Palatalization/Velar Softening: What It Is and What It Tells Us about the Nature of Language

Morris Halle

This study proposes an account both of the consonantal changes involved in palatalization/velar softening and of the fact that this change is encountered before front vowels. The change is a straightforward case of feature assimilation provided that segments/phonemes are viewed as complexes of features organized into the ''bottle brush'' model illustrated in example (4) and elsewhere in the text, and that the universal set of features includes, in addition to the familiar binary features, six unary features, which specify the designated articulator(s) for every segment (not only for consonants).

Keywords: phonetics, palatalization, velar softening, features, articulators

For Ken Stevens, friend and colleague, on his 80th birthday

My purpose in this study is to present an account of the very common alternation between dorsal and coronal consonants often referred to as *palatalization* or *velar softening*. This alternation, exemplified by English *electri[k]* ~ *electri[s]ity*, occurs most often before front vowels. In spite of its extremely common occurrence in the languages of the world, to this time there has been no proper account of palatalization that would relate it to the other properties of language, in particular, to the fact that it is found most commonly before front vowels.

In the course of working on these remarks, it became clear to me that palatalization raises numerous theoretical questions about which there is at present no agreement among phonologists. Since these include matters of the most fundamental importance for phonology, I start by extensively discussing the main issues and the views on them that seem to me most persuasive at this time (section 1). I then discuss palatalization proper and explain the features that different types of palatalization share with one another and with the front vowels next to which the phenomenon most commonly occurs (section 2). Finally, I summarize the main results of the study (section 3).

This study is a revised version of the Plenary Address in Honor of the 80th Anniversary of the Founding of the Linguistic Society of America that I presented in Boston, Massachusetts, on 9 January 2004. I am grateful to the society for inviting me to speak on this occasion.

I thank Sylvain Bromberger, John Frampton, Daniel Harbour, and James Harris for criticisms and other help in preparing the final version. I alone am responsible for errors and shortcomings in the text.

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1 Segments and Features

1.1 Segments and Other Sounds

It has been assumed at least since the invention of alphabetic writing that the words we hear and speak are composed of discrete slices of sound. These slices of sound—which will be referred to here by the term *segment*—differ fundamentally from identical slices of sound when these are produced in nonlinguistic contexts. In a famous paper, Sapir (1925) examined the differences between the sound made in blowing out a candle and the articulatorily and acoustically all but identical segment [h^w] that appears at the beginning of such English words as *when*, *whiskey*, and *wheel*. Among the properties cited by Sapir as differentiating segments from other types of sounds, the most essential one for present purposes is that the segment [h^w]

> is one of a definitely limited number of sounds (e.g. *wh* [h^w], *s*, *t*, *l*, *i*, and so on) which, while differing qualitatively from one another rather more than does *wh* [h^w] from its candle-blowing equivalent, nevertheless belong together in a definite system

where each segment has its own proper place with reference to all other segments, for, as Sapir put it,

> [a] sound that is not unconsciously felt as 'placed' with reference to other sounds is no more a true element of speech than a lifting of the foot is a dance step unless it can be 'placed' with reference to other movements that help to define the dance. (pp. 39–40)

This observation, however, raised for Sapir the question ''How can a sound be assigned a 'place' in a phonetic pattern over and above its natural classification on organic [articulatory] and acoustic grounds?'' (p. 48). His answer was that

> [a] 'place' is intuitively found for a sound . . . in such a system because of a general feeling of its phonetic relationship resulting from all the specific relationships (such as parallelism, contrast, combination, imperviousness to combination, and so on) to all other sounds. (p. 48)

And he illustrated these relationships with examples such as these:

(1) a. [T]he fact that in English we have morphological alternations like *wife* : *wives*, *sheath* : *to sheathe*, *breath* : *to breathe*, *mouse* : *to mouse* helps to give the sounds *f*, *θ*, *s* an intuitive pattern relation to their voiced correlates *v*, *ð*, *z*. . .

b. *P*, *t*, *k* belong together in a coherent set because . . . 1, they may occur initially, medially, or finally; 2, they may be preceded by *s* in all positions (e.g. *spoon*: *cusp*, *star* : *hoist*; *scum* : *ask*); 3, they may be followed by *r* initially and medially; 4, they may be preceded by *s* and followed by *r* initially and medially; 5, each has a voiced correspondent (*b*, *d*, *g*); 6, unlike such sounds as *f* and *θ*, they cannot alternate significantly with their voiced correspondents; 7, they have no tendency to be closely associated, either phonetically or morphologically, with corresponding spirants (*p*:*f* and *t*: *θ* are not intuitively correct for English). (p. 48)

Sapir's point is that because sets of segments are treated alike by grammatical processes of the English language, speakers of English group these segments together in a phonetic pattern—and here I repeat Sapir's words already quoted—''over and above [their] natural classification on organic and acoustic grounds.''

Although what Sapir wrote is true, as far as it goes, it fails—surprisingly—to recognize that the groupings and processes mentioned involve segments that share specific ''organic and acoustic'' aspects in common. The only explanation I have for this apparent oversight is that Sapir must have assumed that the segments were—literally—the ultimate elements of language and that appeal to their component features was therefore illegitimate. He must have taken the segment sets in (1) as fortuitous accidents without theoretical significance, and he must have assumed that functionally equivalent classifications grounded on completely different physical traits should be possible, at least in principle.[1]

1.2 Segments as Feature Complexes

The proposition that segments are complexes of phonetic features and that all regularities and constraints in the behavior of segments must be formulated in terms of their component features was first introduced into linguistic theory by Roman Jakobson in 1928 in a communication to the First International Congress of Linguists, which met in April 1928 in The Hague (Jakobson 1971:3–6).[2] In response to the question ''What are the most appropriate methods for a complete and practical account of the phonology of any language?'' Jakobson wrote:

> Every scientific description of the phonology of a language must above all include a characterization of its phonologic system; i.e., a characterization of the repertory—specific to this language—of the distinctive differences [features] among its acoustico-motor images [segments]. . . Comparative phonology must formulate the general laws which govern the relations among the correlations [features] within the framework of a given phonological system.

This represents a drastic departure from Sapir's position. On Jakobson's view, the atoms of language are not the segments, but the phonetic features. Segments are complexes of features, and all functional groupings of segments must be formulated in terms of feature complexes, rather than in terms of lists of segments.[3] Alternations among segments such as those in (1a) are therefore conceived not as replacements of one whole segment by another, but as the replacement of some component features by others. And the features that figure in the output of the phonological rules determine the phonetic actualization of the utterance.

[1] For an explicit expression of this view, see the review of Trubetzkoy's *Grundzüge* (1939) by Sapir's student Zellig Harris (1941).

[2] The communication was signed by Jakobson, Trubetzkoy, and Karcevsky, but was written by Jakobson (see Trubetzkoy's letter to Jakobson of 22 October 1927 in Jakobson 1975:109).

[3] For Jakobson, see the papers in the first volume of his *Selected Writings* (Jakobson 1971). For Trubetzkoy, see his papers in the nine issues of the *Travaux du Cercle linguistique de Prague* and in particular his *Grundzüge* (1939), which is an extensive illustration of the role of features in the characterization of phonological phenomena in languages all over the world.

From this perspective, in Sapir's example (1a) segments that have the feature [continuant] acquire the feature [voice] while preserving all their other features intact, whereas Sapir's other example (1b) is a list of various distributional constraints that are satisfied by segments that have the features [noncontinuant] and [voiceless]. Since different segments share different subsets of features with each other, the features also account for the different segment patterns encountered in different phonological contexts. As a result, there is no ''pattern above and beyond [the] natural classification on organic and acoustic grounds.''[4]

1.3 A. M. Bell's Visible Speech

While Jakobson and Trubetzkoy have to be credited with introducing into modern linguistics the concept of the segment as a complex of features, they were not the originators of the idea. They were anticipated in this by Alexander Melville Bell, who developed this conception of the speech sound in his 1867 book *Visible Speech*.

Bell's book presented a phonetic alphabet that according to its author could be used to transcribe the sounds in all languages. In particular, the graphic shape of each letter directly encoded the different features that make up the segment represented by the letter. Thus, the basic shape of all consonants is a crescent (partial circle) with an opening pointing in one of four directions. As shown in figure 1, these four directions convey information about the designated articulator of the consonant. The exact form of the crescent opening conveys information about the feature [+/−continuant]: a line across the opening marks the segment as [−continuant], whereas a pair of curlicues rounding off the opening marks the segment as [+continuant]. The feature [+voice] is notated by a short bar opposite the opening; absence of the bar indicates [−voice].

As Bell's son, Alexander Graham, the inventor of the telephone, explained in a 1911 paper, segments are not the atoms of language; like chemical compounds, segments are combinations of features:

> The true element of articulation, I think, is a constriction or position of the vocal organs rather than a sound. Combinations of positions yield new sounds, just as combinations of chemical elements yield new substances. Water is a substance of very different character from either of the gases of which it is formed; and the vowel *oo* is a sound of very different character from that of any of its elementary positions. (p. 38)

It is well known that because of the great expense of printing texts in the Visible Speech type, Bell's alphabet was soon replaced by that of the International Phonetic Association (IPA), where the sounds were represented by letters of the Roman alphabet, available in most printing establishments. Unlike the Visible Speech characters, the letters of the IPA (Roman) alphabet do not

[4] In an early 1928 letter to Jakobson, Trubetzkoy writes about Sapir's 1925 paper:

> Sapir's article ''I have read with pleasure'': in it there is no teleology; in general, there is no concern with the history of the language (the only part where there is a hint of such concern is rather unsuccessful), but there is a very sensibly presented theory of phonemes and of the phonological system. Very much worth reading. (Jakobson 1975:114)

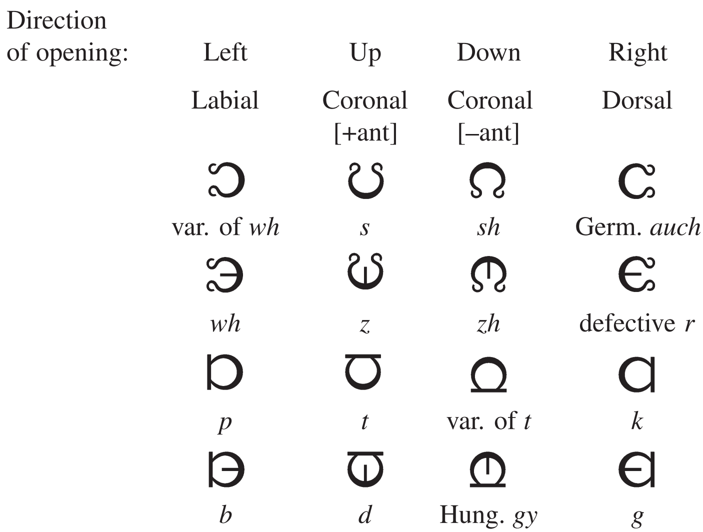


Figure 1
Examples of Alexander Melville Bell's Visible Speech symbols. (After Bell 1911:56, 62; Visible Speech symbols courtesy of Simon Ager, omniglot.com.)

reflect the feature composition of the segments they represent. Moreover, *The Principles of the International Phonetic Association* (1949) specifically instructed users that ''two sounds occurring in a given language . . . should whenever possible be represented by two distinct letters without diacritical marks'' (p. 1).

An unfortunate consequence of these moves, originally adopted by the IPA for reasons of financial economy, was that they obscured and ultimately caused to be forgotten Bell's discovery that speech sounds are complexes of features. As a result, this capital insight had to be rediscovered 60 years later by Jakobson and colleagues.[5]

Bell's main objective in devising Visible Speech was as an aid to speech correction. Like most speech correctionists, Bell was uninterested in aspects of language other than its pronunciation. Facts such as those in (1) that were central to Sapir's paper lay completely outside Bell's concerns. This lack of interest in aspects of a language other than its correct pronunciation has

[5] As reported in *Visible Speech* (pp. viiff.), Bell offered his alphabet to the British government ''in order that the use of the Universal Alphabet might be as free as that of common letters to all persons.'' His sole condition was that ''the expense of casting the new Types and publishing the Theory of the System should be defrayed from public resources.'' Bell's offer was refused by the Prime Minister, Lord Derby, on the grounds that there were no public funds for the purpose. It is by no means inconceivable that Derby, who was a classicist of repute, author of a well-received translation of Homer, might have reacted differently and accepted Bell's offer on the grounds, for example, that the British government—in particular, the Foreign and the Colonial Offices—needed a reliable means for recording foreign names. I have little doubt that if British civil servants had been using the *Visible Speech* alphabet in their daily work, this would have had far-reaching beneficial effects on phonetics, the science underlying the alphabet.

been shared by many phoneticians from Bell's time to the present, and it is a major reason why phonetics and phonology have developed as separate disciplines that commonly ignore each other's results.

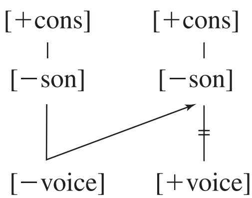
1.4 Feature Spreading and Its Formal Expression

A major consequence of Jakobson's 1928 proposals was that phonetics and phonology were seen as a single field of study: that is, it was recognized that not only do phonetic facts shed important light on the phonology of a language, but also facts of phonology provide insights into the nature of phonetics.

An important argument for the feature composition of segments is provided by the existence of phonological processes such as those illustrated in (2a).

(2) a.	play-[z]	play-[d]	cough-[s]	cough-[t]
	pin-[z]	pin-[d]	unearth-[s]	unearth-[t]
	rob-[z]	rob-[d]	clip-[s]	clip-[t]
	brag-[z]	brag-[d]	track-[s]	track-[t]

b.



As shown in (2a), the English verb suffixes [z] and [d] appear as [s] and [t], respectively, when the verb stem to which they are attached ends with a voiceless obstruent. A change such as that in (2a), where the phonetic shape of a morpheme changes owing to its appearance in a particular environment, is extremely common in languages, and how it is to be characterized is a question of obvious importance for phonology. It is commonly assumed that the change is one of feature spreading, as illustrated in (2b). Specifically, the feature [−voice] of the final obstruent is spread to the suffixes /d/ and /z/, thereby turning them into /t/ and /s/. It is obvious that an account of this kind is possible only on the assumption that segments are composed of features.

The feature [voice] is, of course, not the only feature that can spread; in fact, there is evidence—some of it reviewed below—that every one of the features can spread. The conclusion forced by this observation is that the features that compose the segments must be organized in a form that makes spreading possible. This conclusion also eliminates from consideration any alphabetic notation, including Bell's feature-based Visible Speech, on the simple grounds that letters are unsuitable objects for the purpose of expressing feature spreading. Feature spreading can be expressed in matrix notation such as that introduced by Jakobson (1949) (see also Jakobson and Lotz 1949), where each segment is represented by a column of features. This is shown in (2b), where the English rule spreading [−voice] is represented in this notation. Phonological rules other than feature spreading are also readily expressed in the matrix notation of segments, and this is the primary reason why this notation was adopted in the accounts of the phonology of individual languages that started to appear at the end of the 1960s (e.g., Chomsky and Halle 1968, Schane 1968, Harris 1969, Anderson 1974).

These fundamental revisions in the conception of the segment have exercised less influence than might have been expected on phonetics, conceived as the study of the pronunciation of words and phrases. For example, the summa of twentieth-century phonetics, Peter Ladefoged and Ian Maddieson's *The Sounds of the World's Languages* (1996), reflects in its title its conception of the sound—that is, segment—rather than the feature as the basic entity of language. It is especially to be regretted that the authors did not see fit to include in their book a defense of their choice of segment over feature as the ultimate entity of language.

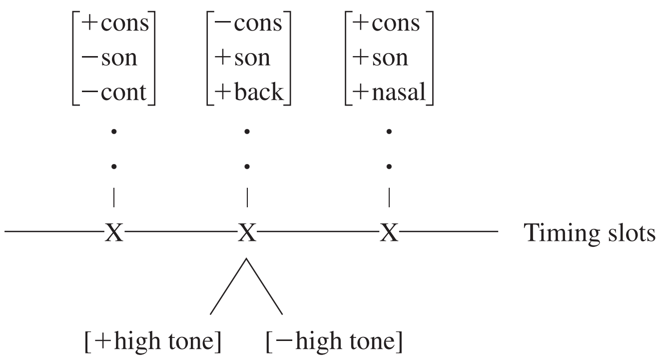
1.5 Autosegmental Representations of Segments and Features

In the 1970s, work with the feature matrix notation revealed a number of interesting shortcomings. In particular, in many languages tonal distinctions play a major role, and a segment sequence (word) with high tone is distinct from one with low tone. Since the number of tones is severely limited, this can be readily accommodated in the matrix notation by adding a few tonal features to the feature columns.

This solution does not work well, however, when we try to extend it to other tonal facts. In particular, an entire melody—a sequence of tones—may be pronounced on a single vowel segment, and conversely, a given tone may be spread to several vowel segments in a sequence. It appears, therefore, that we are dealing with two distinct sequences: a sequence of tones and a separate sequence of segments.

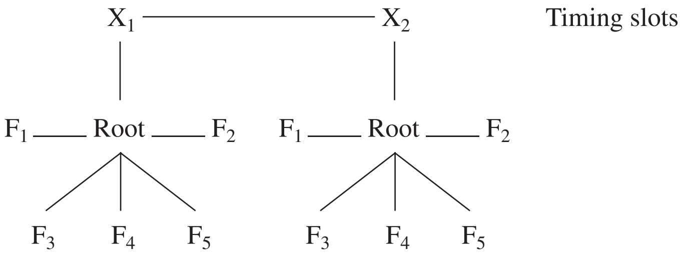
The notational problems posed by facts such as these were solved by the autosegmental representation, which was developed in the 1970s by Edwin Williams (1976/1971), John Goldsmith (1976), John McCarthy (1979), and others. The essential innovation of the autosegmental representation was to separate the features that make up a segment from the time interval that the segment occupies. This made it possible to deal with the problem posed by the assignment of a sequence of tone features to a single vowel in the manner shown in (3).

(3)



In (3), the tone features are represented on a separate tier from the rest of the features, but the two sets of feature sequences are connected to the single sequence of timing slots. The representation in (3) raises the obvious question of how to split up the features. What subsets are to be assigned to one tier? And how many separate tiers should be allowed? A radical solution to this problem is to assume that every feature occupies an autosegmental tier of its own. This solution, which I adopt here, is represented formally in (4).

(4)



The sequence of timing slots X_1, X_2, . . . is at right angles to the plane of the page, and the feature tiers F_1, F_2, . . . of each segment are on planes that are parallel to the page. The label *Root* stands for the line in which the feature tiers of each segment intersect, and we assume that it is these Root nodes that are directly linked to the timing slots. (For some discussion, see Halle 1985.)

The structure illustrated in (4) has been referred to as the ‘‘bottle brush.’’ Given the intrinsic organization of the feature list in (4), only two kinds of feature assimilation are possible: those affecting single features and total assimilation. (The latter is expressed formally by spreading the Root node of the ‘‘bottle brush.’’) McCarthy (1988) has argued that the features [consonantal] and [sonorant] can be spread only in cases of total assimilation. This led him to propose that these two features should be assigned to the Root node. However, it has been shown that the feature [consonantal] spreads like all other features (Kaisse 1992), and that the same is true of the feature [sonorant] (Olson and Schultz 2002). This evidence eliminates the possibility of representing these—or any other—features at the Root node in (4).

As is well known, a more elaborate feature structure than that of the ‘‘bottle brush’’ was proposed by G. N. Clements (1985; see also Sagey 1986) under the heading of *feature geometry*. I now believe that the restrictions noted by Clements and others on the simultaneous spread of more than one feature should not be expressed directly in the feature geometry of the segments, but instead should be captured by special constraints on feature spreading. As this is a very complex issue, a proper discussion must be deferred to another occasion.

1.6 The Universal Repertory of Features

To this point, I have said next to nothing about the features that compose the different segments. As is well known, Jakobson assumed that all features are binary, and this assumption was taken over in Chomsky and Halle 1968 (*SPE*). Our main innovation in *SPE* with regard to features was to replace several acoustic features proposed in Jakobson, Fant, and Halle 1952 with more familiar articulatory features. In particular, we eliminated features such as grave-acute, compact-diffuse, sharp-natural, and flat-plain and replaced them with the traditional articulatory features [+/−back], [+/−high], and [+/−low].

In the years since the publication of *SPE*, additional changes in the feature composition have been proposed. First, it was argued that the familiar [+/−voice] feature of consonants and the tonal features of vowels should all be subsumed under the two articulatory features [+/−stiff] and [+/−slack] (Halle and Stevens 1971). Later, it was shown that this makes possible a better understanding of Verner's Law, which on this view is an instance of the spreading of the feature [−stiff] from an (unstressed) vowel to the following obstruent (Calabrese and Halle 1997; see also Halle 2003b). Finally, a set of unary features has been introduced (Halle, Vaux, and Wolfe 2000), which are discussed below as they are of special relevance to the concerns of this study.

The overall effect of these changes has been to emphasize the primary role of articulation in phonology. I now believe that for phonology, articulatory considerations are paramount and that acoustic aspects of speech play at best a subsidiary functional role. Additional evidence for this obviously important question is provided by the facts to which I now turn.

The term *vocal tract* is the traditional name for the cavities at the upper end of the human alimentary and respiratory tracts. Sound is produced when these cavities are excited by airflow from the lungs. In speaking, we constantly change both the excitation and the geometry of the cavities by changing the position of the movable parts of the tract, to which I will refer here by the technical term *articulators*. There are exactly six articulators, and they are listed in (5).

(5) Lips (Labial)
Tongue blade (Coronal)
Tongue body (Dorsal)
Tongue root (Radical)[6]
Soft palate (Rhinal)
Vocal folds (Glottal)

Every speech sound is produced by actions of one or more articulators, but not all six articulators are implicated in the production of every sound.[7]

Most features are executed by one specific articulator. For example, the feature [round] is executed exclusively by the lips, while [nasal] is executed only by the soft palate. We reflect this fact by saying that such features are *articulator-bound*.

In addition to articulator-bound features, there are features that are *articulator-free*. Such features are executed by different articulators in different segments. For example, the feature [continuant] is executed by the lips in [p b f v m] but by the tongue body in [k g x ŋ] and by the tongue blade in [t d s z ç ð þ n ñ]. If a given segment involves an articulator-free feature, it is obviously necessary to stipulate the articulator that executes this feature. The articulator executing the articulator-free features of a segment is called the *designated articulator* (DA).

The feature [+/−consonantal], which distinguishes consonants from vowels and glides, is articulator-free. If we now make the further assumption that the feature [consonantal] must be

[6] John Esling (1999) has presented evidence suggesting that rather than tongue root, the relevant articulator might be the epiglottis.

[7] The articulator-based theory of speech production employed in this study differs from the theory that underlies the IPA alphabet, where only some aspects of segments reflect actions of articulators, while others—the so-called points of articulation—reflect locations along the stationary portion of the vocal tract without reference to a particular articulator.

specified for every segment—in other words, that every segment must be characterized either as consonant or as vowel/glide—it follows that every segment must include information about a DA.

It is usually the case that if a segment involves more than one articulator-free feature, these are executed by the same articulator. For example, the radical narrowing of the airpassage through the oral cavity, which is the distinctive characteristic of the feature [+consonantal], is executed by the lips in [p b f v m], and it is the same labial articulator that also executes the feature [+/−continuant] in these sounds.

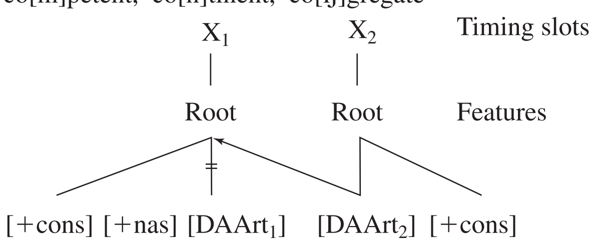
There are well-known cases, such as the labiovelar stops [kp] and [gb] (see Ladefoged and Maddieson 1996:333ff.), where the feature [continuant] is executed by two articulators simultaneously. In the production of such sounds, these same two articulators are also responsible for the narrowing of the airpassage through the mouth, which is the reflex of the feature [+consonant]. The point of this example is that there are speech sounds whose articulator-free features are executed by several articulators simultaneously.

The fact that information about the DA is essential for the proper representation of segments raises the question of how this information is to be expressed. In Sagey 1986, for instance, it was represented by means of a pointer. Implicit in Sagey's proposal was the assumption that the information about the DA is of a different kind than the information represented by features. In particular, the fact that it is represented as a pointer, rather than as a feature, implies that this information does not spread from one segment to its neighbors in quite the same way as the other features. This inference, however, is not correct: information about the DA of a segment spreads exactly like all other features. It was therefore proposed in Halle, Vaux, and Wolfe 2000 that the DA(s) of each segment should be expressed by means of unary feature(s). Since there are six articulators, we posited six unary features, one for each articulator, namely, [DALabial], [DACoronal], [DADorsal], [DARadical], [DARhinal], and [DAGlottal].

Perhaps the best-known instance of the spreading (assimilating) of a DA is the so-called place-of-articulation assimilation, illustrated with familiar English examples in (6a), where the DA of a nasal is replaced by that of the following consonant. The formal expression of this process is shown in (6b), where Art_n denotes one of the six articulators.

(6) a. co[m]petent, co[n]tinent, co[ŋ]gregate

b.



As already remarked, we assume that unlike other features, the DA features are unary rather than binary. In the case of binary features like [+/−nasal] or [+/−back], both values of the feature have an articulatory realization of their own. A [+back] segment is produced with a retracted tongue body, a [−back] segment with an advanced tongue body. Similarly, a [+nasal] segment is produced with a lowered velum, which allows air to flow into the nasal cavities, whereas a [−nasal] segment is produced with a raised velum, which prevents air from flowing into the nasal cavities. By contrast, in the case of a unary feature such as [DACoronal], the presence of the feature means that the blade of the tongue executes the articulator-free features, whereas its absence—its not being mentioned—simply means that the articulator-free features are executed by some other articulator; this fact need not be specifically noted since it follows automatically from the obvious convention that articulator-free features of a segment can be executed only by the articulator specifically designated by a [DAX] feature.

I conclude this section by drawing attention to the enormous changes that have taken place in our understanding of the segment since it was first subjected to serious inquiry by Sapir and Jakobson in the 1920s. Whereas Sapir thought of the segment as the ultimate, further unanalyzable unit of language, we now have reasons to believe that segments are complexes of features with the internal (‘‘bottle brush’’) organization shown in (4). Most features are binary, but there are also six DA features, which are unary. In the next section, I illustrate and support the theory with examples from a variety of phonological processes. If the above discussion is on the mark, some aspects of this model (e.g., the difference between unary and binary features) ought to be directly observable in the production of the different segments. As these more narrowly phonetic consequences of the theory require extensive further thought and investigation, they must be left for another occasion.

2 Examples of Spreading of Designated Articulator Features

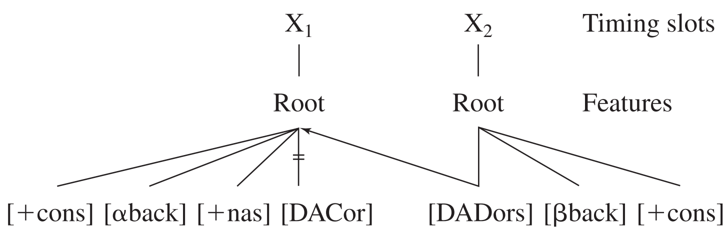
2.1 Place-of-Articulation Assimilation

In Irish, as discussed in Halle, Vaux, and Wolfe 2000 and as shown in (7a), a coronal nasal acquires (assimilates) the DA of the following dorsal consonant. The formal treatment of this process is shown in (7b).

(7) a.

	g [+back]	g^y [−back]
n [+back]	ŋg	$ŋg^y$
n^y [−back]	$ŋ^yg$	$ŋ^yg^y$

b.



What is worth special notice here is that the process does not affect any of the other features of the nasal; in particular, the feature [back] remains unchanged. This is easily expressed formally if, as shown in (7b), the information about the DA of the segments is encoded in a feature.

2.2 The German [ç]-Sound

A very similar process of DA assimilation is involved in the alternation between the voiceless continuants [x] and [ç] (the *ich*-sound) in German. In order to understand this process properly, it is useful to review the feature composition of continuant obstruents (fricatives) in the languages of the world. Of special interest here is the great variety of coronal fricatives shown in (8).

(8)

	f	x	θ	s_1	s_2	ç	$ʃ_1$	$ʃ_2$
DA	Lab	Dors	Cor	Cor	Cor	Cor	Cor	Cor
anterior			+	+	+	−	−	−
distributed			+	−	+	+	+	−
strident			−	+	+	−	+	+

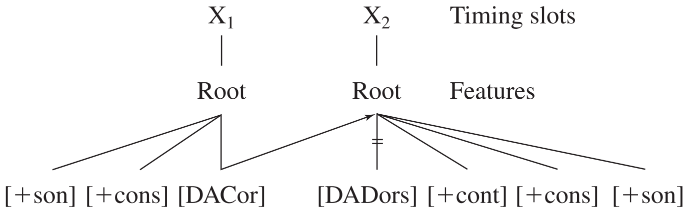
The coronal fricatives [θ s_1 $ʃ_1$] are those of the English words *thin*, *sin*, and *shin*, respectively. [$ʃ_2$] represents the retroflex fricative of Hindi (see Ladefoged and Maddieson 1996:27). [s_2] stands for a laminal alveolar fricative of the kind encountered in Toda (Ladefoged and Maddieson 1996: 155–156). [ç] is the German postalveolar (palatal) fricative alternating with [x]. As indicated in (8), [ç] is analyzed here as a coronal fricative with the features [−anterior, +distributed, −strident].[8] In phonetic studies (e.g., Sievers 1901:para. 161; see also Keating 1991, Keating and Lahiri 1993), [ç] is described as having a closure formed with the middle part of the tongue (blade) against the hard palate. This sound is contrasted with [x] and [k], where the closure is formed with the back part of the tongue (body). In terms of the phonetic theory developed above, this means that [x k] are [DADorsal], whereas [ç] is [DACoronal].[9] Additional support for this analysis of palatal consonants as coronal is provided by the fact that there are German dialects where [x] alternates with the obviously coronal [ʃ] instead of with [ç] (see Robinson 2000).

One of the contexts in which the [ç] sound appears in German is after the sonorant consonants [n r l], as in *manch* 'some', *durch* 'through', and *solch* 'such'. These three make up the entire set of sonorant consonants that can appear in a syllable rime before the postalveolar fricative, and all three have the feature [DACoronal]. It is therefore natural to view this process like those in (6) and (7): that is, as a process whereby a sonorant consonant spreads its DA to the following continuant. The spreading process is stated formally in (9).

[8] See the recent discussion of the German facts by Robinson (2000), with whose conclusions I find myself largely in agreement. I differ with Robinson mainly on the formal properties of phonological representations. In particular, I assume the "bottle brush" geometry of segments shown in (4), where each feature is represented on a separate plane and where every segment includes at least one DA feature. Robinson makes different assumptions about these formal properties of phonological representations, and these determine his somewhat different account of the facts.

[9] I speculate that the movement of the coronal articulator characteristic of these consonants is due to activation of the superior and medial fibers of the genioglossus. By contrast, the forward movement of the tongue body due to the feature [−back] results from the activation of the most inferior fiber layer of the genioglossus muscle and the simultaneous relaxation of the styloglossus.

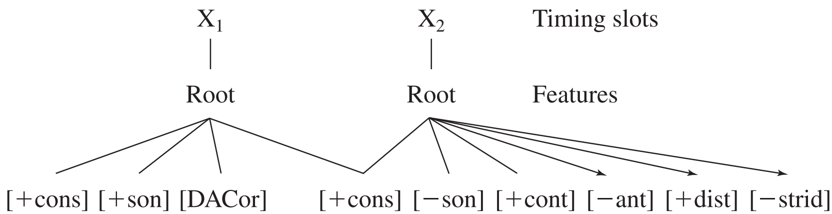
(9)



As a consequence of rule (9), the continuant consonant gets two DAs: its original [DADorsal] and the [DACoronal] spread by the rule. Since German does not admit consonants with two DAs, the linking of [DACoronal] to the continuant results in the automatic deletion of the original [DADorsal] feature.

The formalization in (9) is limited to the spreading of the [DACoronal] feature; it does not indicate that this results in [ç] rather than in [s], [ʃ], or any of the other coronal continuants in (8). To account for the latter fact, I posit a separate rule, which assigns the features [−anterior, +distributed, −strident] to the continuant that shares the [DACoronal] feature with the preceding sonorant. This is shown graphically in (10), where the three features on the right are added by the rule.[10]

(10)



There are, as noted, dialects of German where the [x] in this environment is replaced by [ʃ] rather than by [ç]. This is readily accounted for by replacing the feature [−strident] in (10) with [+strident].

It is well known that the German dorsal continuant [x] is subject to the same modifications as in (9) and (10) not only after a coronal consonant but also after a [−back] (front) vowel. This suggests that (9) should apply not only after sonorant consonants but also after [−back] vowels. But this then would require that the DA of front vowels be Coronal.

It has been assumed at least since Sievers that the dorsal articulator is involved in the production of all vowels, and I have suggested that this insight should be expressed by attributing to all vowels the feature [DADorsal] (see Halle 2003a). There have been proposals in the literature (e.g., Clements 1993) that [−back] vowels are coronal. I adopt this proposal here with the important modification that [−back] vowels have two DAs: [DADorsal] and [DACoronal].

Once this proposal is adopted and the feature [DACoronal] is automatically assigned to every [−back] vowel, we can account for the appearance of [ç] after [−back] vowels in exactly the same way as we explained its appearance after the sonorant consonants [r l n]. Both [r l n] and

[10] The structural change of feature addition in (10) and elsewhere is distinguished formally from that of feature spreading in (9) by the downward versus upward direction of the arrows in the rule.

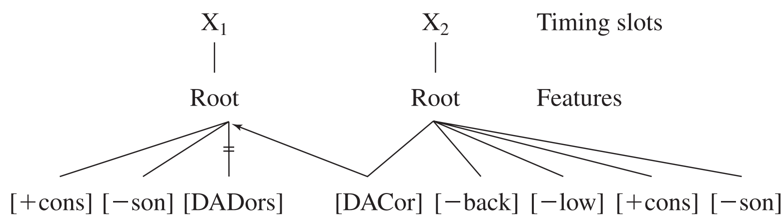
the [−back] vowels spread their [DACoronal] feature to the following dorsal continuant, and to capture this fact formally we generalize rule (9), by deleting the restricting feature [+consonant] under the X_1 timing slot.

This proposal that front vowels include the feature [DACoronal] also provides a straightforward account of the widespread phenomenon of ‘‘velar softening’’ or ‘‘palatalization,’’ illustrated in (11) with examples from English, where a velar/dorsal obstruent is replaced by a coronal.

(11) electri[k] – electri[s]-ity   analo[g] – analo[ǰ]-y
opa[k] – opa[s]-ity   esopha[g]-us – esopha[ǰ]-eal

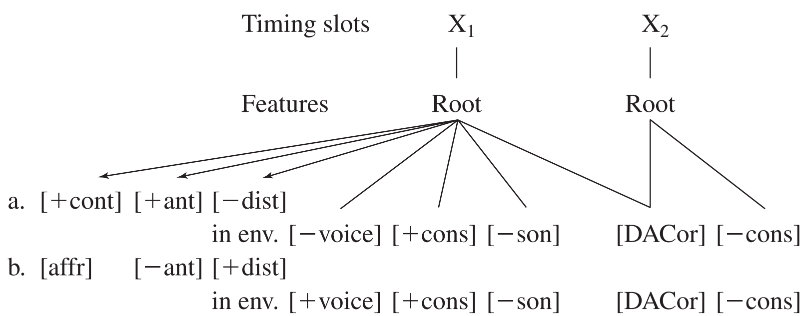
What all types of ‘‘velar softening’’ have in common is that they are triggered by front vowels and that the preceding consonant changes from [DADorsal] to [DACoronal]. This aspect of the change is formally captured in rule (12), where the [DACoronal] of a nonlow front vowel is spread to the preceding dorsal obstruent.

(12)



Aspects of the palatalization process other than the assimilation of the [DACoronal] feature vary quite a bit, even in a single language. In English, for example, the voiceless [k] alternates with the [−anterior] continuant [s], but its voiced cognate [g] alternates with the [+anterior] affricate [ǰ]. It will be recalled from the discussion of the German [x]/[ç] alternation that the spreading of the [DACoronal] was implemented by rule (9), whereas the other features of the [ç] were assigned by rule (10). Similarly, in accounting for ‘‘velar softening’’ in English we need, in addition to rule (12), the two rules in (13) as well, where (13a) applies to the voiceless [k], while (13b) applies to the voiced [g]. These additional changes cannot be combined with the spreading of [DACoronal], because the two processes are very different in character. As shown in (13), these additional changes are not instances of assimilation (feature spreading); rather, they assign features to consonants that share the DA Coronal.

(13)



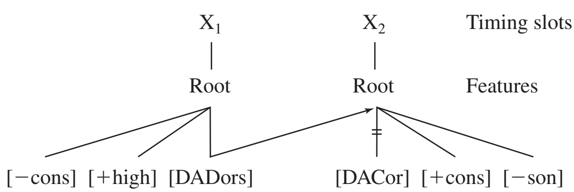
As is well known, historically the process of ‘‘velar softening’’ in English is a by-product of extensive vocabulary borrowing from French. In French, however, ‘‘velar softening’’ is somewhat simpler than in English in that both voiced and voiceless stops become [+continuant] and (as in English) the resulting coronal is [+anterior] when voiceless and [−anterior] when voiced. In Italian, which is also subject to ‘‘velar softening’’ before front vowels, both classes of stops are treated identically in that both become affricates: [č] and [ǰ], respectively. Moreover, both classes of stops also become [−anterior, +distributed]. These facts provide additional support for treating all palatalization processes as consisting of two distinct steps.[11]

Perhaps the most striking support for the analysis proposed here is provided by Kiowa (Harbour 2003, Watkins 1984), where before front vowels and before the glide /y/ the contrast between coronal and dorsal consonants is neutralized. As illustrated in (14), before the front nonhigh vowel /e/, the dorsal consonants /k g/ are replaced by the coronal /t d/ (14a–d), whereas before the front high vowel /i/ and the glide /y/, the coronal consonants /t d/ are replaced by the dorsal /k g/ (14e).

(14)	a.	thou**g**-O	‘legs’ PL
		thou**d**-e	‘leg’ SG, DU
	b.	taa**g**-O	‘eyes’ PL
		taa**d**-e	‘eye’ SG, DU
	c.	t!OO**g**-O	‘ears’ PL
		t!oo**d**-e	‘ears’ SG, DU
	d.	phat**k**-OO	‘stop’ NEG
		phat**t**-e	‘stop’ IMP
		phat**k**-ya	‘stop’ PERF
	e.	bou**t**-OO	‘bend over’ NEG
		bou**t**-ei	‘bend over’ IMPF.HSY
		boo**k**-ii	‘bend over’ IMPF.IMP
	f.	hOO**d**-OO	‘strip’ NEG
		hoo**g**-ii	‘strip’ IMPF.IMP

[11] David Eberhard of the Summer Institute of Linguistics reports (pers. comm.) that in Maimande, a Brazilian language, a coronal consonant is replaced by its dorsal cognate in the coda of a syllable with a [+high] vowel nucleus. In the approach developed above, this is accounted for by positing instead of (7), the rule (11), where the [DADorsal] feature, which is a property of all vowels, is spread from a [+high] vowel to the following coronal consonant, and as a result, the consonant loses its coronality, because—as in most languages—in Maimande, consonants may not have more than one designated articulator.

(i)



The Maimande facts provide additional support for the proposition that has been basic to this study that front vowels have two DAs: the DA Coronal is spread in the more familiar languages, whereas Maimande spreads the DA Dorsal.

In the light of the analyses given above, the facts in (14) are readily accounted for by recalling that front vowels have two DAs: [DACoronal] and [DADorsal]. As stated in (15), the [−high] vowel [e] spreads [DACoronal] to the preceding consonant, whereas the [+high] [i] and [y] spread [DADorsal]. Since Kiowa consonants may have only one DA, the original DA feature of the consonant is automatically deleted.

(15) X_1 X_2 Timing slots

Root Root Features

a. [+cons] [−son] [DADors] [+high] [−cons] [+son]
b. [+cons] [−son] [DACor] [−high] [−cons] [+son]

I conclude this review of the different types of palatalization with a remark about palatalization in the Bantu language Tswana. Tswana palatalization differs from all other types reviewed above in that the prime undergoers of palatalization are not dorsal but labial consonants. The main environment for palatalization is before the passive suffix *-wa*, where consonants with [DALabial]—/p ph b f/—are replaced by the corresponding palatal consonants—that is, by consonants that are [DACoronal] and [−anterior]. Examples are given in (16a) (data from Cole 1969: 43).

(16) a. lop-a 'request' lotš-wa
tlhoph-a 'select, choose' tlhotšh-wa
rob-a 'break' roj-wa
alaf-a 'cure' alaš-wa
b. [DALabial] → [DACor] in env. ____ + [DALabial]

Palatalization here is a process of dissimilation rather than one of assimilation. The passive suffix begins with the [DALabial] glide [w] and it palatalizes the preceding consonant, only if that consonant also has the [DALabial] feature. The rule, given in (16b), states that the feature [DACoronal] is added to a labial consonant if followed by another labial.

3 Conclusion

The main empirical result of this study is a new systematic treatment of palatalization, a type of consonant alternation that is encountered in languages all over the world. I have argued that all types of palatalization involve the spreading of the feature [DACoronal] from a front ([−back]) vowel to an adjacent [DADorsal] consonant.

For this account to go through, however, a number of fundamental propositions about the phonology of a language have to hold. Among these, the following are of special importance:

1. The segments that make up each utterance are complexes of features.
2. The features belong to a closed set, from which each language selects a subset.

3. The features have a dual nature: they are distinctive markers that serve to represent the individual words and morphemes of a language in speakers' memories; they also serve as instructions for the articulatory actions that produce the acoustic speech event.
4. Features figuring in the representation of a morpheme in memory may differ from those that serve as instructions for the articulation. The relationship between these two representations is mediated by rules.
5. All regularities and constraints on the behavior of segments must be formulated in terms of their component features.
6. The features of a segment are organized in the ''bottle brush'' form illustrated in (4).
7. Included in the universal set of phonological features are six unary features providing information about the designated articulator of a segment.
8. All vowels bear the feature [DADorsal], but [−back] vowels are also [DACoronal].[12]

These propositions represent significant progress in our understanding of the nature of phonology compared with views such as those of Sapir (1925) sketched in section 1 and others not reviewed here in detail or even mentioned. It is hoped that future work in phonology will take account of the above propositions, correcting them where needed and using them as stepping stones to further advances in the field.

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[12] The introduction of the six DA features provides a natural means for distinguishing the vowels from the glides, the other major class of [−consonantal, +sonorant] segments. Since the vowels are [DADorsal], we expect to find five classes of glides, each with its own DA, as in fact we do: [DALabial] – [w]; [DACoronal] – [j]; [DARadical] – [ħ ʕ], the pharyngeal fricatives of the Semitic languages; [DARhinal] – nasal glides such as the Sanskrit *anusvāra* and those of Japanese (see McCawley 1968:84); [DAGlottal] – [h ɦ ʔ].

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Department of Linguistics and Philosophy
32-D838
MIT
Cambridge, Massachusetts 02139

halle@mit.edu