PHONETIC VARIATION AND ACOUSTIC DISTINCTIVE FEATURES

JANUA LINGUARUM

STUDIA MEMORIAE
NICOLAI VAN WIJK DEDICATA

edenda curat

CORNELIS H. VAN SCHOONEVELD

STANFORD UNIVERSITY

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PHONETIC VARIATION AND ACOUSTIC DISTINCTIVE FEATURES

A Study of Four General American Fricatives

by

CLARA N. BUSH

STANFORD UNIVERSITY

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INTRODUCTION

A. GENESIS OF THE PROBLEM

The science of phonetics has, since its inception, concerned itself with the specification of the sounds of speech. Necessarily, the earliest attempts employed subjective methods and focused on the physiological relationships and processes which produced, recognizable units of the speech code. The work of the early phoneticians culminated in the classical phonetic formulation of vowels and consonants classified by place and manner of articulation and represented by the symbols of the International Phonetic Alphabet (88).[1]

Since the early 1940's, the development of modern acoustical instrumentation and methods of experimental research has resulted in an ever-increasing number of reports directed toward the specification of speech sounds in terms of their traditional physical parameters – frequency, intensity, and wave composition. At the same time, there has been a growing conviction that the physical parameter of time is also relevant to the acoustic specification of speech sounds.

Attempts to specify the various speech sounds acoustically have met with varied success. Some sounds, notably the vowels in steady-state, lent themselves particularly to such acoustical instrumentation and methodology as was available, and early yielded valuable information. Other sounds were harder to specify. The class of voiceless fricatives, for example, is characterized by a wide range of intensities, by some of the highest frequency components of human speech, and by aperiodic vibration. Each of these characteristics posed special problems for investigators using instruments and methods appropriate to vowel analysis. Consequently, while the acoustic specification of speech has progressed with increasing rapidity, our knowledge of the acoustic characteristics of the several sounds of speech is extremely uneven.

The phonetic specification of speech sounds, both physiological and acoustical, has been of continued interest to those involved in phonemics, the branch of linguistics concerned with cataloguing the essential sound segments of a given language. Traditionally, the phonemicists have held divergent opinions concerning the relevancy of phonetic specifications to phonemic analysis. One of the most basic controversies

[1] Numbers between brackets refer to the Bibliography, pp. 154-161.

has concerned the nature of the phoneme itself, as well as the nature of its representation in the actual stream of speech. Among the theories which have been propounded on that subject is the distinctive feature theory, which holds that each phoneme is an unique bundle of concurrent distinctive features, or sound characteristics, that are specifiable in the terms of physiological and acoustical phonetics. *The Preliminaries to Speech Analysis* (97) by Jakobson, Fant, and Halle (hereinafter referred to as the *Preliminaries*), the basic exposition of this theory, specified certain phonemes of English according to their distinctive features, and presented an initial formulation of the perceptual, physiological, and acoustical characteristics of the distinctive features.

As a basic construct relating certain aspects of phonemic and phonetic analysis, the distinctive feature theory has been widely accepted as extremely promising. The necessary work of elaborating and refining its application, however, is exceedingly complex. Those responsible for its formulation, both in its theoretical aspects and in the specification of the distinctive features, have encouraged the critical consideration of those interested in both phonemics and phonetics. The logic and appropriateness of the theoretical construct must be scrutinized and appraised in terms of phonemic theory, and the relevance of its application to the actual speech event must be tested in terms of experimental phonetics.

B. STATEMENT OF THE PROBLEM

The statement of the distinctive feature analysis in terms of binary oppositions makes it amenable to experimental test phonetically. For example, each distinctive feature has been defined acoustically. The theory states that a given distinctive feature, if relevant to the acoustic specification of a certain phoneme, is relevant on a dichotomous basis, that is, it is either present or absent as evidenced by the acoustic record. If present, it contributes to the unique bundle of distinctive features which characterizes that phoneme acoustically. If absent, it contributes to the unique bundle of distinctive features which characterizes that phoneme's cognate (or opposition pair) on the distinctive feature parameter involved. Thus, according to this theory, through a series of dichotomous judgments in terms of the acoustic records, any phoneme can be distinguished from all other phonemes in the language.

In establishing the acoustic specifications for the distinctive feature opposition, the traditional linguistic method of analysis by minimal pairs was used, i.e., the method of testing for sameness or difference by commutation in identical phonetic context. In spite of this limitation, the results for both phoneme analysis and distinctive feature specification have been presented in the form of generalizations, and not as specific to phonetic environment. That is to say, a given phoneme is said to be characterized by a certain set of distinctive features, the implication being that this holds true whenever that phoneme is recognized. Similarly, the distinctive features, in turn, are characterized as having certain specific acoustic attributes. Thus, the specification of both phonemes and distinctive features must be assumed to be broad enough to embrace each identifiable member of the phoneme class, whatever the circumstances of its utterance, e.g., regardless of speaker, phonetic context, or position in utterance.

On the other hand, there is evidence from research in experimental phonetics that such specifications may not be possible. No one-to-one relationship has been established between sound recognition and acoustic specification. Identical acoustical characteristics have resulted in the recognition of a given phoneme in one phonetic context, and in the recognition of a completely different phoneme when the phonetic environment was changed (53, 71). Conversely, certain sounds identified as representative of the same phoneme have been found to have acoustically divergent characteristics, so divergent as to resemble other phonemes more than they resemble each other (119, 175).

Under these circumstances, it seemed worthwhile to investigate the effect of changing phonetic environment and position in utterance upon the acoustic specification of phonemes in terms of the distinctive features. The hypothesis to be tested stated that the differences which exist acoustically among the allophones of a phoneme are sufficient to alter the distinctive feature specification of that phoneme. To test that hypothesis, the present study was designed.

C. PLAN OF THE STUDY

The general objective of the present study was to take appropriate acoustical measures of certain English sounds in various phonetic contexts and to relate these measures to the distinctive feature specification for the phonemes represented by those sounds. The phonemes selected for investigation were four English fricatives, /f/, /v/, /θ/, /ð/, representing two distinctive feature oppositions: Tense *vs.* Lax (/f/ and /θ/ *vs.* /v/ and /ð/) and Grave *vs.* Acute (/f/ and /v/ *vs.* /θ/ and /ð/).

The consonants selected for test were used in two positions in utterance, medial and final. Phonetic context was varied systematically employing each of the following vowels: /i/, /æ/, /ɑ/, /u/.[2] For the medial condition, each of the consonants preceded the stressed vowel, for example, [hə'fit]. For the final condition, the consonant followed the stressed vowel, for example, [hə'tif]. The four consonants, appearing in two positions with each of the four vowels, resulted in thirty-two stimulus items, which were recorded on tape by eight speakers, four men and four women.

Stimulus items judged to contain acceptable representations of the consonant phonemes intended were recorded graphically, using a sound spectrograph and a high speed level recorder. The acoustic records made were analogous to those specified

[2] See Appendix A (p. 144) for a note on the transcription system used in the present study, and a chart of the relevant phonemic and phonetic symbols.

for the acoustic representation of the distinctive feature oppositions Tense/Lax and Grave/Acute (see Table 2 on p. 22). From these acoustic records, the appropriate measures were taken (see Chapter III, p. 33). Results were tabulated in terms of acoustic representation for both the phoneme and the relevant distinctive feature opposition.

Through comparisons of these acoustical measures, taken from the same phoneme in phonetic contexts varied systematically by both adjacent stressed vowel and by position in utterance, it was possible to observe the effects which change in environment exerted upon the phoneme's acoustical representation, as well as upon the acoustical representation of the distinctive feature oppositions under investigation.

II

BACKGROUND OF THE PROBLEM

A. THE DISTINCTIVE FEATURE THEORY

The publication of *Preliminaries to Speech Analysis* (97) by Jakobson, Fant, and Halle in 1952 presented one of the most interesting and significant constructs in the field of phonemics. Essentially an analysis of the sound features of human language, this theoretical construct specifies twelve attributes (inherent distinctive features) as characteristic of the sounds of speech, i.e., in linguistic terms, the segmental phonemes as represented by their allophones. The theory proposes the analysis of any phoneme in a given language into an unique bundle of certain of these concurrent features. The distinctive features, rather than the phonemes themselves, are said to be specifiable in the stream of actual speech on all levels of the speech event: articulatory, acoustical, and perceptual. For each sound, a series of dichotomous judgments in terms of relevant binary oppositions serves to specify the phoneme. "According to the theory of distinctive features... a phoneme is regarded as the sum of the relevant sound features which preserve its identity versus other phonemes of the language" (36, p. 87; cf. 61, p. 511; 89, p. 34; and 174, pp. 118-119).

The distinctive features presented in the *Preliminaries* are said to be universal and common to all languages and are presumed to be "independent of one another, that is, no one of them can be expressed as combinations [*sic*] of the others" (18, p. 63). The twelve oppositions are stated: Vocalic/Non-vocalic, Consonantal/Non-consonantal, Interrupted/Continuant, Checked/Unchecked, Strident/Mellow, Voiced/Voiceless, Compact/Diffuse, Grave/Acute, Flat/Plain, Sharp/Plain, Tense/Lax, and Nasal/Oral (97, pp. 18-40).

While these twelve binary oppositions theoretically permit the specification of 4096 unique phonemes (19, p. 93), not all of the distinctive features are relevant to a given language. Of those which are, only a small number of the possible combinations are utilized for the phonemes of that language. Thus, since the number of segmental phonemes in any language is relatively small, the information conveyed in the phoneme has a high degree of redundancy, i.e., there are multiple cues among the relevant distinctive features which tend to ensure phoneme identification under less than ideal listening conditions.

The concept of the phoneme as a concurrent bundle of distinctive sound features was not new in 1952. It had been fore-shadowed early in the twentieth century by de Saussure's interest in the simultaneous as well as the successive character of structural linguistic entities (174). Saussure is also credited with the notion that the primary element in the sound system of a language is not the phoneme, but is, rather, the opposition, the differential quality among phomenes (93). Jakobson has stated: "Since 1932 in my papers I have defined the phoneme as a bundle of differentiating properties" (93, p. 328.) In 1933, Bloomfield wrote:

> Among the gross acoustical features of any utterance, then, certain ones are distinctive, recurring in recognizable and relatively constant shape in successive utterances. These distinctive features occur in lumps or bundles, each one of which we call a phoneme. The speaker has been trained to make sound-producing movements in such a way that the phoneme features will be present in the sound waves, and he has been trained to respond only to those features and to ignore the rest of the gross acoustical mass that reaches his ears (11, p. 79).

Bloomfield, himself, did not propose the specification of phonemes in terms of their inherent features. Rather, he held, with Sapir (172), that phonemes should be grouped into categories according to their possibilities of combination with other phonemes in the speech chain. While both linguists employed phonetic criteria in pre-linguistic analysis (172, p. 45), they held that phonemic analysis must be based primarily on distributional patterns in order to have relevance to structural linguistics (11, pp. 129-130).

The extreme of this viewpoint was stated later by Hjelmslev. "As phonemes are linguistic elements, it follows that no phoneme can be correctly defined except by linguistic criteria, i.e., by means of its function in the language. No extra-lingual [*sic*] criteria can be relevant, i.e., neither physical nor physiological nor psychological criteria" (77, p. 49; cf. 39). Other linguists currently active have emphasized that phonemic analysis must be primarily distributional rather than phonetic (73, 167). In recent years, the proposal has been made that linguists either develop rigorous rules for phonetic similarity or drop the criterion entirely. To that point, both Austin (3) and Belasco (7) have proposed formulations for phonetic similarity which they believe to have universal scope.

Most linguists support the use of both distributional and phonetic criteria as providing complementary information important to the cataloging of phonemes, although many express reservations about the use of the distinctive feature analysis as the basic approach to phonemic analysis (29, 40, 41, 79, 136, 159, 189).

However, Trubetzkoy (196) in 1939, supported the inherent distinctive features (phonetic characteristics) as the preferred basis for phonemic analysis. In his view, not every phoneme in each language could be uniquely specified on a solely distributional basis.

Jakobson, Fant, and Halle, have pronounced the distinctive feature analysis fundamental to the distributional analysis. They point out in the *Preliminaries* (97, p. 12) that distributional classifications are based on innumerable assumptions that two sounds may be classed as the "same". Information concerning the patterning of "same" sounds in the language is said to define the phonemes. Judgments of sameness or difference are bound to the informant's response to the sounds as they occur in spoken language, i.e., to his differential response to the acoustical output of native speakers. Consequently, these authors, among others, hold that a catalog of the phonemes of a language can never be actually based on purely distributional criteria.

The problem of relating phonetics, a "natural" science, and phonemics, a "linguistic" (social) science, has long occupied the linguists (139). In relating phonetics and phonemics on the level of the distinctive features rather than on the level of the phonemes, the *Preliminaries* bypasses one of the most persistent problems of twentieth century structural linguistics, that of defining the phonemic concept and the relationship of phonemes to sounds which occur in actual speech (199). The distinctive feature theory is not antithetical to the concept of the phoneme as an "abstractional fictitious unit" of form (199, p. 37) in the functional system of language. At the same time, this theory does provide for the necessary link between phonemics and phonetics. The phoneme is related to the actual sound in the stream of speech through the specification of the "ultimate components", the distinctive features (97).

The distinctive feature analysis utilizes, as a part of its working hypothesis, the theory of binary oppositions. Its authors term the dichotomous scale "the pivotal principle of the linguistic structure. The code imposes it upon the sound" (97, p. 9). While this scale has been accepted as extremely promising for all levels of linguistic analysis (54, p. 60), many linguists reject it as an "ultimate truth" of language structure (107, p. 708; cf. 16), and consider it merely a method of analysis imposed by the analyzer. "The theory that primary recognition is the result of a series of binary choices is convenient from the point of view of information theory, though it is not in any sense a *sine qua non*" (47, p. 170).

The belief that binary classifications are inherent in our recognition of phonemes is defended in the Preliminaries on both theoretical and empirical grounds. Research in multidimensional auditory displays (162) is cited, showing that five different values of six different variables can be accurately recognized by listeners when presented to them one at a time. However, when all six variables are presented simultaneously, listeners are able to do no better than make an accurate binary judgment for each. Such multidimensional stimuli are presumed to bear certain similarities to the complex speech signal.

Empirically, also, there is evidence that perceptual judgments are made on the basis of a series of two-choice decisions. For example, nasality, like many other sound features, is recognized as extending along a continuum from extreme nasal resonance to extreme de-nasal resonance. Yet any given English consonant is conventionally classified as either nasal or not nasal (oral). Thus, whenever such a decision is relevant, the listener is presumed to consign a specific sound to one of the opposing categories. For many English phonemes, e.g., all the vowels, this decision