought. This is not to say the speech perception is simple. To the contrary, speech perception is just as complex as those at the Haskins Laboratories have reported it to be, if not more so. Although there may be no peculiar speech mode, there remains a complex speech code and all the results discussed in this paper remain indicative of speech perception, and in some cases central to it. Instead, the perception of naturally-occurring, nonlinguistic events appears to have been underestimated and oversimplified. The perception of these sounds may be just as complex as the perception of speech, or if not, its complexity may differ in degree rather than kind. Moreover, to say
that the perception of naturally-occurring nonlinguistic events is complex seems to be insufficient. The results discussed in this paper suggest that the perception of these sounds may be complex in the same way that the perception of speech is complex.

If this view is correct, one might say that earlier views of auditory perception were out of joint, and that some links in the Great Chain of Being (Tillyard, 1943) can now be realigned to some small degree. In my opinion, speech perception should be welcomed back to join the perception of other natural events. Perhaps we should end one phase of research and begin another (Osherson & Wasow, 1976). Instead of looking for that which is peculiar to speech perception, we might look for commonalities between speech and other systems of events.

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