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**Title**

WPP, No. 103: Phonetics and Phonology in the Last 50 Years

**Permalink**

<https://escholarship.org/uc/item/3xk6p6hj>

**Author**

Ladefoged, Peter

**Publication Date**

2004-09-01

## PHONETICS AND PHONOLOGY IN THE LAST 50 YEARS

Peter Ladefoged

Dept. Linguistics, UCLA, Los Angeles, USA  
oldfogey@ucla.edu

[Paper presented at: From Sound to Sense: 50+ Years of Discoveries in Speech Communication, MIT, 11-13 June 2004.]

### ABSTRACT

In the last 50 years there have been steady gains in phonetic knowledge and punctuated equilibrium in phonological theories. Phonetics and phonology meet most obviously in the definition of the set of features used to describe phonological processes. The Jakobsonian statement of distinctive feature theory in the 1952 caused a paradigm shift in the relations between phonetics and phonology. Changes occurred again with the introduction of a mentalist view of phonological features in the 1968 publication of *The Sound Pattern of English*. In 1972 Stevens' introduced Quantal theory and the hunt for acoustic invariance for phonological features was on. Autosegmental phonology and notions of a feature hierarchy brought further demands on phonetic knowledge. Now Optimality theory has proposed a new way of relating phonological contrasts and phonetic data, and Articulatory phonology has spurred great phonetic progress that is just beginning to have a direct impact on phonology..

### FEATURAL BEGINNINGS

It's nice to be asked to present a historical survey of half a century of phonetics and phonology in this MIT meeting, because there was a clear cut change in the relations between these fields just over 50 years ago, and it was at MIT. In 1952 Roman Jakobson, Gunnar Fant and Morris Halle published *Preliminaries to Speech Analysis: The distinctive features and their correlates*. It came out as a technical research report of the MIT Acoustics Laboratory and had a great impact on the field. This was a major new coming together of linguistics and speech engineering. There had been other publications concerning speech and acoustics, notably Potter et al, (1947) and Joos (1951). But these were primarily concerned with facts about the acoustics of speech. What was important about Jakobson et al (1952) was that its primary concern was linguistic theory. Jakobson had been propounding the notion of distinctive features for some time as had Trubetzkoy (1939). In *Preliminaries to Speech Analysis* linguistic theory was supported by advanced acoustic notions.

Many MIT people are mentioned in the acknowledgements of *Preliminaries to Speech Analysis*, including a young scholar called Kenneth Stevens, who was just completing his doctorate. Interestingly, the second author of the report, Gunnar Fant, though five years senior to Ken Stevens, did not complete his doctorate till six years later, in 1958. A Swedish doctorate is a mighty thing. The 'junior' author, Morris Halle, had received his doctorate in 1951

There had been several signs of an increasing interest in acoustics and linguistics at MIT around that time. In 1950 the Harvard Psycho-Acoustic Laboratory under the direction of S.S. Stevens joined with M.I.T to sponsor a Conference on Speech Communication (Stevens 1950). A couple of linguists, Martin Joos and John Lotz, gave papers at this conference. Ken Stevens also contributed to the Proceedings. But the full force of Jakobsonian thought was yet to have its impact. Indeed, even the term 'phonology' was not at the forefront of linguistic usage. The phoneme and phonemics dominate in the titles of the 40 papers thought to represent the field as late as 1957, published as *Readings in Linguistics* (Joos 1957). In the early 1950's we were still in the days of structural linguistics.

Whether the field was called phonemics or phonology, the same three strands were distinguishable then as are present in modern phonological research (Goldsmith 1995). We will take it that phonology focuses on three topics: (1) How do we represent the lexical contrasts between words; (2) What are the constraints on the sounds in lexical items in a given language (or, as some would put it, what is a well formed syllable); and (3) How can we describe the relations between the underlying lexical items and the observable phonetic output (or, putting it another way, how can we formalize the sound patterns of languages). Jakobson, Fant and Halle (1952) were mainly concerned with the first of these topics. The aim of their report was to present the acoustic correlates of the minimal set of features required to distinguish the lexical contrasts found in the languages of the world. They noted that "The inherent distinctive features which we detect in the languages of the world and which underlie their entire lexical and morphological stock amount to 12 binary oppositions: 1) vocalic / non-vocalic, 2) consonantal / non-consonantal, 3) interrupted / continuant, 4) checked / unchecked, 5) strident / mellow, 6) voiced / unvoiced, 7) compact / diffuse, 8) grave / acute, 9) flat / plain, 10) sharp / plain, 11) tense / lax, 12) nasal / oral." (Jakobson et al 1952:40). This reduction of the framework required for linguistic description to such a bare minimum entailed what we would now call procrustean techniques in which, for example, several distinctions in different languages involving various types of glottal stricture were all classified as [+checked].

In a discussion of his early collaboration with Jakobson, Fant (1986) notes that: "It was the great undertaking of Roman Jakobson ... to attempt to unify, within the same theoretical frame, ...[1] a language-universal system of phonetic categories selected to serve phonological classificatory functions [and 2] the essentials of the speech code, i.e., distinctive dimensionalities and mechanisms of encoding within the speech chain." (Fant 1986:480). When making these later comments Fant expresses doubts as to the possibility of a unified theory. He gives an interesting insight into the marriage between phonetics and phonology, noting that "Phonetics is the stable part of the marriage, while phonology is promiscuous in its experimenting with widely different frameworks." (Fant 1986:481) As we go on with this review of phonetics and phonology we will see that Fant had it right 20 years ago. Phonetics is deepening its roots in undisputed factual ground, while phonology continues to flirt with new approaches..

## **THE RISE OF MENTALISM**

The next major change in the relations between phonology and phonetics did not come for 16 years. The proposals in *The Sound Pattern of English* (Chomsky & Halle 1968) had been foreshadowed in other publications such as Halle & Jones (1959) but it was not until the later work that they became fully explicit. The crucial difference between *Preliminaries to Speech*

*Analysis* and *The Sound Pattern of English* (SPE) is that Chomsky and Halle were more interested in explaining the patterns of sounds within a language than in describing the lexical contrasts in different languages. The aims of the feature sets proposed in the two works are different. Jakobson, Fant & Halle wanted to develop a minimal classificatory system rather than one that helped explain phonological notions. Chomsky and Halle were interested in explaining observed sound patterns by reference to phonological features in a speaker's mind. Jakobson, Fant & Halle suggested that the acoustic aspects of features were more important because "we speak in order to be heard in order to be understood", and the nearer our descriptions fitted with what was being understood the better they were. Chomsky and Halle proposed a feature set that had both articulatory and acoustic properties that the speaker knows about, neither aspect being more important.

*The Sound Pattern of English* is concerned with all three aspects of phonology, the representation of lexical contrasts, the constraints that produce well formed syllables, and formal explanations of phonological alternations, However it is the latter that is the main interest, the sound patterns of English. Only Chapter 7 is mainly concerned with elaborating the feature set that is required for the first aspect of phonology, specifying lexical items in the world's languages. With its larger feature set (24 binary features for segments) it is able to provide much more straightforward distinctions between lexical items in many languages. However it still tends to use a single feature to cover a wide range of distinctions than many phoneticians find unnatural. The feature Distributed, for example, is used to distinguish both apical vs. laminal distinctions as well as bilabial vs. labiodental differences.

### **DEEPENING ACOUSTIC PHONETIC KNOWLEDGE**

During the 16 years between these two landmark publications in phonology, *Preliminaries to Speech Analysis* and *The Sound Pattern of English*, there were many developments in phonetics. Ken Stevens and Arthur House published a number of studies putting the acoustic analyses of vowels and consonants on a firm basis (House & Stevens 1956, Stevens & House 1955,1956). and the Haskins labs started their epic accounts of the acoustics of speech (e.g. Cooper *et al.* 1952, Delattre *et al.*1952, Liberman 1957) giving us a great deal of data concerning the sounds of speech. The whole acoustic theory of speech production was established by Fant (1960) as part of his glorious Ph.D.. As a result of this and other research on less well known languages (e.g. Ladefoged 1964) Chomsky & Halle were able to propose definitions for 24 binary features for characterizing segments.

The SPE features became widely accepted and the hunt was on to find the properties of each of them. Shortly after the publication of SPE, Stevens (1972) proposed a 'quantal theory' that was highly relevant to the characterization of features. This theory proposed that certain speech sounds are favored because they have acoustic characteristics that can be produced with a comparatively wide range of articulations. Stevens demonstrated a number of instances in which there was a non-linearity in articulatory and acoustic changes. A full account of the quantal theory was given in a review article by Stevens (1989).

In the course of the hunt for the defining aspects of phonological features, Stevens, Keyser and Kawasaki (1986) offered further suggestions. They start with a strong statement of the principle of invariance: "Our point of view is that, when a word is spoken, a particular acoustic property

appears in the sound whenever a given feature is being used to identify the word, and thus to distinguish it from other words. This acoustic property is invariant in the sense that it is independent of the context of other features and segments in which the feature occurs.” (Stevens et al, 1986:427) They then point out that some combinations of feature are more common than others, and in many cases a seemingly redundant feature may enhance the perceptual cues for the distinctive feature. Thus English vowels (and those of the majority of the world’s languages) can be specified using just the features High, Low and Back, and without using the feature Round. The feature value [+ back] is characterized by a lowering of F2, making it closer to F1 than to F3. The feature Round also causes a lowering of F2 for [+ back] vowels (and of either F2 or F3 for [– back] vowels).As a result, [+back] is enhanced by the co-occurrence of [+round].

Other ‘helping features’ that work alongside the principal phonological features include the role of length in enhancing the distinction between [+voice] and [–voice], in, for example, *bad* as opposed to *bat*. When spoken in isolation (or at the end of a sentence or before a word beginning with a voiceless sound), almost the only difference between these two words is in the relative lengths of the segments. In *bad* the vowel is long and the closure for the stop is comparatively short. In *bat* it is the other way round, the vowel is short and the closure for the stop is relatively long. On some occasions there may be no difference whatsoever in the voicing of the final segments, both of them being voiceless. If this state is reached then the feature length has supplanted the feature voice. Often, however, there is some difference in the voicing, and then, phonologically, the feature length may be considered a helping feature and voicing the principal phonological feature.

In addition to the work on feature theory, many phoneticians with linguistic interests were investigating other phonological problems. For example, the classic study by Liljenkrants & Lindblom (1972) demonstrated that some vowel systems were likely to be more prevalent because the vowels were better differentiated. Studies by Ohala (1981) demonstrated the importance of the listener as a source of sound change, and chronicled other phonetic issues in historical linguistics (Ohala 1983). Maddieson published phonetic and phonological data on the patterns of sounds in 310 languages (Maddieson 1984). Yet other linguists were looking to phonetic data in new ways. Labov’s quantitative phonetic analyses of sociolinguistic issues started in the 1960’s (Labov 1966) and continued to have repercussions for issues such a neutralization in phonology.

## **LATER PHONOLOGICAL DEVELOPMENTS**

The next major step in phonological theory was the development of autosegmental phonology (Goldsmith 1976, 1979). The problem with the theories discussed so far is that they all represented words in terms of segments, which were thought of as like beads on a string. With few exceptions, there was no notion of time within a segment; all the feature values stopped and started at the same moment. In a tone language a tone feature had to be placed on a segment in a word. If it applied to more than one segment, then the feature had to be placed on that segment as well, which is obviously inappropriate. A falling tone does not start on one sound and then start again on the next sound. The fall continues over more than one segment.

The inadequacies of segmental systems were solved in autosegmental phonology by placing properties such as tone on a separate tier. Speech was represented by symbols in a number of

tiers, each of which had its own time line. Items in a tier occurred one after another, but with no preconceived relation to changing items on other tiers. Relations between tiers were indicated by association lines. Thus changes in voicing occurred on the laryngeal tier, with no necessary relation to articulatory changes on other tiers. Similarly nasality could be on another tier and thus extend beyond the bounds of features on the articulatory tier. Tones could be considered as properties of larger units encompassing several segments. It was also easier to show relations within contour segments such as prenasalized stops and affricates.

During the 1980's varying degrees of emphasis were placed on detailed phonetic observation. Some phonologists considered it important to be 'hugging the phonetic ground' to use a phrase that first occurred in controversies between more abstract and more concrete structural linguists, such as Bloch & Trager (1942) as opposed to Hockett (1955). But despite attempts to give a greater role to phonetics, autosegmental phonology did not involve much change in the feature sets that linked abstract phonological descriptions with observable phonetic facts. A noticeable improvement in the interaction between phonology and phonetics came with the start of the Laboratory Phonology series of conferences in 1987 (Kingston & Beckman 1991). The LabPhon conferences, as these events are now called, have taken place every two years since then, alternately in America and Europe. These comparatively small meetings, usually attended by leading phonologists and experimental phoneticians, have become significant events on the boundaries of the two disciplines.

Also important in the 1980's were notions of feature hierarchy. In the early work in this field every feature corresponded to a physical scale and all features were at the same level. There were different groups of features, such as 'major class features' and 'place of articulation' features, but these groupings were established simply by listing the features within them. They had no theoretical status. Later it became apparent that some higher level features were best described in terms of other features and the notion of a hierarchical feature structure emerged. Clements (1985) proposed a model of feature geometry, later extended to a formal account of feature organization in Clements and Hume (1995).

### **FURTHER DEVELOPMENTS IN PHONETICS**

At the same time as these phonological developments were occurring, there was continuing work in linguistic phonetics. Many of the previously mentioned themes were further investigated. The phonetic observations of sociolinguistic problems originated by Labov and carried on by his students expanded to more detailed studies of natural speech by, for example, Docherty & Foulkes (1999). Stevens (1998) has summed up a life's work in a wonderful account of virtually every aspect of acoustic phonetics, including a current view of phonological features. Lindblom continued his work on vowel systems (Lindblom 1988) and models of phonetic variation and selection (Lindblom 1990). Keating (1990) proposed a window model of coarticulation that enabled researchers to move away from the notion of a strict target that had to be reached. Ladefoged and Maddieson (1996) summarized their knowledge of the contrasting sounds in the world's languages, and Maddieson further underpinned phonological findings through his studies of phonetic universals (Maddieson 1997).

## PROSODY

So far we have not considered studies of prosodic aspects of language. Dwight Bolinger was the leading figure in the early part of the period under review, many of his papers appearing in Bolinger (1965). He pointed out that intonation cannot be determined simply from grammatical aspects of sentences, noting that "Accent is predictable (if you're a mindreader)" (Bolinger (1972). A comprehensive cross-language survey of suprasegmentals was provided by Lehiste (1970). Notable studies of the intonation of British English were conducted by O'Connor and Arnold (1973) and Cruttenden (1986). In these studies whole tunes appropriate for sentences and for phrases within sentences were described. Selkirk (1980) and Nespor and Vogel (1986) took the study of prosody in a different direction, suggesting a hierarchy of prosodic units, and thus laying the foundation for work by Pierrehumbert (1980) and Pierrehumbert & Beckman (1988) in which key syllables in an utterance are characterized in terms of discrete tones. This kind of description of intonation has been formalized in the ToBI (Tone and Break Indices) transcription system (Silverman et al.1992), in which the H (high) and L (low) tones and their combinations, together with the break indices (the degree of cohesiveness or separation between words), designate the hierarchical prosodic structure and the intonational pattern of a phrase. ToBI has become extensively used for describing a wide variety of languages (Jun in press).

Several other systems have been used for describing intonation in the last two decades. There has been a new emphasis on the phonetics and phonology of prosody, partly because of interest in intonation differences between languages and between dialects, and partly because it has become evident that a major failing in TTS (Text to Speech) systems is the inability to produce computer synthesized speech with a natural intonation. The dialect studies often involve work on large corpora, such as the IviE (Intonational Variation in English) project (Grabe et al 2001). Many of the researchers generating intonation in speech synthesis systems use models specifying the intonation curves in phrases rather than the sequences of tones provided by the ToBI model. A model made explicit by Fujisaki (1992) in which the f<sub>0</sub> contour is generated by a phrase control mechanism with superimposed accent commands is widely used. Current phonetic–phonological relations.

Now, in the first decade of this century, interest in the precise nature of phonological features has waned. There is no agreed set of binary features that form part of a universal grammar. Even staunch advocates of binarity such as Halle recognize some unary features — features that can have only one value and cannot have a minus value. Typical unary features are those under the Place node: Labial, Coronal, Dorsal, Radical and Laryngeal (Halle et al.2000). Others, such as Steriade, (1993) have suggested that there might be ternary features such as Stricture. Ladefoged & Maddieson (1996) provided a complex, hierarchical set of features, many of them being multivalued, but in their case the features form a system for organizing observed differences between languages rather than the basis for phonological descriptions. The feature wars are clearly waning.

We must also consider two other phonological theories that have sprung up more recently, fulfilling Fant's vision that "phonology is promiscuous in its experimenting with widely different frameworks." (Fant 1986:481). The first is Optimality Theory (OT), developed in 1993 and widely circulated in a prepublication form of a monograph that has now appeared (Prince and Smolensky 2004). In this theory, instead of a set of ordered rules linking underlying forms to the

phonetic output, ranked constraints select the optimal output from the set of logical possibilities available at that point. One of the principal constraints is that the output should be as similar to the input as possible. Ideally input and output should be identical. In OT jargon, the output should be faithful to the input. Other constraints embody the general principles of markedness, ensuring that the output reflects generally known phonetic effects. In OT the relative importance of the various constraints on the output differs from one language to another. A language like Swahili ranks a constraint forbidding syllable final consonants more highly than English which permits them. Optimality Theory has close links with general phonetic theory (Hayes 1997).

The other new theory, articulatory phonology (Browman & Goldstein 1989, 1992, Saltzman 1995), is also very much concerned with phonetic activity. The heart of this theory is that the underlying forms of words can be represented in terms of gestures formed by five independent articulators. These articulators are very similar to those specified by the unary features under the Place node: mentioned above. The gestural movements that form constrictions can be specified in terms of well known equations, similar to those that specify the movements of a spring. The theory has done wonderful work in relating high level descriptions of languages in abstract terms to low level observable phonetic facts. It has provided the basis for a principled account of several phonological and physical properties of speech including: the hierarchical structure of syllables in terms of onsets and codas, syllable-structure sensitive allophony, re-syllabification, syllable weight, and regularities in gestural timing and its stability.

So far, however, articulatory phonology has been little concerned with formal descriptions of languages and with phonology as it is traditionally conceived. It has not been in the forefront of the three major areas of phonology discussed above. It could be used in the first area, defining the possible contrasts in a language, but, as yet, there is no complete list of all the parameters that would be needed to specify the sounds of the world's languages. There is nothing comparable to a set of phonological features, and without such a set it is difficult to see how articulatory phonology could specify the set of phonological contrasts in one language as opposed to another. Most practitioners of articulatory phonology are not adherents to the principles of universal grammar and see no need for a universal set of features,

Nevertheless, at least a defined set of parameters is also required for the second principle concern of phonology, formalizing the constraints on possible syllables. Articulatory phonology has shown how some syllable shapes are more likely to occur than others, but has generally done this in terms of phonetic principles rather than phonological expressions (Browman and Goldstein 1995, Byrd 1996). But there are signs that phonotactics can be fitted into gestural phonology (Davidson 2004).

The third area, writing rules or constraints to account for sound patterns such as those exhibited by *photograph*, *photography*, *photographic*. has also not been the topic of much work employing articulatory phonology. However, a start in that direction has been made by Gafos (2002), who describes constraints in the grammar of Moroccan Colloquial Arabic that refer to temporal relations between gestures.

It is probably inevitable that phonological theory lurches forward while phonetic knowledge expands more smoothly. Putting this in evolutionary terms, we can say that phonologists live in a state of punctuated equilibrium, while phoneticians are in continual growth. In addition,



phonologists have the problem of deciding whether they are describing something that actually exists, or whether they are dealing with epiphenomena, constructs that are just the result of making a description. Phoneticians are seldom faced with this problem.

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### **ACKNOWLEDGEMENT**

Many thanks to all my UCLA colleagues who provided me with many references and tried to keep me on the strait and narrow path of impartial reporting. It's not their fault that they don't succeed.