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Distinctive Features: Theory and Validation

Sadanand Singh

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One of the most striking properties of language is its quantal character. Although the speech signal is acoustically a quasicontinuous event with long stretches where all noticeable changes are quite gradual, the speaker and hearer are certain that the signal consists of a sequence of discrete sounds following one upon another. This picture of the speech signal is, of course, reflected in our writing system which transcribes each word as a sequence of letters. The picture, however, is not the result of literacy; speakers and hearers that have no idea of writing also share it fully. To cite one bit of evidence consider how the plural of English nouns is formed. As everyone knows there are at least three distinct plural suffixes:

(1) /Iz/ as in *horse–horses, bush–bushes, beach–beaches, rose–roses, garage–garages, judge–judges;*
/s/ as in *cap–caps, cat–cats, cake–cakes, cough–coughs, fourth–fourths;*
/z/ as in *cab–cabs, cog–cogs, play–plays,* etc.

In order to produce the correct plural form we need to know the last sound of the noun form, for as the examples in (1) show the plural ending must be

(2) (a) /Iz/ if the noun ends with the consonants /s š č z ž j/;
(b) otherwise, /s/ if the noun ends with the consonants /p t k f θ/;
(c) otherwise, /z/.

Implicit in (2), however, is the analysis of the word into discrete sounds, minimally, into the last sound and whatever precedes it. Since illiterate speakers of English—children aged 2—regularly produce plurals of nouns they have never heard before (e.g., the well-known "errors" *mouse–mouses* or *sheep–sheeps*) one must assume that such speakers know a rule much like (2) and are capable of analyzing words they hear into sequences of discrete sounds.

The speech sounds or phonemes of a language, however, are themselves complexes of discrete properties, which are commonly referred to as distictive features. One sees this quite clearly when one considers the groups of sounds in (2) above. The sounds in (2a) /s š č z ž j/ are all produced with a common gesture which consists of raising the tongue and blowing a jet of air against the bottom edge of the front teeth. This gesture results also in a specific "hissing or hushing" noise which acoustically is marked by a broad spectral peak located somewhere between 2500 Hz and 5000 Hz. (Speakers who have lost their upper front teeth are usually incapable of producing these sounds.) The sounds in (2b) also share a property in common. They are produced in such a manner that the vocal cords are *not* set into vibration, which in turn has the clear perceptual acoustic consequence of absence of any periodic component in the sound.

For purposes of the present discussion let us call the property exemplified by the phonemes in (2a) – *hiss*, and that exemplified in (2b) – *voice*. It will be noted at once that these properties are not mutually exclusive; there are voiced hiss sounds: /z ž j/, voiceless hiss sounds: /s š č/, voiced hissless sounds: /b d g v n m/ and voiceless hissless sounds: /p t k f θ/. The claim that has motivated much phonetic research during the last quarter of a century is that human beings perceive phonemes as complexes of such distinctive features. It is obvious that to establish this claim one cannot question naive subjects, because naive subjects have never heard of features and find it difficult, if not impossible, to talk about it. This fact can, however, not be taken as negative evidence, anymore than one can take as counterevidence to the claim that speech is a sequence of discrete sounds, the fact that three year old children cannot answer direct questions about the sound composition of words. As was done above, an experiment must be devised that gets at the answer in an indirect fashion.

If phonemes are complexes of features a rule such as (2) will be given in feature terms; i.e., in the form (3)

(3) The plural form of a noun is
(a) /Iz/ if the noun ends with a *hiss* sound;
(b) otherwise, /s/ if the noun ends with *voiceless* sound;
(c) otherwise, /z/.

We will now show that speakers of English know the plural rule in the form (3) rather than (2). Suppose we made up a noun that ended with a sound that does not exist in English and asked English speakers to give its plural form. If they had internalized the rule in the form (2) they should invariably select /z/ as the plural of such a noun for they would go through the lists of phonemes in (2a) and (2b), not find the phoneme in question there (since the word ends with a phoneme that is not part of the English phoneme repertory) and thus be forced to utilize rule (2c). If on the other hand, they had internalized the rule in form (3)—i.e., if they truly viewed phonemes as feature complexes—they would respond according to the feature composition of the sound ending the word in question. An appropriate test word is the name of the German composer J. S. Bach, which ends with the hissless and voiceless sound /x/ which does not exist in English. For most English speakers the plural of *Bach* is *Bachs* with /s/, not /z/. This is predicted, of course, by rule (3) but not (2). We have thus shown that speakers treat phonemes not as further unanalyzable atoms, but rather as complexes of distinctive features. (This experiment was suggested to me by Lise Menn.)

Demonstration experiments of the sort just described can obviously be devised for speakers of languages other than English and will produce the same results, showing that it is a linguistic universal that utterances are perceived as sequences of discrete phonemes and that phonemes are treated as complexes of features. This conclusion leads directly to the question as to the why and wherefor of these universals. The only plausible answer to this question ever suggested is that these universals reflect fundamental aspects of the apparatus involved in processing speech: the vocal tract, the auditory system, and the structures in the brain that control the speech process. In some instances, such as the distinctive feature of *voice* referred to above, this is perfectly obvious; in other instances, the precise anatomical structures and auditory mechanism involved are subject to considerable discussion. What must, however, be taken as established is that speech is made up of phonemes and phonemes are complexes of distinctive features.

The book under review attempts to summarize some of the research and the thinking that has dealt with these issues. Unfortunately the author's command of the material appears not quite up to the task. Thus, for example, the author writes:

"Distinctive features are the physical (articulatory and acoustic)

and psychological (perceptual) realities of the phoneme. In other words, each phoneme can be described and differentiated in terms of: (1) articulatory features, namely, the place of articulation, the manner of articulation, and voicing; (2) acoustic features, namely, frequency, intensity, and duration of speech sounds; and (3) perceptual features, which are the result of the auditory discrimination between phonemes." (p.5).

Disregarding minor inacuracies such as the list of properties in each of the three categories, this passage reflects a basic misunderstanding by Professor Singh as to the nature of the features. According to him, there are three different types of features: articulatory, acoustic and perceptual; i.e., each type of data has its own set of descriptive parameters. While this approach may satisfy the empiricist strain in each of us not to construct fanciful hypotheses for which there is no clear warrant in the data, it does so only at the price of an arbitrary disregard of the most crucial evidence, namely, that the acoustic signal is produced by a human being who manipulates his speech organs and at the same time perceives and understands the signal as an utterance in his language. In many cases the parallelism among articulatory, acoustic and perceptual attributes is practically self-evident (e.g., nasality, voice, plosiveness, etc.) To assume, as anyone adopting Professor Singh's theoretical stance must, that these striking instances of parallelism are purely accidental coincidences should strain the credulity of even the most gullible. A more reasonable attitude is to assume as was done long ago by Roman Jakobson that there is only a single set of features which have specific manifestations in the different domains—the articulation, the acoustics, and the perception. This approach presents one with the challenge to account for a number of instances where the parallelism is not directly apparent. While this challenge is anything but trivial, it is clearly much less daunting than the need to explain as statistically random coincidences the striking parallelism mentioned above.

These theoretical shortcomings of the book are unfortunately parallelled by nontrivial shortcomings in the command of the empirical subject matter. I will cite just two.

On p. 89 Professor Singh asserts that "the criterion or basis of a phoneme can be acoustic (as in Jakobson, Fant, Halle), articulatory (as in Chomsky and Halle)..." This assertion does not jibe with the facts.

In Jakobson, Fant, and Halle, [*The Sound Pattern of English* (Harper and Row, New York, 1968)] it was explicitly stated that "the specification of the phonemic oppositions may be made in respect to any stage of the speech event from articulation to perception and decoding." (p. 13). Moreover, in the rest of the book the description of each distinctive feature contains separate sections on acoustics (under the heading *Stimulus*), articulation (*Production*), perception and utilization in individual languages (*Occurrence*). Thus it is not true that the criteria in Jakobson, Fant, and Halle are acoustic.

It is true that in Chomsky and Halle [*Preliminaries to Speech Analysis* (MIT, Cambridge, MA, 1972)] the features are described almost exclusively in articulatory terms. It is, however, noted that this is not a matter of principle but rather due purely to expository convenience. "We shall speak of the acoustical and perceptual correlate of a feature only occasionally, not because we regard these as either less interesting, or less important, but rather because such discussions would make this section, which is itself a digression from the main theme of our book, much too long." (p. 299). Thus, it is not the case that for Chomsky and Halle the criteria are solely articulatory.

Professor Singh states: "... the production and perception of consonants and vowels have separate bases. The production of vowels involves periodic vibrations of the vocal folds, and the production of consonants involves either no periodicity or quasi-periodicity." (p. 33). Both assertions in the last sentence are false. Since whispered vowels exist, although they do not involve periodic vibrations of the vocal folds, such vibrations are not essential for vowel production. On the other hand, as anyone who has ever looked at sonagrams or oscillograms of speech cannot fail to have noticed the consonants /n/ as in *new*, /l/ as in *lien*, and /z/ as in *zoo* all have striking periodicities.

In summary the book under review deals with a topic of capital importance. It contains extensive summaries of different studies on this subject by various workers as well as explanatory comments by Professor Singh. Unfortunately, both the summaries and the comments are not free of errors and misapprehensions. [This work was supported in part by Grant 5 P01 MH 13390-11 from the National Institute of Mental Health to the Massachusetts Institute of Technology.]

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Handbook of Industrial Noise Management

Richard K. Miller

Fairmont Press, Atlanta, 1976.
210 pp. Price $19.95.

This book was written "for plant managers and safety engineers" but, in some ways, it appears to be more of a publicity brochure for the author (and his firms) than a serious technical book. The jacket describes the author's successful consulting business, while the introduction and preface do more to praise the author and the book than to introduce it. Although an attempt is made to balance the advantages and disadvantages of using an outside consultant, the advantages are favored. By mentioning the author's firms and credentials in selected places throughout the book (his firm is even located in the index), the advertisement is clear.

This book is designated as a handbook and, as such, should allow the reader to look up specific topics, find them easily and have them explained well. Most handbooks have figures, tables, and charts, which display empirical or theoretical data, and provide "simple" methods to solve the reader's immediate problem. However, Miller tends to put information in this book which, although interesting, is difficult for the intended reader to employ. For example, he provides tables showing costs of noise-control materials but gives no indication or estimate of the possible noise reduction resulting from the use of these materials. Thus the reader can choose a lead sheet, a lead vinyl sheet, or ¾-in. plywood sheet at respective per square-foot costs of $0.40–$0.75, $1.70–$3.00, and $0.45, but there is no way to determine, from the text, which to select or how to make the choice. Noise-control engineers can find data like this helpful but, for others, its value is dubious. In discussing costs of materials, the author uses the term "dollar per square foot" costs for mufflers and the term is not clear—especially since the insertion loss of the units is not mentioned nor is the area term defined (i.e., is it a square foot of cross section or of surface area of the muffler?). A handbook for the safety engineer should mention the proper equipment for measurement and analysis of noise, but here the reader is referred to other sources (including Miller's previous book, *Secrets of Noise Control*, in which little or no information is available).

There are several statements that are unsubstantiated or vague. Miller says, for example, that hearing loss is of less severity than loss of limb. When discussing feasibility of noise control solutions or compliance, his approach as a consultant is so encompassing that it appears overwhelming. Yet, when he lists "six concepts that include all possible solutions to any noise problem," he neglects to mention items like proper maintenance, source noise replacement or redesign. (These latter methods may only require a change of component, minor redesign, or proper alignment of