Some of

The Sounds of the World's Languages

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Preface

This book lays the foundation for a theory of phonetics by surveying the data that such a theory must explain. The primary data are the phonetic events that are linguistically significant in the languages of the world. These events include not only those aspects of sounds that have been actually observed to distinguish meanings within a language, but also all the phenomena that make one language sound different from another. The phonetic theory we are attempting to develop must also provide appropriate connections to a phonological theory that can account for the patterns of sounds that occur in each language. In satisfying these goals, the theory must describe the relation between at least three types of phonetic facts -- those which lie in the articulatory, the acoustic and the auditory domains.

In this book we will try to describe all the segments that are known to distinguish lexical items within a language. We have in this way determined the level of description at which we will operate. We are concerned with the lexical segments that account for minimal pairs. (We must admit that in a number of cases we have insufficient knowledge of the phonology of the language being described to be absolutely sure of this assertion, but it is highly likely to be correct in that information at the level of minimal pairs is relatively accessible to both the native speaker and the linguist.)

Although our primary data are the lexical contrasts within languages, we hope that we will also be able to develop a phonetic theory rich enough to describe all those events that distinguish one language or accent from another. These phonetic events are at least potential conveyers of lexical contrasts for speakers of other languages. But it is often difficult to know whether or not there is a difference between two languages with respect to a particular phonetic parameter. For example, two languages may appear to differ slightly in the qualitity of some vowel. But we may not have sufficient data to know whether this is a statistically reliable difference. In all such cases we have simply used our best judgment as practising phoneticians.

Inevitably the proposals in this book fall far short of our goals; but we believe that there are several ways in which this book improves on previous attempts. It deals with a wider range of phenomena than in any previous study, so that we hope that it presents nearly the full range of human phonetic possibilities. Many of these possibilities are illustrated by instrumental records; and a recording is available illustrating a number of the less well known contrasts. This book also examines dynamic aspects of speech. Speech is not a static process, but an active one. The description of the dynamics of that process provides many difficulties; but it is becoming increasingly clear that many properties of a language and many differences between languages can be understood only from a dynamic perspective.

When we started this project we knew that we were being ambitious. But we did not realize the extraordinary amount of physiological and acoustic data that is available on the little known languages of the world. Our library research has led us to hundreds of books and papers that contain wonderful instrumental data that has never been summarized or otherwise made available to the general phonetician who is not concerned with the particular languages being described in the original work. We also found that our own files and the UCLA phonetic archives accumulated over many years contained a great deal of previously unpublished material. We were often pleased to find that illustrative recordings and analyses of particular sounds cited could be obtained from our own resources. The great wealth of material available to us led to some problems in trying to decide which of many pieces of data we should include in this book. We wanted to write a book that would advance linguistic and phonetic theory. Accordingly we have limited ourselves to discussing just the data required for this purpose. We have not included a number of things that are well known and readily available, such as acoustic data illustrating the contrasting stop consonants in English. Nor have we tried to be comprehensive and include references to every account of the less well known phenomena. Our aim is simply to exemplify the range of phonetic events. At the close of our survey we offer some thoughts on what the data suggest about the form that a phonetic theory should take. We welcome comments on this work. This is the present state of our knowledge about the linguistic phonetic events that occur in the languages of the world, and the theory of phonetics that is required to describe them.

2.

Places of articulation in stops and nasals

Descriptive framework

In this chapter we will be concerned with characterizing one aspect of the articulatory gestures required for the production of stops and nasals. Each gesture is a complex affair, involving the generation of an airstream, possible variations in the state of the glottis, and movements of the articulators. Here we will consider only the major movements of the articulators, leaving the glottal states and airstream mechanisms for later discussion.

The specification of movement requires three different kinds of statement. We must say what moves, in which direction does it move, and how fast is it moving. In the case of articulatory gestures, this means that we must first characterize the parts of the vocal apparatus that are involved; we must then state the direction of the movement (where the articulators are moving from, and where they are going to); and thirdly we must specify the timing of the movements in this direction. At the moment we have very little to say about the timing of the movements, beyond noting that the change of position of each point in the vocal tract should be given by an equation describing its motion. Possible equations have been suggested by Browman and Goldstein (1986) in their account of articulatory phonology. These equations require the specification of such factors as the mass and elasticity of the articulator involved, as well as the muscular forces that are being exerted. The correct form of these equations of motion must be determined before we can have a full understanding of phonetic processes. But for the moment we will concentrate simply on describing the articulators and the directions of the movements within each gesture, using the traditional terms of phonetic description.

The starting point of the movement in a stop consonant gesture depends on the position of the vocal tract in the previous sound. The most convenient approach in this chapter is to consider the movement from a neutral state of the vocal tract towards some articulatory target. The target position may be one in which the lower articulator is considered to have been moved to just above the upper articulator. This painful thought is achieved without bloodshed because we never actually achieve our targets. But it is nevertheless useful to think of the forceful coming together of the tongue or lips in a stop consonant as being programmed in the brain (or in a computer) as an attempt to throw one part of the vocal tract through another.

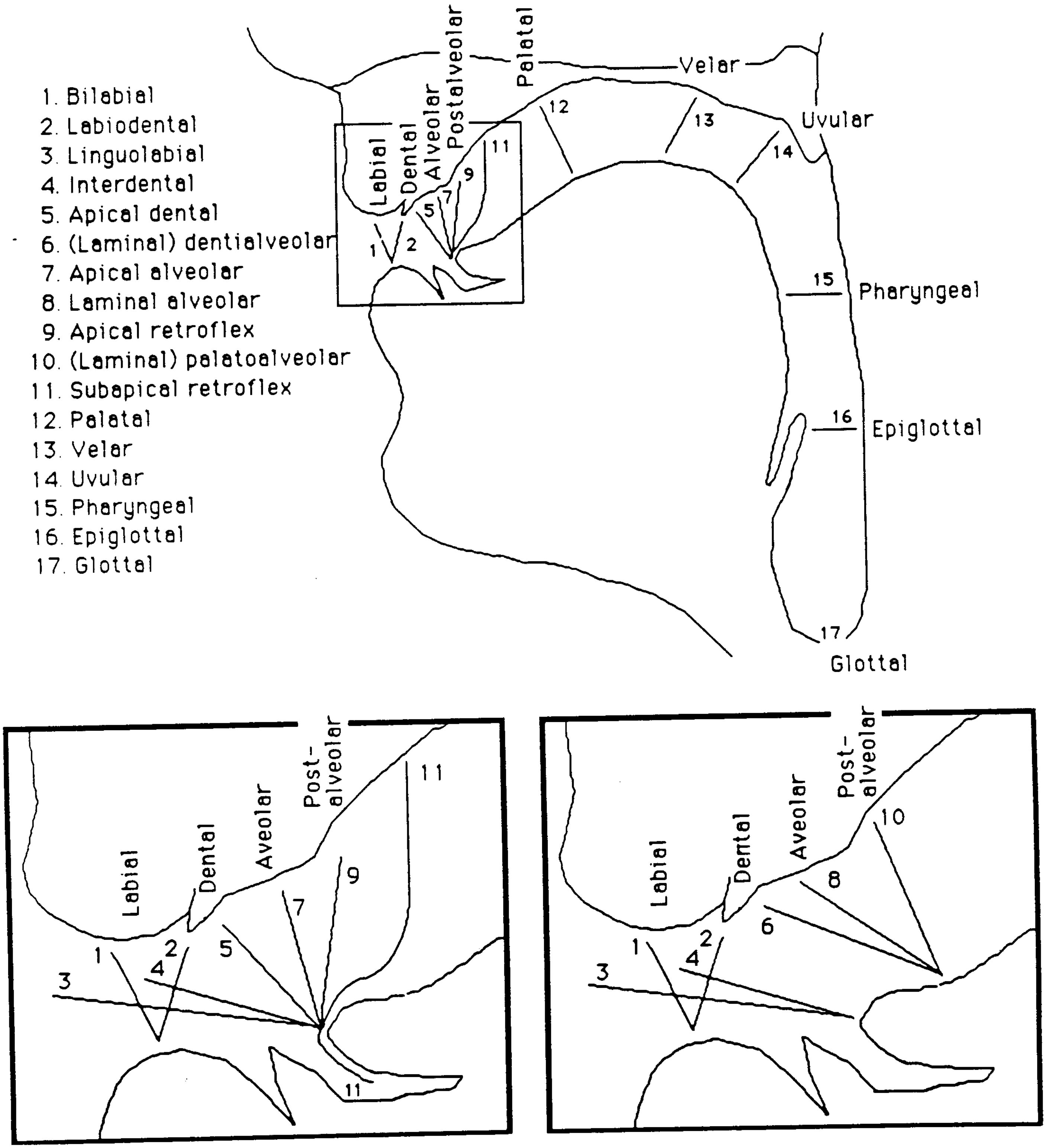


Figure 2.1. The 9 target regions on the upper or back surface of the vocal tract (plus the Glottal region) and 17 articulatory gestures considered as "Places of articulation".

Properly speaking, this kind of description would require us to say something about the movements of the whole vocal tract when specifying the articulatory gesture needed for a particular stop consonant. For the moment, however we will consider only the part of the vocal tract that has to be moved to achieve the required closure. In most cases this involves a fairly localized region of the vocal tract. Thus to describe a stop as velar we will consider the movement of only the back of the tongue. Possible concomitant movements of the lips or the tip of the tongue would be only a minor part of the specification of a primary articulation in the velar region. In this chapter we will give a preliminary survey of the primary components of each movement, neglecting any secondary articulations. We will also neglect aspects of the vocal tract that are associated with the activity of the glottis or with the velic opening. All these additional components of sounds will be discussed in subsequent chapters.

A convenient way of considering the targets required in the description of stop consonants is to examine a traditional set of so-called "places of articulation." Theories of phonetics have virtually always included some notion of place of articulation which is very comparable to the notion of an articulatory target as we have outlined it above. But the traditional terms are more powerful in that they can be taken to describe both the principal moving articulator and the principal direction of movement. Thus the terms specify both the target and the shape of what moves towards it. Figure 2.1 provides an overview of some of the terms that we will use in the remainder of this chapter. It illustrates nine target regions on the upper or back surface of the vocal tract, which we will term labial, dental, alveolar, postalveolar, palatal, velar, uvular, pharyngeal and epiglottal. Note that we use the term alveolar to denote only the front part of the alveolar ridge. This seems to be the practice of most phoneticians, although it is somewhat confusing in that it means that the point of maximum curvature in the alveolar ridge forms the boundary between what we call the alveolar as opposed to the postalveolar region. In the dental, alveolar, post-alveolar and palatal regions, we will take into account the part of the tongue used in producing the gesture. The traditional terms apical, laminal and sublaminal will be used to indicate differences in the way in which the tongue is used to form articulatory gestures in these regions.

Many of the "place of articulation" terms denote two distinct components of the articulatory gestures: the articulatory region involved (on the upper or back surface of the vocal tract), and the action of the lips or tongue. Thus velar implies an action involving the back of the tongue and the velar region, and epiglottal implies the epiglottis and the back wall of the pharynx. In some cases the traditional term does not make a complete specification. Alveolar sounds can be either apical or laminal. But in other cases there is a traditional term that incorporates both the apical-laminal distinction and the articulatory region in which the sound is made. Thus dentialveolar is often used to refer to sounds that are articulated in the dental region and involve the blade of the tongue. The name is appropriate in that it seems that laminal dental sounds always involve contact in the front part of the alveolar region as well as on the teeth. Apical postalveolar sounds are often called (apical) retroflexes; and laminal postalveolar sounds are called palatoalveolars. Sounds in an area behind the alveolar ridge can also be made with the underside of the blade of the tongue, in which case they are called sublaminal retroflex sounds. Table 2.1 presents some of the terminology that may be used for labeling articulatory gestures in which different parts of the tongue are used, together with examples of the symbols.

Table 2.1. Terminology and symbols for summarizing the articulatory gestures in stops and nasals.

"Place of articulation"	Articulatory region	Moving articulator	Symbol examples
1. Bilabial	Labial	Lower lip	p b m
2. Labiodental	Dental	Lower lip	ɱ
3. Linguolabial	Labial	Tongue tip	p̼ m̼
4. Interdental	Dental	Tongue blade	t̪̟ d̪̟ n̪̟
5. Apical dental	Dental	Tongue tip	t̺ d̺ n̺
6. (Laminal) dentialveolar	Dental and alveolar	Tongue blade	t̪̻ d̪̻ n̪̻
7. Apical alveolar	Alveolar	Tongue tip	t d n
8. Laminal alveolar	Alveolar	Tongue blade	t̻ d̻ n̻
9. Apical retroflex	Postalveolar	Tongue tip	t̪̣ d̪̣ n̪̣
10. (Laminal) palatoalveolar	Postalveolar	Tongue blade	t̠ d̠ n̠
11. Sublaminal (retroflex)	Palatal	Tongue underblade	ʈ ɖ ɳ
12. Palatal	Palatal	Front of tongue	c ɲ
13. Velar	Velar	Back of tongue	k g ŋ
14. Uvular	Uvular	Back of tongue	q ɢ ɴ
15. Pharyngeal	Pharyngeal	Root of tongue	- - -
16. Epiglottal	Epiglottal	Epiglottis	ʡ
17. Glottal	Glottal	Vocal cords	ʔ

The 17 possibilities listed above indicate the major movements of part of the vocal tract from a neutral position towards the center of each target. In the next section of this chapter we will show that each of these possibilities (with the exception of pharyngeal) represents one of the different articulatory movements that are used in stop consonant gestures. The final section will discuss how these articulatory movements can be related to phonological features. We will also consider whether there is a discrete set of places of articulation, as is implied by the terms shown in table 2.1, or whether the 17 possibilities we have been discussing should be considered merely as expository devices.

Contrasting places of articulation

Stops and nasals in which either the upper or lower lip is involved as an articulator can be called labial. The lower lip can articulate with the upper lip (biliabial) or the upper teeth (labiodental). The upper lip can also be the target for the tongue (linguolabial). We do not know whether true labiodental stops occur in any language. The stop closure in labiodental affricates is bilabial. Labiodental stops contrasting with bilabial stops have been reported in Tonga (Guthrie 1948), but we have not heard this language. We have heard labiodental stops made by a Shubi speaker whose teeth were sufficiently close together to allow him to make an airtight labiodental closure. For this speaker this sound was clearly in contrast with a bilabial stop; but we suspect that the majority of Shubi speakers make the contrast one of bilabial stop versus labiodental affricate (i.e. bilabial stop closure followed by a labiodental fricative), rather than bilabial versus labiodental stop.

Labiodental nasals occur in many languages; they are usually coarticulated allophones of other nasals. They have, however, been reported as gestures contrasting with both bilabial nasals and labiodental fricatives in Teke. Paulian (1975) describes these sounds as "réalisé comme une occlusive nasale, labio-dentale, toujours sonore; l'occlusions se produit entre les dents du haut et l'intérieur de la lèvre inférieure; elle est accompagné d'une forte avancé des deux lèvres." We do not know if a true occlusive could be made with this gesture, when we take into account the gaps that often occur between the incisors. But it was this possibility that lead us to include the labiodental gesture in table 2.1 and figure 2.1.

Table 2.2 Some contrasting places of articulation in Thenen Taut (Big Nambas). (Fox, 1979.)

	Bilabial	Linguolabial	Alveolar
plosive	'pama	p̺u	timʌx
	come	wart	feast
nasal	'maməx	m̺ə'mənmən	'nunu
	well	I might be drunk	breast
fricative	iβi'βiln̩	'fanu	'sasi
	it is right	settlement	whittle it

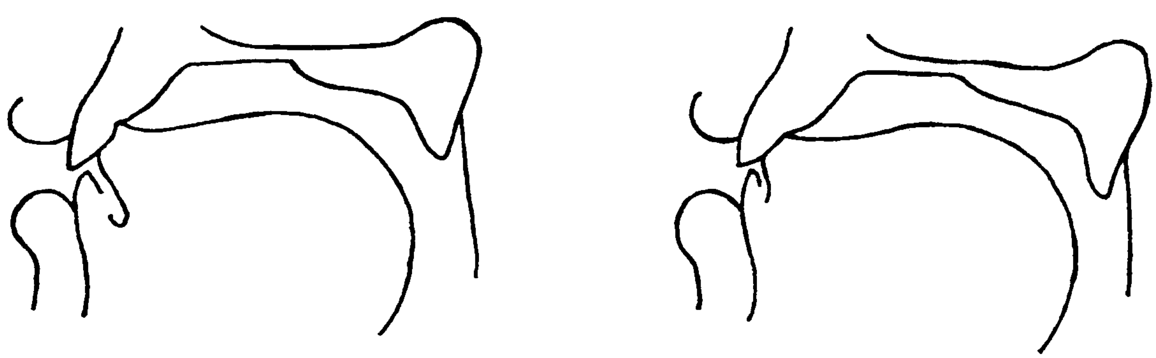
In a group of languages from the Island Malekula in Vanuatu a series of linguolabial segments has developed. These languages have stops and nasals with a linguolabial gestures contrasting with bilabial and alveolar gestures, as illustrated in table 2.2. Tryon (1976) and Fox

(1979) describe these sounds as "apico-labials" but we have adopted the term linguolabial suggested by Loundsberry (personal communication) for a similar articulation that occurs in Umotina, a language of the Bororo group spoken in South America. Fox (1979) says that during the production of the gesture in Thenen Taut (which he calls "Big Nambas") "the apex of the tongue comes into contact with the upper lip."

An even more unusual sound occurs in Pirahã, a Mura language spoken by approximately 100 people in Brazil. According to Everett (1982) this language has "a voiced, lateralized apical-alveolar/sublamianl-labial double flap with egressive lung air. In the formation of this sound the tongue tip [first] touches the alveolar ridge and [then] comes out of the mouth, almost touching the upper chin as the underblade of the tongue touches the lower lip." More research is needed before we can decide how to add an anomalous gesture of this type to those shown in figure 2.1.

We have included a distinction between dental and interdental stops in table 2.1 and figure 2.1, but we do not know of any use of this distinction to form phonemic contrasts. It seems that some languages consistently use one possibility while others use the other. French, for example, typically has stop consonants in words such as ty "tu" (you) in which the tongue touches the upper teeth; but (according to Dixon 1980) many Australian languages typically have interdental stops in which the "teeth are slightly apart, and the blade of the tongue [projects between and] touches both sets of teeth." This gesture may be similar to that described by Fox (1979) for lingualabials. It would be difficult to make the tongue project between both sets of teeth without having it touch the upper lip as well.

Both apical dental and interdental gestures occur in Malayalam. The speakers we investigated typically made n̪ as an interdental nasal in words such as pʌn̪n̪i (pig), but they made t̪ as a dental stop without tongue protrusion in words such as kut̪t̪i (stabbed). Acoustically, the dental and alveolar plosives are distinguished from one another by both bursts and formant transitions, and are comparatively distinct. The nasals have virtually no distinguishing bursts, but have more distinct formant transitions than the stops as a result of the greater articulatory differences among them.



t̪ d̪

Figure 2.2. Dental t̪ and d̪ in Breton (after Bothorel 1982).

In the languages we have investigated dental stops are typically laminal rather than apical, with contact on both the teeth and the front part of the alveolar ridge. Thus the d̪ gestures in widely dispersed languages such as French, Malayalam, and Ewe all have a long contact region, and might better be regarded as laminal dentialalveolars rather than pure dentals. Apical dentals seem comparatively rare. They occur in the West African languages Temne and Limba (which will be discussed shortly), and in Breton, as shown in figure 2.2 (based on Bothorel 1982). The apical laminal distinction also applies to alveolar stops. There is evidence for consistent apical alveolar stops in Isoko, which will be discussed shortly. We have not found many clear cases in which a laminal articulation is required for alveolar gestures for stops or nasals; but, from the x-ray tracings in Stojkov (1942), it seems as if a major part of the difference between n and what is traditionally called palatalized n in Bulgarian is that the former is produced with an apical alveolar n, and the latter with a laminal alveolar gesture ɲ, as may be seen from the data in figure 2.3.

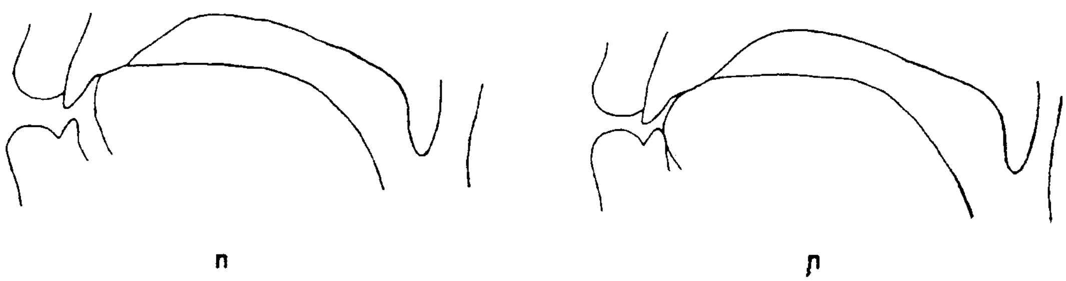


Figure 2.3. Apical and laminal alveolar nasals in Bulgarian (after Stojkov 1942).

As noted by Ladefoged (1968), if a language has a contrast between dental and alveolar stops, then there will be differences in the action of the tongue accompanying the distinction. Both Temne and Isoko have two contrasting stops in this region. In Temne the one made further forward in the mouth is articulated with the tip of the tongue, and the one further back involves the blade of tongue; whereas in Isoko precisely the reverse is true. Consequently the apical dental in Temne has much in common with the apical alveolar in Isoko. The similarity of the auditory and acoustic effects of these two sounds is increased by the fact that in both languages the consonants made with the tip of the tongue are unaspirated; whereas the two different blade of the tongue consonants are aspirated and affricated in both cases. It seems likely that if a language has both an apical and a laminal stop consonant, then the laminal consonant will be more affricated, irrespective of which one of the two is dental and which alveolar.

The Isoko dental and alveolar stops are illustrated in figure 2.4. There are clear differences in the formant transitions which are due to using the blade of the tongue in the laminal dental (dentialveolar) as opposed to the tip of the tongue in the apical alveolar articulations. The joining of the third and fourth formants at the start of the stop release, and the unusual second formant which can be seen in the first part of the laminal dental closure, occured in a number of utterances of this word by this speaker. The affrication which occurs with the laminal articulation may also be seen.

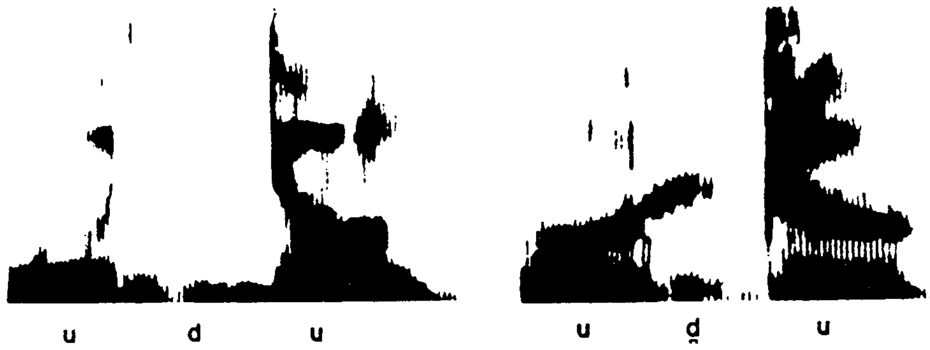


Figure 2.4. Spectrograms illustrating the difference between an apical alveolar d and a laminal dentialveolar d̪ in Isoko. (Based on Ladefoged, 1968.)

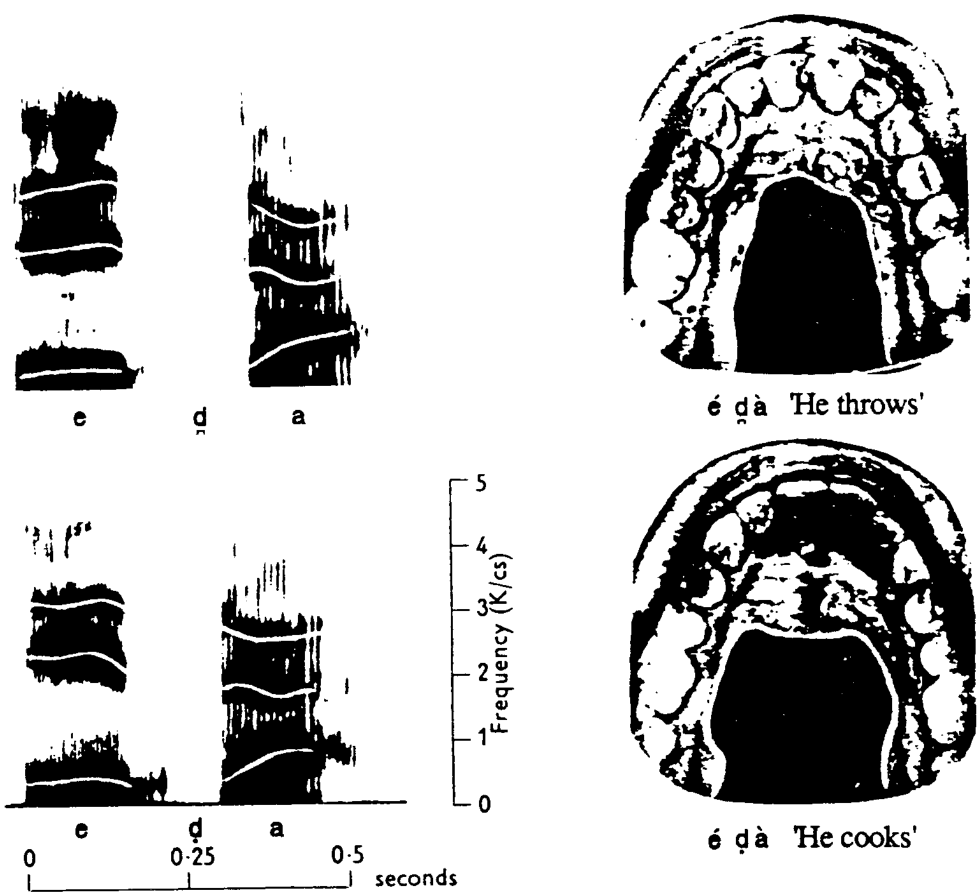


Figure 2.5 Spectrograms and palatograms illustrating the difference between a laminal dentialveolar d̪ and an apical retroflex ḍ in Ewe. (Based on Ladefoged, 1968.)

The next question that we should consider is the nature of retroflex articulations. The term "retroflex" seems to have been used for several different articulations, one of which is an apical postalveolar (retroflex) gesture. We have symbolized such gestures by a subscript dot beneath the symbol for the alveolar sound. We examined the contrast between d̪ and ḍ in two dialects of Ewe (Kpandu and Peki) and in some of the neighbouring Central Togo languages. Instrumental records were obtained from a total of six speakers using this contrast. The principal articulatory difference between these two sounds is in the part of the tongue that is used. The dentialveolar d̪ is articulated with the blade of the tongue against the teeth and alveolar ridge, whereas ḍ is articulated with the tip of the tongue against the alveolar ridge (usually but not always, the posterior part). Figure 2.5 shows palatograms of an Ewe (Kpandu) speaker saying the words e d̪à 'he throws' and e ḍà 'he cooks'. The other five speakers investigated all produced very similar sounds. The palatograms show that the area of contact between the tongue and the roof of the mouth is smaller in the second phrase than in the first. Examination of the speaker's tongue after the pronunciation of each phrase also made it clear that in the case of e ḍà only a small part of the tip about 5 mm across had touched the roof of the mouth; as the area of contact on the roof of the mouth is wider than 5 mm the tip of the tongue must have moved as it made contact. Spectrograms for these words are shown in the lower part of the figure. The acoustic difference produced by these slightly different articulations is very small, consisting mainly of a greater lowering of F2 before the closure and a slower and rising rather than falling F2 transition after the closure in e ḍà.

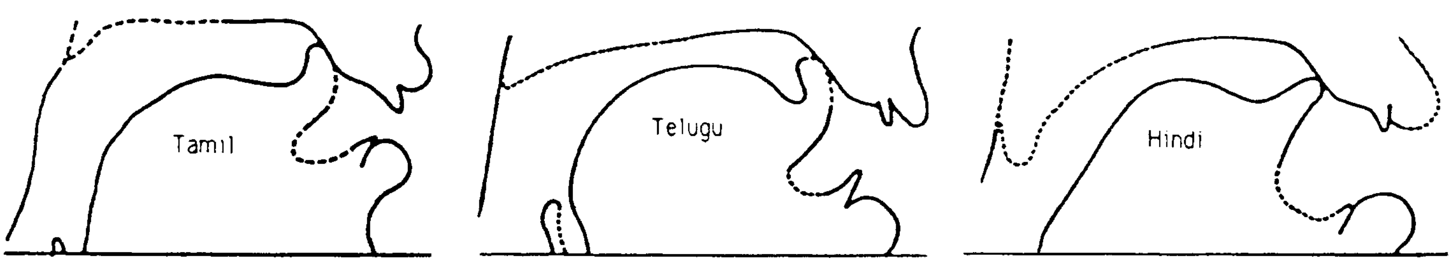


Figure 2.6. Sublaminal retroflex ɖ in Tamil and Telugu and apical retroflex ḍ in Hindi. (Based on Ladefoged and Bhaskararao, 1983.)

Ladefoged (1968) suggested that the Ewe apical postalveolar (retroflex) ḍ might not be the same as the similarly symbolized sound in Hindi, a suggetsion that still seems likely to us. Ewe ḍ does not sound as retroflex as Hindi ḍ. We do not have comparable data on the two languages, so we have no way of deciding this issue. But Ladefoged and Bhaskararao (1983) have shown that languages can differ in the kind of retroflexion that they employ. Figure 2.6, which is based on data in Ladefoged and Bhaskarao, shows typical tongue positions for the retroflex consonants in Tamil and Telugu, two Dravidian languages, and Hindi, an Indo-Aryan language. The Dravidian languages have sublaminal consonants in which the underside of the tongue contacts the anterior part of the hard palate, whereas Hindi speakers do not usually have the tongue tip curled so far back. We use hooked symbols such as ɖ for sublaminal palatal (retroflex) sounds, and dotted symbols such as ḍ for apical postalveolar (retroflex) sounds. The Dravidian languages are the only well known languages that have sublaminal retroflex stops, but Eastern Ostyak may also have a sound of this kind (Gulya 1966).

The acoustic results of retroflexion have been studied by a number of authors. The general concensus seems to be that retroflexion affects mainly the higher formants. Fant (1968) notes that a retroflex modification of alveolar sounds lowers F4 so that it comes close to F3; but a retroflex modification of palatal sounds modifies F3 so that it comes close to F2. As a result of a theoretical analysis of the relative sizes of the cavities involed, Stevens & Blumstein (1975) note that "(1) the F2 transition is similar for both retroflex and non-retroflex consonants; (2) the F3 transition tends to be rising from the retroflex position; and (3) (F4) starts very low, and undergoes a brief interval in this position before rising rapidly to the normal F4 position for the vowel". They go on to note that: "the overall acoustic pattern is characterized by a clustering of F2, F3 and F4 in a relatively narrow frequency region". The latter point is confirmed by Dave (1977). Stevens & Blumstein also find that retroflex stops have a burst of noise with a center frequency near F3 or F4. Dave (1977) notes that he has difficulty observing this, but, in general, he does find that the bursts for Gujerati dental stops are higher than those for retroflex stops. Ramasubramaniam and Thosar (1971) give a series of rules for synthesizing retroflex sounds, including: "when ṭ,ḍ,ṇ [our symbols] precede and/or follow a vowel, the steady-state value of F3 of the vowel is lowered by about 225 c.p.s." They also list the locus for both F2 and F3 in association with front vowels as 1900 Hz, with central vowels as 1450 Hz, and with back vowels as 1000 Hz. Dave (1977) is somewhat critical of this work. On the basis of his acoustic analysis of two speakers he consider the F2 Locus to be at 2100 Hz, with F3 and F4 having very low, but not fixed, loci. He also notes that in both his data and that of Stevens & Blumstein (1975) there are much greater formant transitions in going from a vowel into a retroflex consonant than in going from a retroflex consonant into a following vowel. This effect, which is also evident in our data, indicates that the tongue tip first bends back into the retroflex position, and then, during the closure phase, straightens out somewhat, so that by the time of the release of the closure it is in a less extreme position.

We do not know if there is a language with two contrasting retroflex articulations, apical and sublaminal, but it seems that this might be the case in Toda. We have not heard Toda ourselves, but Emeneau (1984) provides a great deal of phonetic detail. Emenau uses slightly different terminology from our own, but his descriptions are so elaborate that there is usually no difficulty in equating his categories with ours. He lists seven places of articulation, using the terms shown in column (2) of table 2.3. The most likely correspondences to the terms we are using are shown in column (1).

Table 2.3. (1) The set of terms that we have been using for describing stop consonant places of articulation; and (2) the terms used by Emenau (1984) for the seven places of articulation in Toda. The asterisks in the third column mark those places of articulation that are clearly equivalent in the two sets of terms.

(1) Our terms	(2) Emenau (1984)	(3) Equivalent terms
bilabial	labial	*
apical dental		
laminal dental	dental	*
apical alveolar		
laminal alveolar	post-dental	
apical postalveolar (retroflex)	alveolar	
sublaminal palatal (retroflex)	retroflex	*
laminal postalveolar (palatoalveolar)	alveolo-palatal	*
palatal		
velar	velar	*

Emenau's descriptions make it unambiguous that five of these terms (those which we have marked with a following asterisk in table 2.3) are equivalent to the corresponding terms used in this chapter. The remaining two terms "post-dental" and "alveolar" are a little harder to equate with our terms. It is quite clear that "post-dental" refers to an articulation made further forward than that referred to by "alveolar". It is also clear that "alveolar" implies an apical articulation, as he comments "my attempts at pronunciation with the blade in contact with the alveolar ridge did not satisfy the informants." But it may be that what Emenau regards as "alveolar" is the center of the alveolar ridge. This would mean that we should equate his "alveolar" with our apical retroflex, which we described as having the tongue raised to make contact in the postalveolar region, which is near the center of the alveolar ridge. This interpretation is supported by his description of **s** as being "post-dental (pre-alveolar)." If we consider his "post-dental" as being, in our terms, alveolar, it would then still be in front of what he calls "alveolar." But if we regard what Emenau calls "alveolar" in Toda as our apical postalveolar retroflex, then we would be equating the Toda sound with the Hindi sound we categorized in this way. As Emenau makes it quite plain that Toda also has a sublaminal retroflex sound, it seems that Toda might be a counter-example to Ladefoged and Bhaskararao's (1983) claim that, although the Hindi apical retroflex and the Telugu sublaminal retroflex sounds are quite different from each other, no language uses this possible contrast. However we do not consider the evidence at hand to be sufficient to decide this point.

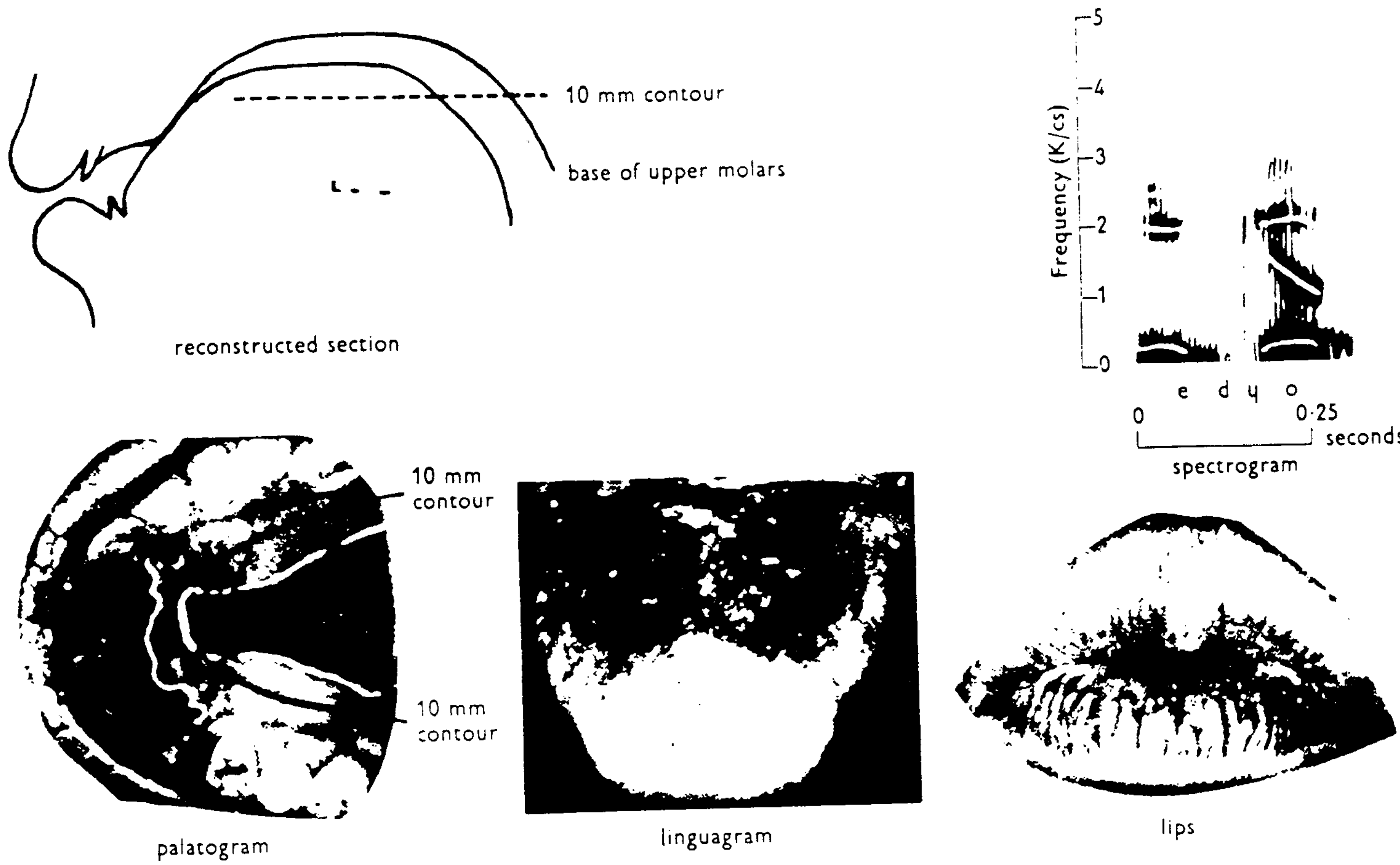


Figure 2.7. Data illustrating a labialized palatalized laminal palatoalveolar affricate in Late. (Based on Ladefoged, 1968.)

We have now considered all the articulatory gestures required for stops made in the dental and alveolar regions, and those made with the tip and the underside of the tongue in the post-alveolar region (the apical and sublaminal retroflex sounds). Laminal sounds made with the upper side of the tongue in the postalveolar region are usually called palatoalveolar. We will begin our discussion of these sounds by describing some stop consonants in Ghanaian languages. The general characteristics of laminal postalveolar stops may be illustrated by reference to the records for Late, a Guang language. Figure 2.7 provides data on the pronunciation of the word edɥò (in the local orthography edwo) 'a yam', which contains a labialized laminal postalveolar affricate. The figure (adapted from Ladefoged 1968) includes a sagittal section and a contour line superimposed on the palatogram. From a consideration of the contact area in relation to this line, the shape of the center and back of the tongue has been deduced. The linguagram shows that the tip and blade played no part in the articulation of the consonant; the black marking medium appears only further back on the tongue. The photograph of the lips shows that they come very close together, making this sound very labialized. The acoustic effect of all these articulations is shown in the spectrogram, which also illustrates three other points: the lack of voicing during part of the consonant; the small amount of affrication that occurs after the release of the closure; and the comparatively lengthy offglide involving a semivowel of the ɥ type.

We found a considerable amount of variation among the stops with this type of articulatory gesture in different Ghanaian languages. In sounds written in the local orthography as dw and tw (as in the name of the Akan dialect, Twi) some speakers made the stop closure with the blade of the tongue, and others with the front of the tongue. In all cases the tip of the tongue was down behind the lower front teeth, and the center of the tongue was raised towards the hard palate, so that the gesture included strong palatalization. There was usually considerable affrication. This sound is therefore either a laminal postalveolar affricate tɕ or a palatal stop c or a palatal affricate cç. In most of the West African languages in which these sounds occur there is a contrast between labialized and non-labialized affricates articulated in this way. But it is important to note that the labialized and non-labialized sounds do not necessarily have the same tongue gesture. Thus our main Fante speaker had the same mid-point of articulation in the voiced labialized consonant in ɔ̀dʑwè 'he calms' as in the voiceless non-labialized consonant in ɔtɕè 'he catches'; but the extent of the contact was greater during the labialized consonant. Our main Akwapim Twi speaker had very little affrication in this sound, and had the same center point of articulation in ocɥà 'he cuts' and càcà 'mattress'; but in this case the contact was greater in the non-labialized consonant. In Nzima we found the articulations to be affricated palatal stops in both in ɔcçɛ̀ 'he divides' and ɔcçwɛ 'he pulls'.

Some of the other languages that use laminal postalveolar gestures make greater use of the apical/laminal distinction. Thus many Austtralian languages contrast laminal dental, apical alveolar, apical retroflex, and laminal postalveolar (palatoalveolar) stops. Nunggubuyu examples are given in table 2.4.

Table 2.4. Some contrasting lingual stops in Nunggubuyu.

laminal dental (dentialveolar)	apical alveolar	apical postalveolar (retroflex)	laminal postalveolar (palatoalveolar)
t̻arag	tarawa	ṭakowa	t̠aru
whiskers	greedy	prawn	needle

Spectrograms of the first syllable of each of these Nunggubuyu words are shown in figure 2.8. It may be seen that all four of them have voiceless stops, differing only slightly in voice onset time. The major differences are in the intensity and frequency of the burst spectra. The first two sounds, t̻ and t, which are in the dental and alveolar regions, have sharp bursts with energy spread throughout the frequency region displayed. The second pair, ṭ and t̠, which are both made in the postalveolar region, have much more localized bursts, principally in the region of the second formant for the apical retroflex ṭ, and in a slightly higher region for the laminal postalveolar t̠. Both the laminal stops t̪ and t̠ have slightly more friction during the release, but in neither case is it enough to classify it as an affricate. The laminal dental t̪ has a double burst, somewhat similar to that often seen in velar stops. We do not have a large number of tokens of this sound; but it is interesting to note that a double burst occurs in 5 out of 7 examples of laminal dental stops we have analyzed in this and other related Australian languages. There are also differences in the formants associated with these four different stops, notably the higher origin of the F2 transition for the laminal postalveolar t̠ and the lowering of the second formant during the vowel after the apical retroflex stop ṭ.

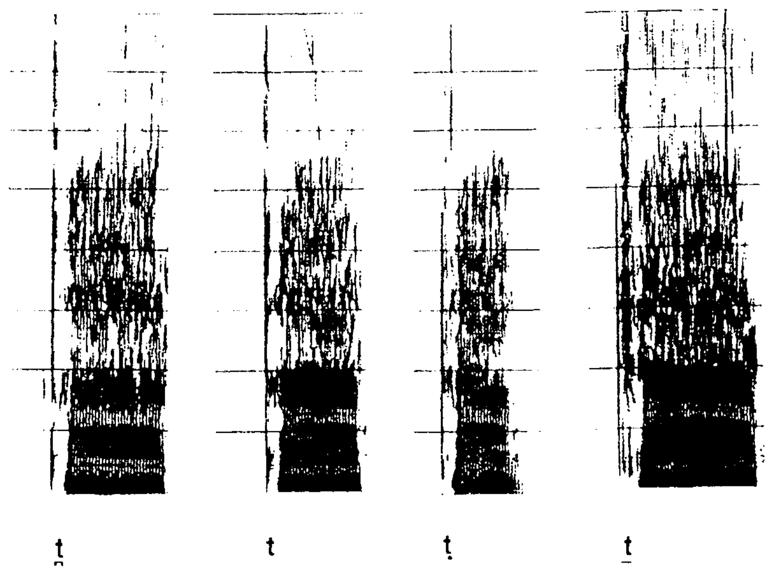


Figure 2.8. Spectrograms illustrating the first syllables of the Nunggubuyu words in table 2.4.

The places of articulation that distinguish the stop consonants illustrated in figure 2.8 also operate to distinguish nasals in many Australian languages. Wangurri examples are included in table 2.5. The spectrograms of all six contrasting nasals are given in figure 2.9. They show that the apical retroflex ṇ and the laminal postalveolar (palatoalveolar) n are clearly distinguished from all the others by the F2 and F3 transitions into the nasal (for ṇ and out of it (for n). But, without the data for a full investigation involving a number of speakers and tokens, the differences among all these places of articulation are by no means clear to us. All these sounds contrast in initial position, so that there may be no entering transitions, and in some languages some of them also occur in consonant clusters before voiceless stops, so that there may be no final transitions. As an exemplification of this latter point, spectrograms of a Pitjantjara minimal triplet, wanka, waṇka, waŋka 'life, caterpillar, talk' are shown in figure 2.10.

Table 2.5. Intervocalic contrasts involving nasals at six places of articulation in Wangurri.

bilabial	laminal dental (dentialveolar)	apical alveolar	apical postalveolar (retroflex)	laminal postalveolar (palatoalveolar)	velar
m	n̪	n	ɳ	ɲ	ŋ
ŋamaʔ	ban̪a	ganaʔ	maɳa	gaɲawu	naŋa
mother	over there	enough	shark	species of tree	see

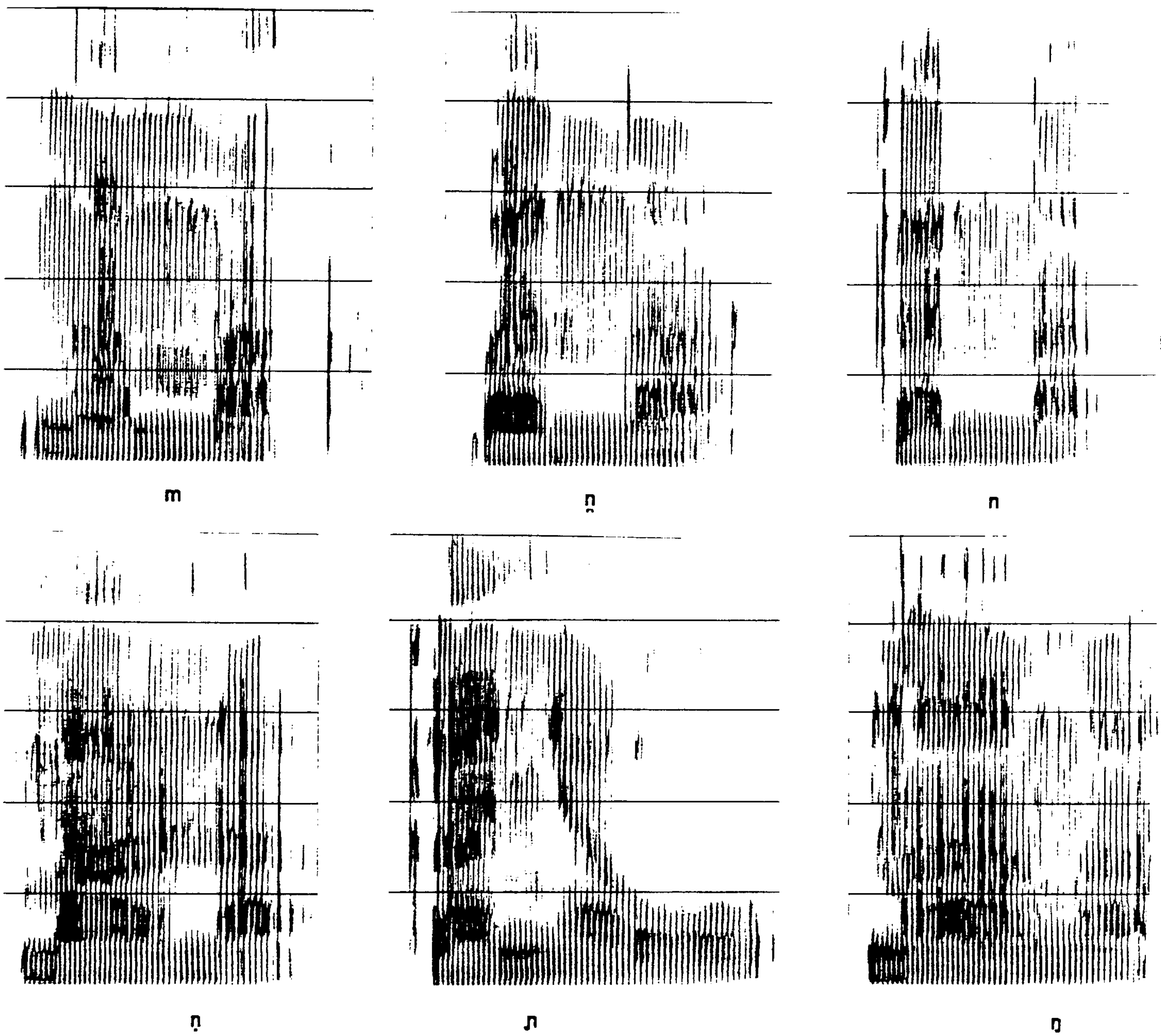


Figure 2.9 Spectrograms showing six contrasting nasals in the Wangurri words in table 2.4

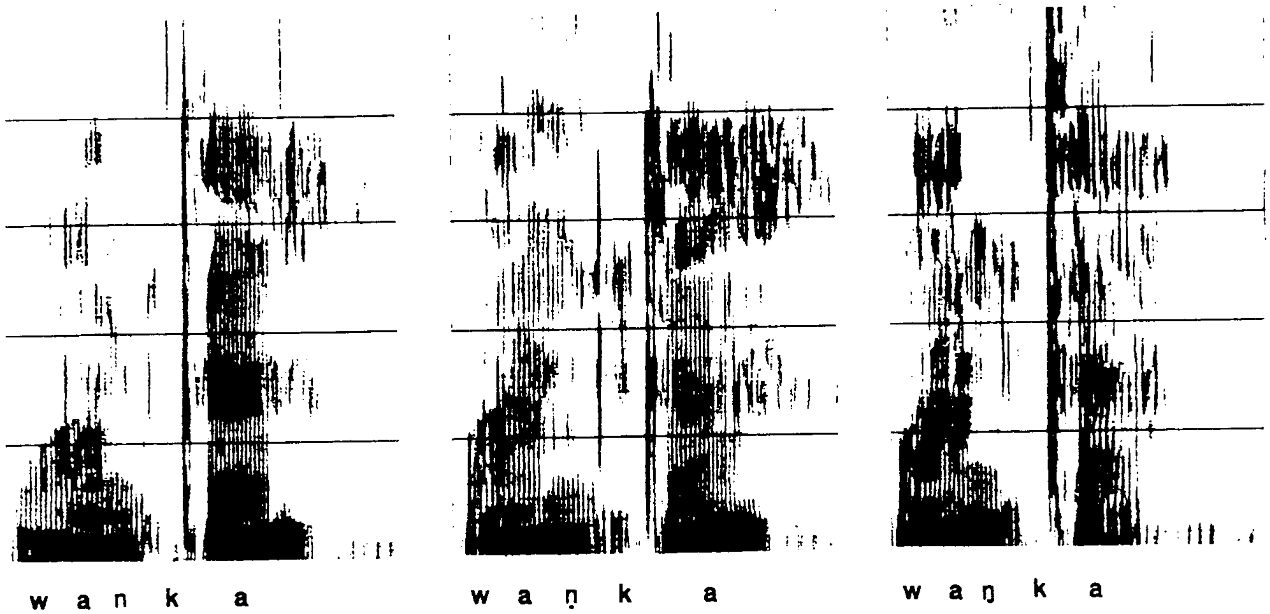


Figure 2.10. Spectrograms showing contrasting nasals before k in Pitjantjara.

It might be possible to regard Nunggubuyu and Wangurri t and n to be palatal rather than palatoalveolar sounds, a possibility which leads us to consider whether palatal and laminal postalveolar sounds really do involve two distinct articulatory gestures. As we have noted in the case of the West African languages the actual area of contact in sounds of this type may vary over a wide range, so that it is often hard to decide whether a given sound should be classified as a palatoalveolar or a palatal. Languages seldom distinguish between sounds simply by one being a palatal and the other a palatoalveolar, preferring instead either to have affricates in the one position and stops in the other, or in some other way to supplement the contrasts in place of articulation with additional variations in the manner of articulation. For example Ngwo has palatal stops and laminal postalveolar affricates in a stop system which includes d,dz,dʒ,ɟ,g. The middle three terms in this series are illustrated in figure 2.11, which shows that there are three distinct places of articulation, which we would now classify as being laminal dental (dentialveolar), laminal postalveolar (palatoalveolar), and palatal. (Other palatograms show that g is also distinctly different, but the contact area for d is the same as that for dz.)

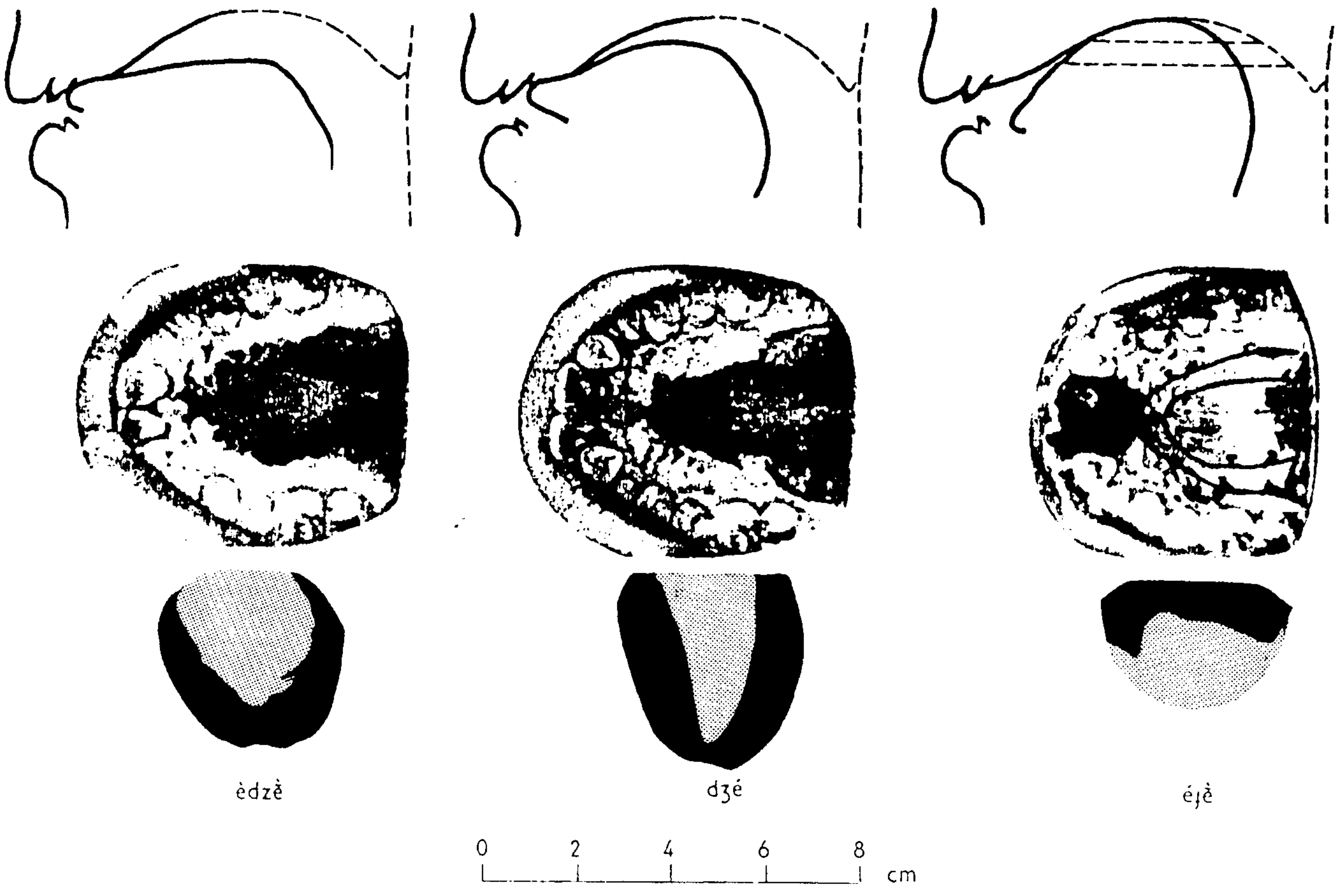


Figure 2.11. Laminal dentialveolar, laminal palatoalveolar, and palatal stops in Ngwo. (Based on Ladefoged, 1968.)

Lahiri and Blumstein (1984) have argued that phonological theories need not recognize the distinction between palatoalveolars and palatals, because the differences are always, as in Ngwo, supplemented by differences in manner of articulation. However, there are counter-examples. According to both Bubrikh (1949) and Lytkin (1966), Komi, a Ural-Altaic language, has both postalveolar and palatal affricates (as well as palatal stops). So in this case differences in place of articulation are not supplemented by differences in manner. In addition, some dialects of Malayalam contrast laminal postalveolar, palatal, and velar nasals. Although the more well known dialects of this language contrast only six places of articulation, Mohannan and Mohannan (1984) note that there is a dialect that distinguishes seven places on the surface by having both n̠ and ɲ.

A further indication of the necessity for distinguishing between laminal postalveolar (palatoalveolar) and palatal sounds comes from Australian languages that have sounds that are definitely further back than the Nunggubuyu and Wangurri laminal postalveolars, but nevertheless further forward than contrasting sounds that are more nearly in the velar region. These stops have been described as palatovelar in Djingili (Chadwick 1975) and Garawa (Furby 1974). Chadwick (personal communication) and Kirton and Charlie (1978) suggest that they may have arisen from a simplification of consonant clusters such as dg and nŋ, which occur in many of the neighboring languages. In at least one of these languages, Yanuwa, the palatal stops are in contrast with both laminal postalveolar and velar stops, so that there are seven places of articulation, as exemplified in Table 2.6. (Data from our own field observations with Jean Kirton [to whom many thanks], supplemented by that in Kirton and Charlie, 1978.)

Table 2.6. Intervocalic contrasts in Yanuwa stops and nasals.

bilabial	dentialveolar (laminal dental)	apical alveolar	apical retroflex	palatoalveolar (laminal postalveolar)	palatal	velar
wubuwiŋgu for a small one (female)	wud̪urumaya laugh!	wuduru full of food	wuḍuḷu in the stomach	wud̠uḷu into the grass	guɟuḷu sacred	wugugu grandparent
wumuwaḍala in the canoe	wun̪un̪u cooked	wunala kangaroo	waṇura white egret	n̠an̠alu tea	l̪uwaɲu strip of turtle fat	waŋulu adolescent boy

The terms in the table differ from those used by Kirton and Charlie (1978), notably by the use of laminal dental (dentialveolar) in place of their apical dental. Their term notes the contact between the tip of the tongue and the upper front teeth, whereas we want to note not only this contact, but also the contact between the blade of the tongue and the front part of the alveolar ridge. There is no doubt that this sound is like that in many other Australian languages, involving what is in our terminology a laminal articulation. We have also used the term palatal (and the regular palatal symbols ɟ and ɲ) in place of their term palatovelar, although we agree that these sounds are made further back than the sounds that are usually called palatal. In addition the velar stops in Yanuwa appear to us to be made slightly further back than those in other languages; but they are in no way equivalent to stops classified as uvular in other languages. The precise place of articulation of all these sounds is difficult to specify because, as we noted earlier, there are no fixed categories for regions of the roof of the mouth.

While discussing sounds in the central oral region, we must note another problem in deciding precisely what is meant by a palatal articulation. In several languages our palatograms (and those of others, e.g. Doke 1931) show that palatal sounds may have two contacts, a tongue tip (or blade) and alveolar ridge contact, and, probably simultaneously, a tongue front and hard palate contact.

These contacts are best considered to be due to accidents of the shapes involved. The center of the target articulation can be considered to be in the palatal region, but the target is not reached, and there is only alveolar and postpalatal contact instead.

Table 2.7. Contrasts involving palatoalveolar (laminal postalveolar), velar, and uvular stops in Quechua.

	Laminal postalveolar (palatoalveolar)	Velar	Uvular
Unaspirated stop	**tʃaka** bridge	**karu** far	**qaʎu** tongue
Aspirated stop	**tʃʰaka** bridge	**kʰujuj** to whistle	**qʰaʎu** shawl
Ejective	**tʃ'aka** hoarse	**k'ujuj** to twist	**q'aʎu** tomato and locoto sauce

We have not ourselves heard any language that contrasts palatal stops with both velars and uvulars. Usually, when there are three stops in this area the most forward of the three is a laminal postalveolar (palatoalveolar) affricate rather than a palatal stop, as is the case in the Quechua words in Table 2.7 (note that this is contra Ladefoged 1971 and 1982). There are, however, a few reports in the literature of languages that contrast palatal, velar and uvular stops without making the first of these an affricate. The most convincing case of this kind is that of Jaqaru, a language fairly closely related to Quechua. Hardman (1966) describes this language as contrasting not only **c,k,q** but also **ts**, **tʃ**, **tʂ**, making it plain that the palatal stop is not an affricate, but actually contrasts with a series of affricate, as well as velar and uvular stops.

There is very little published data on the difference between velar and uvular stops. Al-Ani (1970) has provided data for a single speaker of Arabic. He notes that the uvular stop lowers F2 for a following **i** or **a**. He also suggests that F2 is slightly raised in **u** following a uvular stop, but this is not so apparent in his spectrogams. What is evident, which he also notes, is that the major energy in the burst of the stop consonant is lower for **q** than for **k**.

Table 2.8. Contrasting velar and uvular plosives and ejectives in K'ekchi.

Velar plosive	Velar ejective	Uvular plosive	Uvular ejective
ka grindstone	**k'a** bitter	**qa** our	**q'a** bridge

We analyzed recordings of 12 speakers of K'ekchi that had been made for us by Ava Berinstein (to whom many thanks). Each of these speakers said (among many other words) the four words shown in table 2.8 each within a frame sentence. Spectrograms of the four words as pronounced by one speaker are shown in figure 2.12. The bursts that occur on the release of the stop closure are particularly clear for the ejective stops. We found that for all 12 speakers the major energy in the burst was lower for the uvular stops than for the velars. However F2 was lower at the onset of the vowel for only 9 of the 12 speakers. For these 9 speakers there was also a noticeable lowering of F2 throughout most of the vowel (as may be seen in the case of the speaker in figure 2.12). We found no significant difference with respect to Voice Onset Time for the plosives; the mean VOT for the velars was 52 ms (Std. Dev. 16) and for the uvulars 56 ms (Std. Dev. 21). Nor was there any significant difference in the length of the glottal closure after the release of the ejectives, which was 97 ms (Std. Dev. 38) for the velars and 92 ms (Std. Dev. 38) for the uvulars.

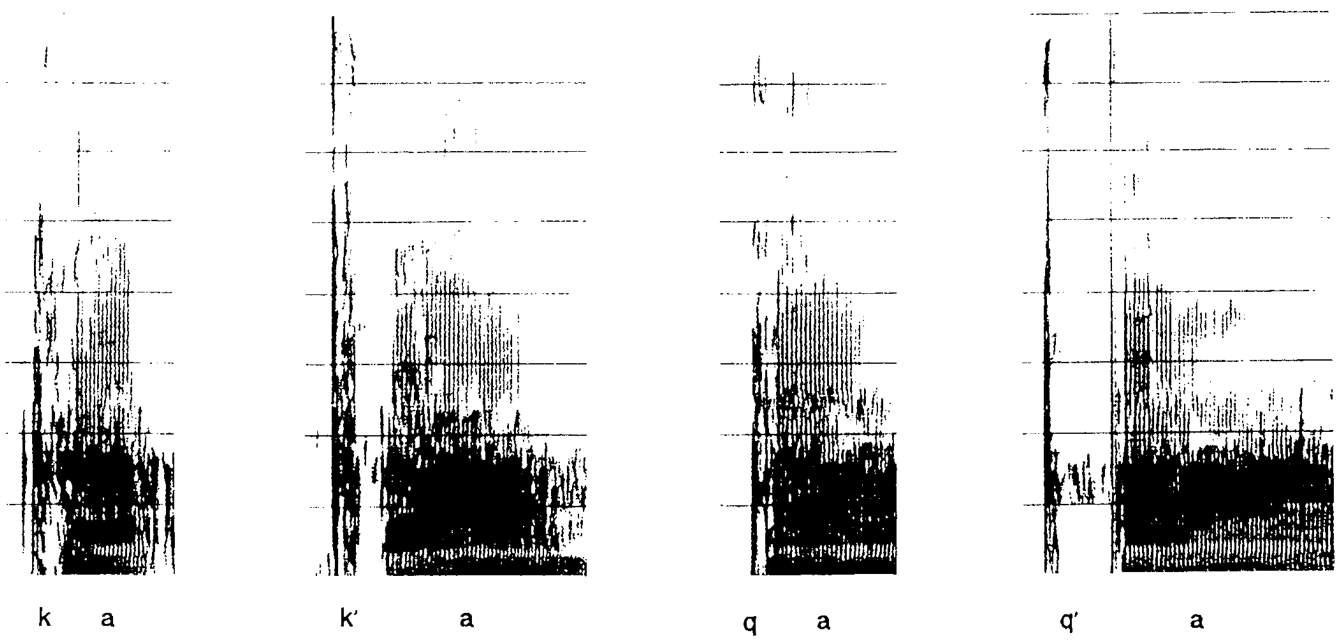


Figure 2.12. Spectrograms of contrasting velar and uvular plosives and ejectives in the K'ekchi words in table 2.8.

Below the uvula are the pharyngeal and epiglottal regions. No language makes stops consistently in the pharyngeal region (although, as we will see, they do occur in the epiglottal region). Pharyngeal nasals are, of course, an impossibility. We will consider gestures of tmade in this region when discussing fricatives.

The lower part of the pharynx contains the root of the tongue and the epiglottis. Catford (1983) has suggested that the Chechen "pharyngeal stop" may be produced by "the epiglottis actively folding back and down to produce an epiglotto-arytenoidal constriction, or closure." (Italics in the original.). We will regard this sound, which Catford and Soviet linguists symbolize by ʔ, as an epiglottal stop. There is considerable evidence that a number of languages that are spoken in the Caucasus produce fricatives in the epiglottal region, and there seems to be no doubt that some of them, such as Chechen, have contrasting stop gestures made in the same region. Epiglottal stops have also been observed by Laufer and Condax (1981), who point out that they occur as allophones of so-called pharyngeal fricatives in Semitic languages.

Glottal stops occur in many languages. They frequently pattern with other voiceless stops (e.g. in Hawaian), making it clear that glottal gestures must be taken into consideration when discussing places of articulation that are possible for stop consonants.

Lastly we must mention stops made with two simultaneous articulatory gestures. The only well attested cases of this kind are labial velars. There may be other possibilities, combining a labial gesture with articulatory gestures involving the tip or blade of the tongue. Labial alveolars have been reported in a number of West African languages, for example in Margi, by Hoffmann (1963), Ladefoged (1968), and Newman (1977). But in all the West African languages there are both phonetic and phonological grounds for claiming that these combinations are sequences of bilabial stops followed by alveolar stops. As a result, Maddieson (1983) has suggested that it may be that "there are no human languages in which underlying labial-alveolar segments occur." This suggestion has been disputed by Catford (personal communication) who notes that from both a phonetic and a phonological point of view labial alveolar stops occur in languages of the Caucasus.

We will regard labial velars and other possible combinations of articulatory gestures as involving no additional places of articulation, and thus neeeding no further commment in this chapter. There is, however, more to be said concerning the phonetic nature of these sounds. Labial velar stops typically involve complex gestures in which the back of the tongue makes contact with the soft palate and then moves back and down during the labial closure. This produces a suction effect akin to that in clicks, in which the same sort of movement occcurs. All these gestures will be discussed in the chapter concerned with multiple gestures.

Table 2.9 A matrix giving examples of contrasts among stops and nasals. (Data from our own

	(2) Labio-dental	(3) Linguo labial	(4) Inter dental	(5) Apical dental	(6) Laminal dental	(7) Apical alveolar	(8) Laminal alveolar
(1) Bilabial	m ɱ *Teke*	p p̼ *Thenen Taut*	m n̪̟ Malayalam	p t̺̪ Temne	p t̪̻ Isoko	p t English	p t̻ Temne
(2) Labiodental		vvvvvv	vvvvvv	vvvvvv	vvvvvv	ɱ n *Teke*	vvvvvv
(3) Linguolabial			######	######	#####	p t *Thenen Taut*	######
(4) Interdental				------	------	n̪̟ n Malayalam	------
(5) Apical dental					ǀ ǂ !Xóõ	ǀ ǃ !Xóõ	t̺̪ t̻ Temne
(6) Laminal dental (Dentialveolar)						t̪̻ t Isoko	------
(7) Apical alveolar							------
(8) Laminal alveolar							
(9) Apical postalveolar (retroflex)							
(10) Laminal postalveolar (Palatoalveolar)							
(11) Sublaminal palatal (retroflex)							
(12) Palatal							
(13) Velar							
(14) Uvular							
(15) Epiglottal							

observations except in the case of italicized language names, for which the references are in the text.)

(9) Apical postalveolar	(10) Laminal postalveolar	(11) Sublaminal palatal	(12) Palatal	(13) Velar	(14) Uvular	(15) Epiglottal	(16) Glottal
b ḍ Ewe	p t̠ Nunggubuyu	p ʈ Tamil	p c Yanuwa	p k English	p q Quechua	p ʡ *Chechen*	p ʔ *Ko*
vvvvvv	ɱ n̠ *Teke*	vvvvvv	vvvvvv	ɱ ŋ *Teke*	vvvvvv	vvvvvv	vvvvvv
######	######	######	######	p k *Thenen Taut*	######	######	######
------	n̪̟ n̠ Malayalam	n̪̟ ɳ Malayalam	n̪̟ ɲ Malayalam	n̪̟ ŋ Malayalam	------	------	------
------	------	------	t̰ c *Breton*	t̰ k Temne	-----	------	------
t̪ ṭ Ewe	t̪ t̠ Nunggubuyu	t̪ ʈ Malayalam	t̪ c Malayalam	t̪ k Tamil	t̪ q Urdu	t̪ ʡ ****	t̪ ʔ *Dargi*
t ṭ Nunggubuyu	t t̠ Malayalam	t ʈ Malayalam	t c Ngwo	t k English	t q Quechua	t ʡ *Chechen*	t ʔ Ko
------	------	------	------	ț k Temne	------	------	------
	ṭ t̠ Nunggubuyu	ṭ ʈ r r r r	ṭ c Logba	ṭ g Ewe	ṭ q Urdu	ṭ ʡ ****	t ʔ *Maba*
		n̠ ɳ *Malayalam (some dialects)*	d̠ʒ c Ngwo	t̠ k Yanuwa	t̠ q Quechua	t̠ʃ ʡ *Chechen*	t̠ʃ ʔ *Dargi*
			ɳ ɲ Malayalam	ɳ ŋ Malayalam	ʈ q r r r r	ʈ ʡ r r r r	ʈ ʔ *Kuvi*
				c k *Jaqaru*	c q *Jaqaru*	c ʡ ****	c ʔ *Ko*
					k q Quechua	k ʡ *Chechen*	k ʔ *Ko*
						q ʡ ****	q ʔ *Ubykh*
							ʡ ʔ *Agul*

Place features for stops

We have now described some (we hope most) of the phonetic events that are significant in characterizing the place of articulation (the direction of movement in the articulatory gesture) of stop consonants. The next point to determine is whether we can express all these observations in terms of a phonetic theory of the kind described in the introductory chapter. Table 2.9 summarizes most of the contrasts that occur within languages among the articulatory gestures mentioned in this chapter. We have heard all these contrasts ourselves, except for those in the following languages, for which the references are as given: Agul (Magometov 1967), Breton (Bothorel 1982), Dargi (Gaprindasvili 1966), Chechen (Catford 1983), Jaqaru (Hardman 1966), Ko (Schadeberg 1981), Kuvi (Zvelebil 1970), Maba (Tucker and Bryan 1966), the dialect of Malayalam that contrasts [n̲] and [ɲ] (Mohanan and Mohanan 1984), Teke (Paulian 1975), Thenen Taut (Fox 1979), Ubykh (Vogt 1963). In one case we have gone slightly beyond the bounds of the data available to us in that our sources do not tell us whether Chechen /t/ is apical or laminal, or dental or alveolar. On the basis of what we do know of this and neighboring languages, we have said that there is a contrast between [t] and [ʔ]; but it might well be between one of the other possibilities, such as [t̪] and [ʔ]. Whichever it is, it is clear that we have not filled in too many contrasts.

If the 16 gestures specified in table 2 are all individually controllable, each of them might be expected to contrast with each of the others. This would make a total of 120 possible contrasts, of which only 69 have been observed. Of the 51 contrasts that have not been observed, 26 are associated with missing labiodentals (marked vvvvv), or missing linguolabials (marked with #####), or missing epiglottal contrasts (marked *****). However it seems clear that all of the 26 missing contrasts associated with labiodental, linguolabial, and epiglottal gestures are probably accidental gaps due to the very small number of languages that contain examples of any of these possibilities. If it had so chanced that, for example, Thenen Taut had developed a labiodental stop and Teke had developed a linguolabial stop, the gaps would have had a different distribution, dependent on the other contrasting sounds that happen to occur in these languages.

There are also three cases, marked r r r r, involving retroflex stops, with either apical postalveolar or sublaminal gestures. Judging from the description given by Emenau (1984), it is possible that the contrast between apical retroflex and sublaminal retroflex stops may actually occur in Toda. In any case Ladefoged and Bhaskararao (1983) showed that some languages use one of these possibilities and others the other, making this a reliable phonetic contrast. We conclude that the missing contrasts involving retroflex stops of either kind are also accidental gaps, due to the fact that only a comparatively small number of languages have these sounds. Further evidence to this effect is provided by the case of Kuvi. The great majority of languages with sublaminal retroflex stops belong to the Dravidian family. Contrastive glottal stops do not occur in most of these languages, so there might well have been a gap in the chart for the [ʈ] vs [ʔ] contrast. But, according to Zvelebil (1970), phonemic glottal stops do occur in Kuvi, a little known Central Dravidian language, allowing this gap to be filled in.

It is not clear whether the remaining gaps are accidental or not. These gaps, which are marked with dashed lines, are associated with the laminal interdental, apical dental and laminal alveolar gestures. Contrasts among these gestures are very rare. In our own data, laminal interdental stops do not contrast with either apical dental or laminal alveolars; and these latter two gestures contrast only in Temne and Limba. There is only limited evidence for within language contrasts among apical dental, apical alveolar and laminal dental sounds. We do not know of any within language contrasts of this kind among plosives or nasals, although Albanian seems to contrast apical dental and apical alveolar laterals (Bothorel 1970). The clearest evidence for the necessity of distinguishing between apical dental and apical alveolar sounds comes from the specification of the place of articulation in clicks. In many Khoisan languages such as !Xóõ there are four clicks, symbolized [| ! || ǂ] in which the primary articulation is in the dental or alveolar region. The data in Trail (1985) show that, at the moment just before the release of the anterior closure, [|] is an apical dental click, and [!] and [||] are apical alveolar clicks, the latter two being distinguished by [!] having a central release, and [||] having a lateral release. There is thus unambiguous evidence for a contrast between apical dental and apical alveolar sounds. The remaining click, [ǂ], is plainly laminal, with contact over a large area of the roof of the mouth, so that it is difficult to know whether it should be called dental, alveolar, denti-alveolar, or even denti-postalveolar.

Although there are only a limited number of within language contrasts in this region, phoneticians have long realized that some languages use laminal interdentals (e.g. Malayalam, at least for nasals), others use apical dentals (e.g. Breton), others use laminal dentals (e.g. French), others use apical alveolars (e.g. Isoko), and yet others use laminal alveolars (e.g. Bulgarian). From a phonetic point of view, all these possibilities have to be taken into account.

We will now consider how the 16 places of articulation listed in table 2 might be related to phonological features. We will take as our starting point the familiar feature set adopted by Chomsky and Halle (1968). They argued that a small subset of their features will account for all the contrasting gestures (or cavity shapes) that we have referred to as having different places of articulation. There have been many developments in phonology since the publication of *The Sound Pattern of English* (SPE); but these developments have usually been more concerned with formal relations among features rather than with their phonetic definitions. Clements (1985), for example, raises interesting questions but not substantial issues for the present discussion, as his terminal nodes have the same phonetic characterizations as the corresponding features in SPE, with minor additions such as the more recently established feature [Labial]. It is therefore still useful to compare the places of articulation we have been considering with the SPE system.

The relation between SPE features and our categories is as shown in table 2.10 (see Ladefoged 1982 for a similar comparison). We have left out linguolabials, as we are not sure how Chomsky and Halle would have categorized them. This classificatory system uses six binary features to distinguish 11 possible places of articulation. It relies on the feature [Distributed] to separate apical from laminal articulations, and also to distinguish bilabial from labiodental, laminal postalveolar (palatoalveolar) from retroflex articulations, and uvular (and, for fricatives, pharyngeal) from epiglottal (the latter possibilities not being explicitly distinguished by Chomsky and Halle, but providing no difficulty within their system).

The SPE system considers some of the missing potential contrasts to be motivated by theoretical considerations, rather than being just accidental gaps. Instead of considering it to be just chance that there is so little evidence for contrasts between apical dentals and apical alveolars, this system treats this gap as a theoretically impossible contrast. In order to do this it disregards the limited data from Albanian, and the clear difference of this sort among clicks, the latter presumably being considered in some way as an incidental effect of the velaric airstream mechanism. It also presumes, probably correctly, that no contrast is possible between interdentals and dentals. Given all this, the SPE system collapses our rows (4), (5) and (6), leaving the difference between, say, Temne and Limba with their apical dentals, and English with its apical alveolars, to be specified by some phonetic detail rule specifying the amount of alveolarity that each language has. Similarly the SPE system gives theoretical status to the lack of contrasts within any single language between laminal dentals and laminal alveolars. This allows our rows (6) and (8) to be collapsed, again specifying the degree of alveolarity in each language by a phonetic detail rule.

Table 2.10. An interpretation of the phonetic categories for places of stop consonants in terms of the phonological features proposed by Chomsky and Halle (1968).

	Anter.	Coron.	High	Low	Back	Distr.
Bilabial	+	-	-	-	-	+
Labiodental	+	-	-	-	-	-
Laminal interdental / Apical dental / Apical alveolar	+	+	-	-	-	-
Laminal dental / Laminal alveolar	+	+	-	-	-	+
Apical postalveolar / Sublaminal palatal (retroflex)	-	+	+	-	-	-
Laminal postalveolar (palatoalveolar)	-	+	+	-	-	+
Palatal	-	-	+	-	-	+
Velar	-	-	+	-	+	+
Uvular	-	-	-	-	+	-
Pharyngeal	-	-	-	+	+	+
Epiglottal	-	-	-	+	-	+

The next reduction inherent in the SPE system is far more problematic. We feel that it is incorrect to consider that there is no theoretical reason to maintain a difference between apical postalveolar retroflex stops and sublaminal retroflex stops. We think that this is just an accidental gap, which might be filled by contrasts in Toda or some other language yet to be described. By disregarding this possibility the SPE system collapses rows (9) and (11), considering the very different degrees of retroflexion in different languages to be a matter for a phonetic detail rule. This seems to be a dubious tactic; there is a clear phonetic distinction between the two groups of sounds, which is much larger than some small distinctions, such as those between apical alveolar and apical retroflex stops, that are used contrastively; and in any case the contrast may be present in Toda.

Many of the more theoretical problems with the SPE system have long been recognized by contemporary phonologists. Indeed, within the last part of SPE itself some of these problems are addressed by adding a theory of markedness to the feature system. Without marking conventions the SPE features are subject to the criticism that they can specify far too many possibilities. In principle the six features could specify more than five times as many gestures as are required by the theory. Furthermore, as Halle (1982) himself has pointed out, the features do not of themselves show that there are a number of mutually exclusive possibilities. Nor does the SPE system show that these possibilities are arranged in an ordered sequence, and that contrasts between many adjacent places are very rare and have to be considered as highly marked. A more highly valued theory relating phonological features and their phonetic correlates would not simply divide a phonetic continuum by a number of binary cuts, but would establish a hierarchical relationship betwen major categories that are potentially independent and subordinate categories containing sets of mutually exclusive terms. It would then be possible to use multivalued features within the lower orders of this hierarchy so as to define a notion of phonetic adjacency.

Grouping labial places of articulation so as to take into account their phonetic adjacency was proposed by Ladefoged (1971), who also suggested that "feature systems should be permitted to have a hierarchical structure". This notion was further developed by Ladefoged (1972) and Vennemann and Ladefoged (1973), who used the term 'cover features' for what we would now call tiers or higher nodes in the feature specification. The particular hierarchical arrangement required for grouping places of articulation has traditionally involved three major sub-groups, often called Labial, Lingual and Dorsal. We now suggest that phonologies will find it convenient to recognize a fourth subgroup resulting from distinguishing between Dorsal and Radical articulations; and we will also need to recognize Laryngeal gestures in that, from a phonological point of view, glottal stops often occupy a similar place within the sound pattern of a language to that occupied by stops made at other places of articulation. Table 2.11 shows the relation between these five general articulatory categories and the 17 places of articulation that we have been discussing.

We are well aware that simply naming groups such as those shown in table 2.11 is insufficient; the particular subgroups must be expressed and justified within a proper formalism. Sagey (1986) has now done much of this for a very similar hierarchy to that shown in table 2.11. Sagey uses the term Coronal for our Lingual, and she places what we call Radical articulations within the Dorsal category. She also uses the well known SPE features for the terminal nodes, with some modifications to the phonetic definitions, the most important of which involve the restriction of the domain of some of the features. Thus she restricts the terms Anterior - Non-anterior and Distributed - Non-distributed (which we, following more traditional usage, have called Laminal - Apical) to Coronal (our Lingual) sounds. She ends up with a specification of places of articulation (the place node in the feature hierarchy, in her terminology) that is very similar to that shown in table 2.11, as may be seen by reference to the parenthesized terms.

Table 2.11 A hierarchical feature system for places of articulation. The terms in parentheses and the dotted lines are not part of our theory of phonetics, but are added so as to show the relation between our system and that of Chomsky and Halle (1968) as modified by Sagey (1986).

Labial			1	Bilabial
			2	Labiodental
Lingual (Coronal)	1. Laminal (Distributed)	(Anterior)	1	Linguolabial
			2	Interdental
			3	Laminal dental
			4	Laminal alveolar
		(Non-anterior)	5	Laminal postalveolar
	2. Apical (Non-distributed)	(Anterior)	1	Apical dental
			2	Apical alveolar
		(Non-anterior)	3	Apical postalveolar
	3. Sublaminal		1	Sublaminal palatal
Dorsal			1	Palatal
			2	Velar
			3	Uvular
Radical			1	Pharyngeal
			2	Epiglottal
Laryngeal			1	Glottal

Sagey does not consider the notion of phonetic adjacency, a point that is implicit in the numbering system in table 2.11. As we noted above, a feature theory should allow us to formalize our expectations concerning which contrasts are likely to occur most frequently as opposed to those that are rarely observed, and must be regarded as highly marked within a universal grammar. The numbers for the elements in the subgroups provide a way of doing this. They indicate that these elements form ordered sets within each category. The notion of phonetic adjacency thus becomes part of the theory, making it formally possible to state as a principle that contrasts between adjacently numbered places are highly marked. Note that, because the numbering is peculiar to each subgroup, contrasts between what appear in the table as adjacent members in the list of places of articulation, but which are actually in different subgroups (e.g. sublaminal palatal and palatal) are not highly marked; only contrasts within groups (e.g. palatal vs. velar vs. uvular) are formally marked. Note also that this theory requires a non-binary classification of phonological elements. This is a point that is largely irrelevant in a hierarchical system that is clearly not binary at higher levels; but it is the cause of our not using the term Anterior in the restricted way suggested by Sagey (1986).

We must now consider the question we asked earlier, namely, are the 17 places of articulation we have been discussing discrete categories or simply convenient fictions useful for expository purposes? Putting this another way we can ask whether there is a fixed set of language independent phonetic categories for places of articulation, or whether there is only a phonetic space, definable in terms of general phonetic parameters? The answer is somewhere between these two extremes. The possibilities listed in the left hand column of table 2.11 are clearly discrete categories; but the numbered elements in the right hand column are more like the modal possibilities within a continuous range.

The discrete nature of the items in the left hand column follows Halle's insight in which the articulators that can act independently are separately specified (Halle 1982). We have extended this notion so as to allow a distinction between Dorsal and Radical articulations, as it is quite possible for epiglottal articulations to occur simultaneously with velar articulations. We have also added Laryngeal because of the similarity between glottal stops and stops made at other places of articulation, and because glottal stops can co-occur with all the other possibilities. Chapter 3 provides further explication of the relationship between sounds that are characterized as Laryngeal within the place hierarchy and similar gestures in which the glottal activity is characterized as being part of a particular phonation type.

We regard the numbered items in the right hand column as simply labels for commonly found articulatory possibilities within a continuous range. These items are in many senses the modal articulations. Within the Labial range, articulations are typically bilabial or labiodental. In the case of stops, simple mechanical, physiological, reasons require a bilabial gesture. But for fricatives in which the physiology of the vocal tract allows either a bilabial or labiodental gesture, the usual articulation is often somewhere between the two. The point of articulation for most speakers of English depends on their individual physiological characteristics. It is often very hard upper teeth, or the upper lip, or both. In other languages, such as Ewe, in which there is a phonological contrast between these two possibilities, bilabial and labiodental fricatives are clearly distinguished.

Within the Lingual articulations, there is a range of both laminal and apical articulations. We have not ourselves observed linguolabial gestures, but as far as we can infer from the literature and our own production of these sounds, they can be made with varying degrees of tongue protrusion, involving an articulation between the upper surface of the tip or blade of the tongue and the upper teeth. We would in fact be surprised if some native speakers of languages using these sounds did not use gestures that were virtually indistinguishable from some of the interdental gestures that we have observed in Malayalam, in which the interdental nasal involves not only tongue protrusion between the teeth but also incidental tongue contact with the upper lip. Given this it would seem that there is not a clear cut distinction between linguolabial and interdental articulations. Similarly the terms interdental, dental, alveolar, and postalveolar all refer to points within a continuum rather than discrete locations. When examining the results of any palatographic investigation, it rapidly becomes obvious that the dental region is not clearly separated from the alveolar region; the upper edges of the front teeth are curved, and blend into the alveolar surface. The location of the alveolar ridge itself is also hard to define; many people do not have protruberances of the kind seen in textbook illustrations. Dorsal articulations all involve gestures in which the body of the tongue is raised. But some languages (e.g. Yanuwa, as described by Ladefoged 1983b) may have an articulation that is between what is usually called palatal and what is usually called velar; again there is a continuous range of possible articulations within this category. Even among Radical sounds there are various phonetic possibilities exemplified among different dialects of Arabic. We have observed some so-called pharyngeal fricatives in which the constriction is in the upper part of the pharynx, and others in which it can be associated with epiglottal gestures.

In the case of Lingual articulations there are two interacting continua, in that not only is there a range of possibilities for the upper articulator, but also the part of the tongue involved may be anywhere from the underside of the blade of the tongue to somewhere fairly far back on the upper surface of the blade. It might seem as if it should be comparatively simple to determine at least an apical point within this range. But investigators (e.g. Bladon and Nolan, 1977) who have tried to categorize x-ray data on articulations have reported that the apical-laminal distinction is often by no means self evident. In searching the literature in order to find x-ray tracings representing these different possibilities we have found similar difficulties.

In many cases certain points within an articulatory range are favored in the interest of making the best match between the required acoustic structure and the possible articulatory gestures. This is the basic tenet of the quantal theory proposed by Stevens (1972). A related concept that has not yet been fully worked out is that some gestures are easier to make than others for purely anatomical reasons. Considerations of this kind probably account for the comparative lack of palatal sounds among the world's languages. The quantal theory and some ease of articulation principle together account for the occurrence of the modal articulations listed in table 1.

Linguistic considerations sometimes account for the appearance of non-modal places of articulation. The situation is somewhat analogous to that described by Keating (1984) for Voice Onset Time. Keating notes that within the continuum of possible VOTs languages choose among three modal possibilities: voiced, voiceless unaspirated, and aspirated. She also notes that there is a polarization principle by which languages keep adjacent pairs within these possibilities further apart. This polarization principle causes the second possibility, voiceless unaspirated stops, to be realized in two different ways. If a language contrasts a voiced stop series with one other stop series then that second series will probably be slightly aspirated; whereas, if a language contrasts an aspirated stop series with one other stop series, the second series will probably be slightly voiced. We can point to the same polarization principle in the realization of different places of articulation. In Ewe the fact that there is a contrasting bilabial fricative results in the labiodental fricative being made with a more extreme articulation, in which the upper lip is actively raised. In Yanuwa, the use of dorsal articulations at non-modal places may be a response to the linguistic pressures associated with contrasting seven places of articulation. Without these systematic linguistic pressures, modal places of articulation are likely to prevail; but when there are two similar contrasting gestures, more distinct articulations may occur.

There are two distinct claims made by the theory of places of articulation that we are proposing. The first is that places of articulation are organized in a hierarchy such that languages are likely to use contrasts that can be specified by non-terminal nodes, leaving the precise specification of articulations as a language particular matter that can be handled within lower level phonetic rules. Of course this is not always the case; and the mechanism is there to account for highly marked contrasts. Ewe, for example, contrasts bilabial and labiodental fricatives. But the theory makes plain by the non-adjacency convention that this is an unusual situation, and that most languages use simply the major categories in the first two columns of table 2.11. Secondly we suggest that, within each of the ranges defined by the major categories, there are modal articulations that occur for non-linguistic, physical phonetic reasons. The theory thus provides for an appropriate relationship between phonological considerations and observed phonetic facts.

As we noted in the Preface, our main concern in this book is to describe the distinctive phonetic events that occur in the languages of the world. We want to describe the phonetic data that a phonological theory has to take into account. Accordingly we will not at this time provide further phonological justification for the feature hierarchy given in table 2.11. We are simply trying to lay the foundation for a more complete discussion of the relation between phonetic events and phonological structure.

4.

Nasals and Nasalized Consonants

This chapter describes the types of nasal and nasalized consonants that occur in the languages of the world. It is also concerned with some general questions concerning the timing relationship between oral articulation and velic function. We will divide the discussion into three principal sections; 4.1 on purely nasal consonants, 4.2 on the analysis of consonant sequences that are partly nasal (that is, for part of their duration they are nasal and for part of their duration they are oral), and 4.3 on nasalized consonants (where nasal airflow accompanies oral airflow). A final section discusses the featural representation of nasals and nasalized consonants.

4.1. Nasals

A nasal consonant is one in which the velum is lowered and there is a closure in the oral cavity somewhere in front of the velic opening. Hence, air from the lungs is directed out through the nasal passage alone. Note that what we call simply nasals are called nasal stops by some linguists. We avoid this phrase, preferring to reserve the term 'stop' for sounds in which there is a complete interruption of air flow. Ingressive nasals can be produced but they are not known to occur in human languages. In principle, nasal segments could also be produced using a glottalic airstream, but we do not know of any language which uses such sounds; so-called glottalic nasals are nasals produced with a laryngeal constriction, but with pulmonic air. As noted in chapter 2, nasals occur at a subset of the places of articulation used for stops - the most retracted possible nasal is a uvular one, since with a closure in the pharyngeal or glottal areas it is not possible for air to pass into the nasal cavity. Symbols for nasals at all of the sufficiently forward places of articulation were provided in table 2.1, and examples of many of the contrasts in place of articulation between nasals are included in tables 2.2, 2.5 and 2.6. Spectrograms of the six contrasting nasals in Wangurri are given in figure 2.9 and, in this chapter, nasals at four different places in Burmese are illustrated in figure 4.3 below.

Nasals have an articulatory similarity to stops by virtue of their oral closure, but in other respects they are similar to approximants. This is because there is an uninterrupted outward flow of air that does not pass through a constriction sufficiently narrow to produce local turbulence. It is quite possible to narrow the velic opening so that friction is produced (while maintaining an oral closure) but, as far as we know, languages do not contrast nasals which vary in the degree of velic opening in this way. Pike (1943) also noted that 'frictionalized nasals' can be produced by making a forward oral closure and narrowing the pharynx sufficiently to create turbulence before the air enters the nasal passage. Again we do not know of any linguistic use of this possibility. So distinctions of degree of stricture (stop, fricative, approximant) are irrelevant for nasals; rather, 'nasal' is a term which is mutually exclusive with these strictural categories.

It has, however, been suggested that nasals can differ in degree of velic opening without involving friction in the contrast. In many Austronesian languages, nasals occur alone and in nasal + stop sequences (frequently analyzed as prenasalized units). Commonly, vowels are allophonically nasalized after nasals in these languages, but are oral after the nasal + stop elements. In a number of languages of Indonesia and dialects of Malay a special development has occurred which results in the loss of the stop component in the nasal + stop sequences while preserving the oral character of the following vowels. In at least some cases these newly developed nasals remain phonetically distinguishable from the original plain nasals, as well as having distinct phonological characteristics. Durie (1985) reports that in Acehnese they have a lesser rate of air-flow through the nose than the plain nasals. (They also have a longer duration.) It is as if the gesture of raising the velum preparatory to initiating the oral stop component of the earlier sequence remains, but now only has the effect of reducing the volume of air-flow through the nose, since it is not completed before the oral articulation is released. If this distinction between the width of the velic opening in the new and the original nasals is inherent, then open and close approximation of the velic distinguishes between types of nasals, i. e. there is a difference of manner of articulation. This is essentially the way that Catford (1977a:139-140) interprets the Acehnese situation, distinguishing between 'lightly nasal' and 'heavily nasal' nasal consonants with controlled articulatory differences in the velic aperture.

There is, however, another possibility and that is that in order to produce the required phonological contrast of oral and nasal vowel after a nasal which the new phonology requires, a start must be made on the velic closure during the nasal to avoid nasalization spreading to the vowel when an oral vowel follows. In this view the measured difference between the newly derived and original nasals is a coarticulatory effect. Data from other languages where oral and nasal vowels are in contrast after nasal consonants, such as French, lend some plausibility to this idea. In a cineradiographic study of a Parisian French speaker, Rochette (1973) finds that the velum typically doesn't reach such a low position in a nasal preceding an oral vowel as it does in one preceding a nasal vowel, and that it has usually been raised most of the way towards its maximum height before the release of the oral closure for the nasal occurs. Measurements of velopharyngeal width from a fiberscopic study of a Swiss French speaker (Benguerel et al. 1977) indicate that there is a considerably smaller maximum opening of the velic aperture for the nasal in the syllable [na] than for the nasal in the syllable [nã], and that the duration of the opening gesture is also substantially shorter.

The newly derived nasals in Acehnese and other languages mentioned by Durie (1985), including those misleadingly labeled 'implosive nasals' in Rejang by Coady and McGinn (1984), could be different from the older nasal segments in these languages simply because they are followed by oral vowels. A more limited velic opening gesture for the preceding nasal is required to produce a following vowel that is oral. In any case, all descriptions agree on the fact that the main perceptual cue to which kind of nasal is involved is the presence or absence of nasalization on the following vowel.

Given that this is so, the measurable differences in the nasals seem to reflect a coarticulatory phenomenon like that which has been observed in nasals before oral and nasal vowels in French. At this time we continue to believe that no linguistically distinctive use is made of nasals which differ in manner of articulation of the velum.

Phonation types in nasals

In the great majority of languages all the nasal segments are produced with modal vocal cord vibration. However, a number of languages do employ nasals with different phonatory settings. In addition to modally voiced nasals, nasals occur breathy voiced, laryngealized, and voiceless. We do not know of a language with four series of nasals differing in phonation type, but several Southeast Asian and North American languages have three. Examples from Klamath exemplifying modally voiced, voiceless and laryngealized nasals are given in Table 4.1.

Table 4.1. Klamath Nasals (Barker 1964)

	bilabial		alveolar	
voiced	gama	'grinds'	nis	'me'
voiceless	q'im̥atʃ	'ant'	n̥as	'one'
laryngealized	jam̰a	'admires'	n̰at'a	'Wilson snipe'

More commonly, a language has only one series of nasals in addition to the modally voiced ones; this second series being either breathy voiced (Hindi, Marathi, Newari), or laryngealized (e.g. Kwakw'ala, Stieng, Nambiquara) or voiceless (Burmese, Hmong, Iaai, Kwanyama). Words exemplifying these phonation contrasts among nasals in Hindi (examples from Kelkar 1968), Kwakw'ala (examples from Grubb 1977) and Burmese are given in Table 4.2.

Usually every voiced nasal has a corresponding nasal in these other series, although in some languages the voiceless, breathy or laryngealized nasal series has fewer members than the voiced series. For example, !Xu (Snyman 1975) has plain voiced, laryngealized and breathy voiced nasals at the bilabial place of articulation, but only voiced nasals at the alveolar and velar places of articulation. Jino (Gai 1981) has voiced and voiceless velar nasals but only voiced bilabial, alveolar and palatal nasals.

Spectrograms illustrating the modally voiced and breathy nasals of Hindi are given in figure 4.1. Dixit (1975) has studied this contrast in detail in his own speech. He showed that the breathy voiced nasals (which he calls 'aspirated nasals') have a shorter oral closure duration than their modally voiced counterparts. After the closure is formed, the initial portion of a breathy voiced nasal has modal voicing. The glottal opening gesture for breathy voice starts in the middle of the closure period some 40 milliseconds before oral release. The peak of this glottal opening gesture occurs 30-40ms after oral

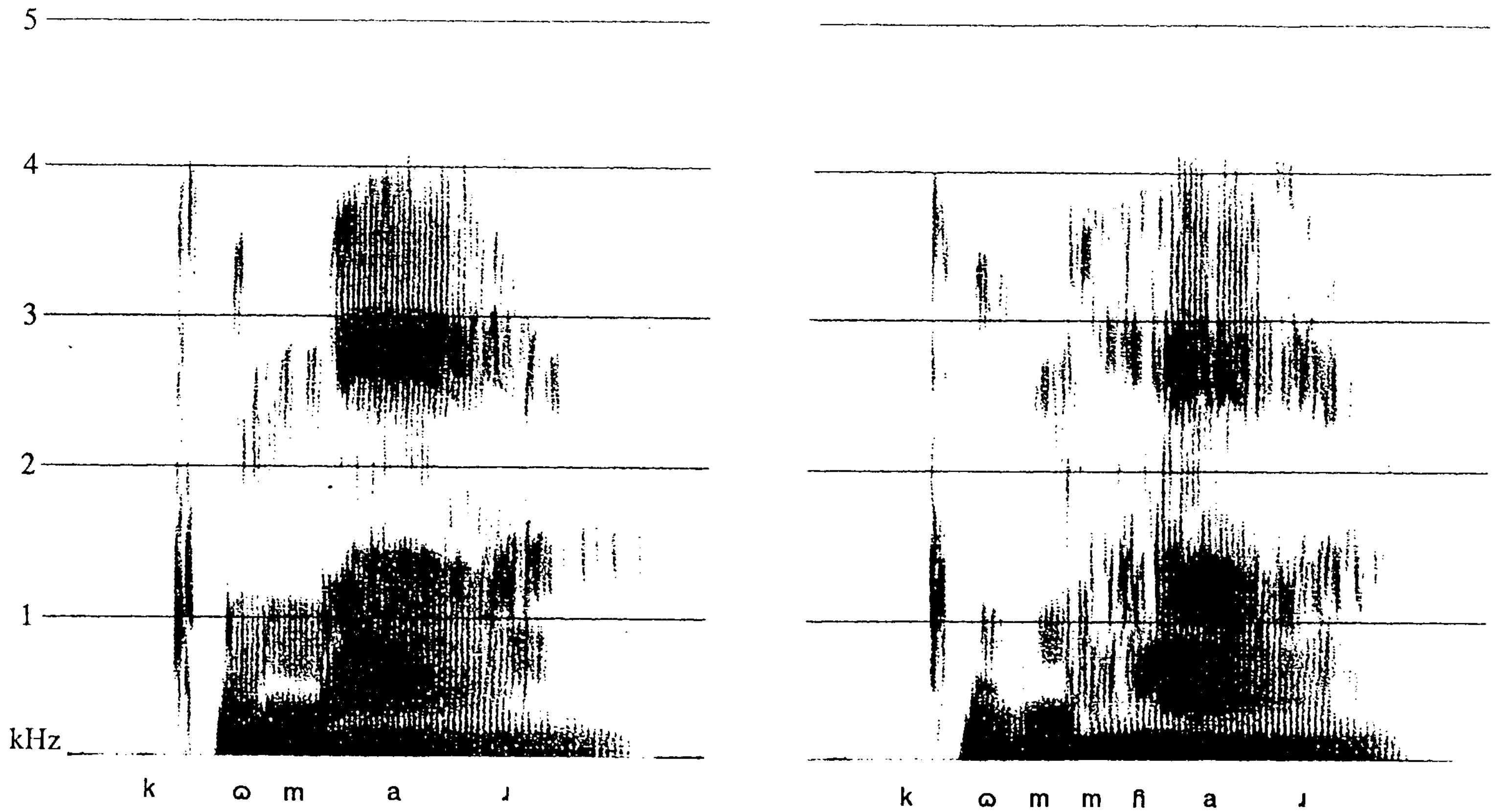


Figure 4.1 Spectrograms illustrating (a) modally and (b) breathy voiced nasals in Hindi.

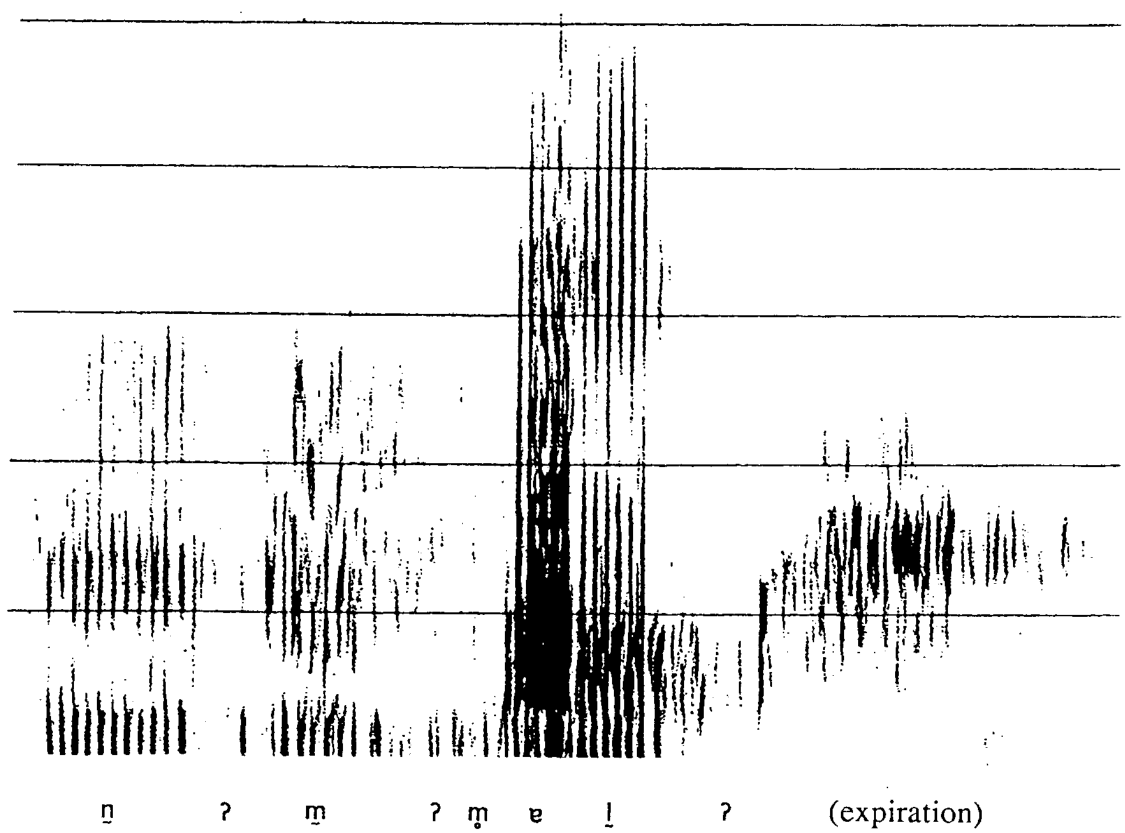


Figure 4.2 Spectrogram of the Columbian Salish word /n̰m̰mal̰/ 'lukewarm', containing two laryngealized nasals.

release, and 80-90ms of 'voiced aspiration' is observed at the onset of the vowel. Vocal cord vibration continues throughout the duration of the glottal gesture. Our observations generally agree with the pattern that Dixit reports. In the breathy nasal in figure 4.1 a short period of modal voicing occurs at the beginning of the nasal before breathiness begins. It is difficult to determine the time of oral release but the duration of breathy voicing is about 100ms in total and the sequence is voiced throughout. Oral and glottal gestures for intervocalic breathy voiced nasals in Hindi are thus coordinated in a similar way to those for breathy voiced stops, as discussed in chapter 3, but we do not have enough information on other languages to know if this timing pattern is typical. There do seem to be differences between languages in voicing and in the degree of breathiness that accompanies breathy nasals. For example, Marathi breathy nasals sound more breathy than those in Newari (Ladefoged 1983a), and in Lianchang Yi breathy nasals in initial position have a voiceless onset which extends for about one quarter to one third of their duration.

Table 4.2. Examples of contrasts of voiced with breathy, laryngealized and voiceless nasals.

(a) Hindi voiced and breathy voiced nasals

	bilabial		dental	
voiced	kʊmar	'boy'	sʊn̪ar	'goldsmith'
breathy voiced	kʊm̤ar	'potter'	dʒʊn̪̤ai	'moonlight'

(b) Kwakw'ala voiced and laryngealized nasals

	bilabial		alveolar	
voiced	mixa	'sleeping'	naka	'drinking'
laryngealized	m̰um̰uxdi	'balsam tree'	n̰ala	'day'

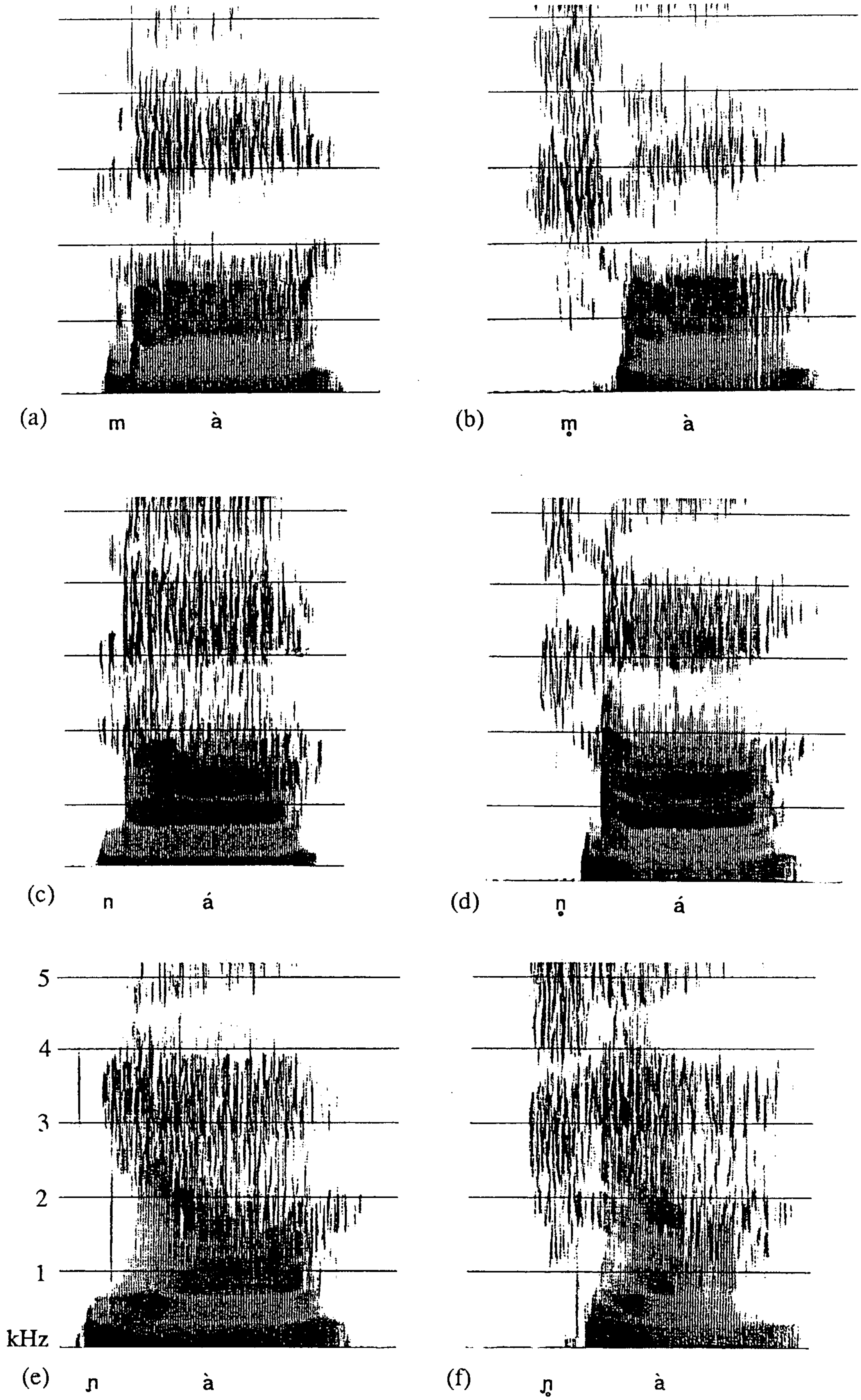
(c) Burmese voiced and voiceless nasals

	bilabial	alveolar	palatal	velar	labialized alveolar
voiced	mà	ná	ɲà	ŋà	nʷà
	'hard'	'pain'	'right'	'fish'	'cow'
voiceless	m̥à	n̥á	ɲ̥à	ŋ̊à	n̥ʷà
	'notice'	'nose'	'considerate'	'borrow'	'peel'

We have heard laryngealized nasals (e.g. in Kwakw'ala) in which the timing of the laryngeal constriction gesture seems to be centered at the same point in time as the oral closure, but in other languages laryngealization in nasals only occurs with a preceding or following glottal closure. Figure 4.2 shows an utterance from Columbian Salish that includes, phonetically speaking, two syllabic laryngealized nasals (and also a voiceless one). Note that the first of the laryngealized nasals shows strong, almost periodic, low frequency pulses, while the second appears to have quite turbulent airflow. In both cases, the nasal is followed by a glottal stop. Phonologically speaking, in this language either the laryngealization of the nasals or the presence of the glottal stop could be regarded as redundant, or the sequence could be labeled a 'postglottalized' nasal. By contrast, Traill (1985) reports that the glottalized nasals of !Xoo "are invariably pronounced with a glottal stop preceding the nasal." He also notes that the duration of the voiced portion of the nasal in this position is shorter than it is in the plain nasals. There is obviously room for further language-specific variation in the way that these oral and laryngeal gestures are related to each other, but the documentation is not yet very extensive.

Voiceless nasal segments are usually longer than voiced nasals, at least in the languages in which we have heard this contrast, such as Burmese and Hmong. They are audible principally because of the noise created by a relatively high volume of air flowing through the rather constricted passages of the nose. Onset of voicing following a voiceless nasal usually occurs a few milliseconds before oral release or, at the latest, immediately on release of the oral closure (Ladefoged 1971, Ohala 1975, Maddieson 1984b, Dantsuji 1984). Spectrograms of all the Burmese words in table 4.2 are given in Figure 4.3. In this particular set of data, quite considerable anticipation of voicing (about 85 ms) occurs with the voiceless alveolar nasal. In the other words with voiceless nasals the onset of voicing only just precedes the nasal release.

Ohala (1975) suggests that an early onset of voicing is necessary to make a voiceless nasal segment perceptible, and especially to distinguish between voiceless nasals with different places of articulation by providing a more audible consonantal transition to the following vowel. In truth, the noise portions of voiceless nasals do not differ greatly according to place of articulation, though there are some indications that bilabials may be distinguishable from those made at other places because of greater energy in the lower frequency range (Maddieson 1983, Dantsuji 1984, and see figure 4.3). But voiceless nasals with an early onset of voicing may not be the only type to occur. The term 'aspirated nasal' is also sometimes encountered in connection with voiceless nasals, e.g. in Manley's account of Sre (Manley 1972) which is said to have bilabial, alveolar and palatal aspirated nasals. In this language we suspect that voiceless nasals of the familiar type were described in this fashion in order to draw attention to a parallel between voiceless nasals and aspirated stops in the phonology. But it has been suggested that truly aspirated nasals, i.e. voiceless nasals in which voicing onset is delayed for some time after the oral release occurs, might also be found. Dai (1985) draws a distinction between voiceless and aspirated nasals; both types having voicelessness during the period of oral closure, but the aspirated type being followed by aspiration at the onset of the vowel. He says that the voiceless nasals of Achang have 'slight aspiration'; as such, they are neither exactly like simple voiceless nasals nor like aspirated nasals. He does not exemplify a language with what he would consider fully


(a) m à
(b) m̥ à
(c) n á
(d) n̥ á
5
4
3
2
1
kHz
(e) ɲ à
(f) ɲ̊ à

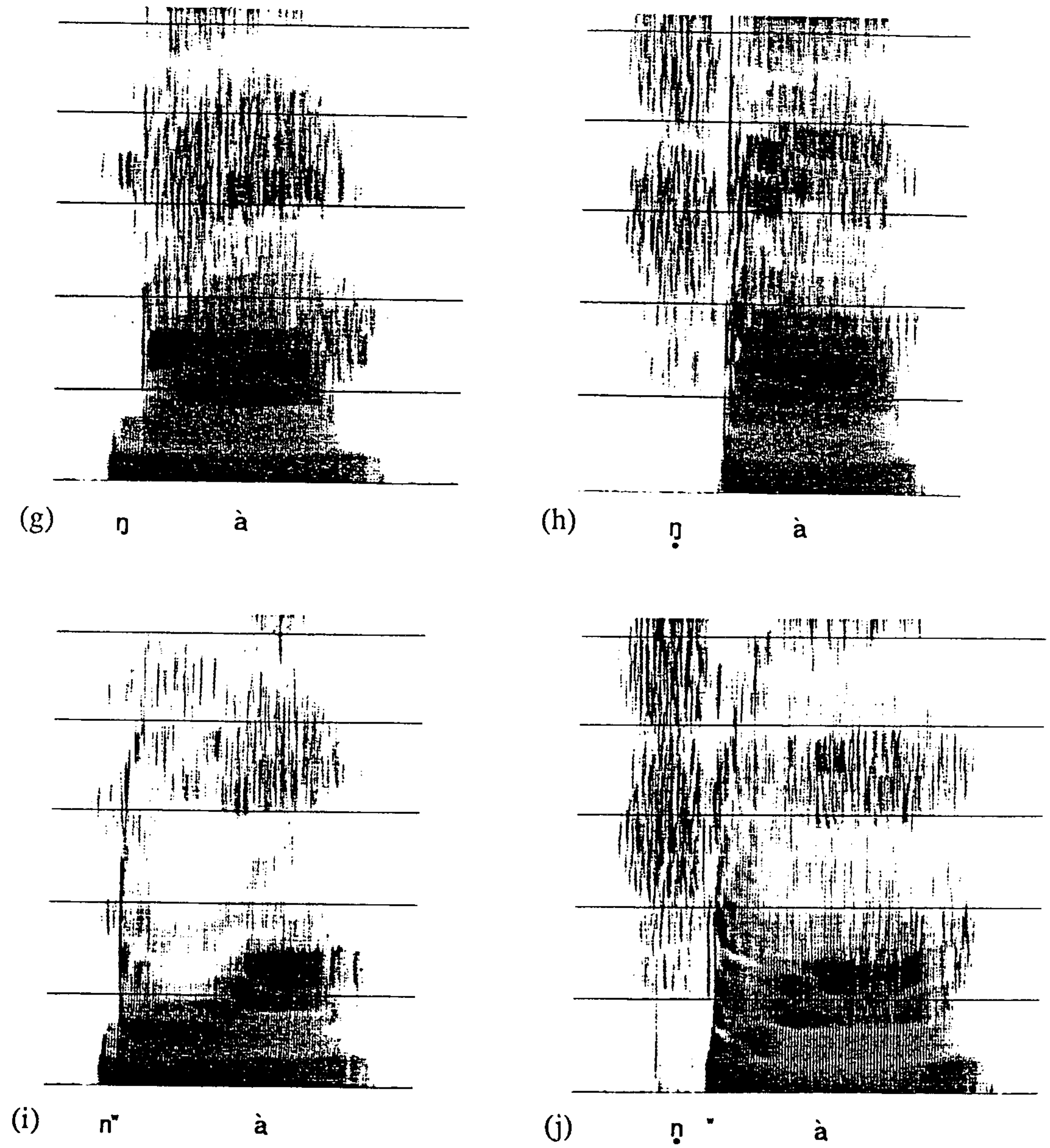


Figure 4.3 Spectrograms illustrating 5 pairs of Burmese voiced and voiceless nasals. The words are those listed in table 4.2

aspirated voiceless nasals, and we do not know of one, but if the description of Achang is correct then this is nonetheless a language in which the usual early onset of voicing after a voiceless nasal does not occur.

Acoustic structure of voiced nasals.

As noted above, nasals are most frequently modally voiced. Voiced nasals are perceptually quite distinct from other speech sounds. The steady state portion of a voiced nasal consonant is characterized acoustically by a low frequency first formant with a higher intensity than the other formants, a zero (or antiformant) due to the acoustic coupling of the oral cavity, and a set of weak higher formants (Fujimura 1962, Recasens 1983). The overall amplitude of voiced nasals is weak. The frequency of the first formant and the zero are both higher the closer the oral articulation is to the uvular region. The first formant is rising in relation to the decreasing size of the pharyngeal cavity as the tongue is positioned further back, and/or the size of the velic aperture itself which is narrower when the back of the tongue is raised. The zero rises in relation to the decreasing size of the oral cavity in front of the nasal escape passage. There have been few studies of the acoustic distinctions between nasals in natural languages. However, Recasens (1983) provides some acoustic data on nasals in Catalan. Means of the first nasal formant from word-final nasals for 13 Catalan speakers are given in Table 4.3. His estimates of the nasal zero frequency for one of these speakers are also reported.

Table 4.3. Principal acoustic features of Catalan nasals.

	m	n	ɲ	ŋ
First nasal formant	250	280	290	300
Nasal zero	(not given)	1780	2650	3700

Despite these acoustic differences, nasals with different places of articulation are poorly discriminable one from another on the basis of the voiced steady state portion isolated from the transitions which might precede or follow it (Malecot 1956, Nord 1976). Coarticulation with adjacent vowels also may have a strong influence on the perception of place of articulation for nasals (Zee 1981, Kitazawa & Doshita 1984). In particular, these studies suggest that high front vowels present an environment in which bilabial nasals are heard as if produced with a further back articulation. This effect may have contributed to the change of Classical Latin / m / to / n / in Old French in monosyllabic words, such as *rem* --> *rien, meum* ---> *mien* (final nasals were lost except in monosyllables).

4.2. Partially nasal consonants

Since the raising or lowering of the velum is independent of the movements of (most of) the oral articulators, an essentially static position of these articulators can be maintained while the position of the velum is changed. In this section we will discuss the existence of sounds which could be described as being partially nasal, that is, the velic position is changed during their production so that for part of their duration they are nasal and for part of their duration they are oral.

Prenasalization

The similarity in the mode of production between plosives and nasals results in a connection between nasals and stops in the phonology of many languages. In many cases a sequence of a nasal and a stop must be homorganic; for example, in English, nasal + stop sequences within a morpheme must be homorganic. In such a sequence the nasal portion is terminated and the stop initiated simply by raising the velum; a change in laryngeal setting may also occur. It has often been argued that similar gestural sequences in some languages should be treated as unitary segments, particularly if they occur in syllable-initial position. In this case, these segments are known as prenasalized stops, and are customarily notated by a superscript nasal symbol preceding the stop symbol, i.e. as / ^{m}b, ^{n}d, ^{ŋ}g / etc. We are here concerned with the question of whether phoneticians should distinguish between prenasalized stops and nasal + stop sequences. The discussion can also be taken to apply to prenasalized affricates and fricatives, but for convenience we will confine our examples to stops.

On the face of it, it would seem that we need to make such a distinction, given that there are reported to be languages which distinguish between prenasalized stops and nasal + stop sequences. One frequently cited example is Sinhala (Jones 1950, Feinstein 1979). The contrast referred to this way is illustrated by pairs of examples such as the words normally cited as / landa / 'thicket' and / la^{n}da / 'blind'. Spectrograms of these words are provided in figure 4.4. We measured the duration of the interval from the onset of the oral closure for the nasal to the burst of the stop in several such pairs in recordings of two Sinhala speakers. For both speakers the mean duration of this interval in the so-called prenasalized stops was close to 100 ms. For one speaker the contrasting sequence was twice as long, and for the second closer to three times as long, 275 ms. The additional duration is added in the nasal portion, resulting in a nasal of comparable duration to a geminate nasal, as may be seen from the Sinhala examples of single and geminate nasals in figure 4.5. Note also that the 'prenasalized stop' in / la^{n}da / is of comparable duration to nasal + stop durations in other languages, such as English, where word-medial nasal + stop clusters have durations in the range 90-80ms according to Vatikiotis-Bateson (1984). On a phonetic basis at least, this contrast in Sinhala is more appropriately described as a contrast of single versus geminate nasals followed by stops, that is [mb, nd] vs [mmb, nnd], etc. The phonological difference between these is principally that the geminate nasals are heterosyllabic, but the single nasal + stop sequences form a syllable onset (Cairns & Feinstein 1982).

There is a similar contrast in Fula, but whereas in Sinhala nasal + stop elements only occur

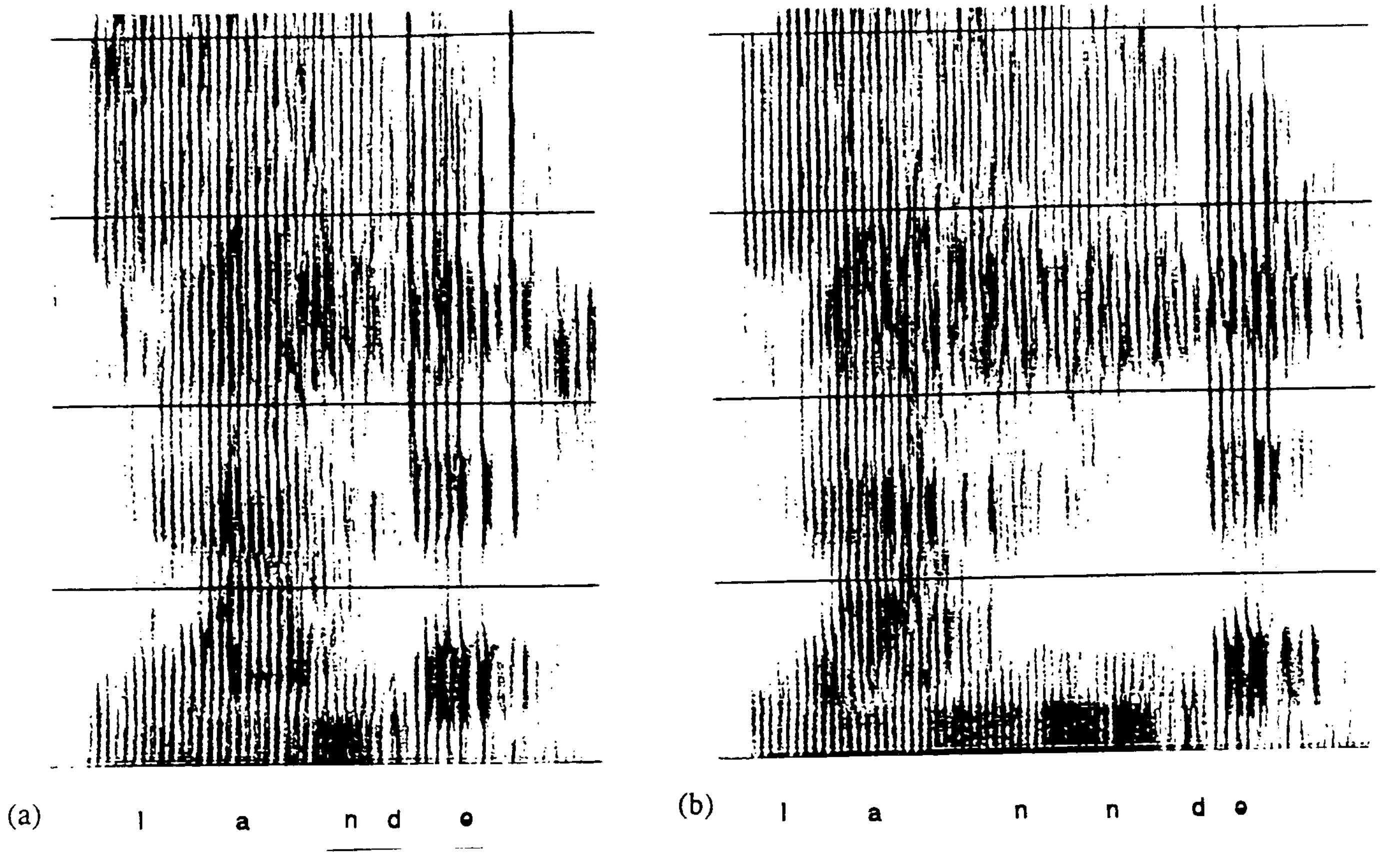


Figure 4.4 Spectrograms of Sinhalese words contrasting (a) nasal + stop sequence /landa/ 'thicket' and (b) 'prenasalized stop' /la^{n}da/ 'blind'.

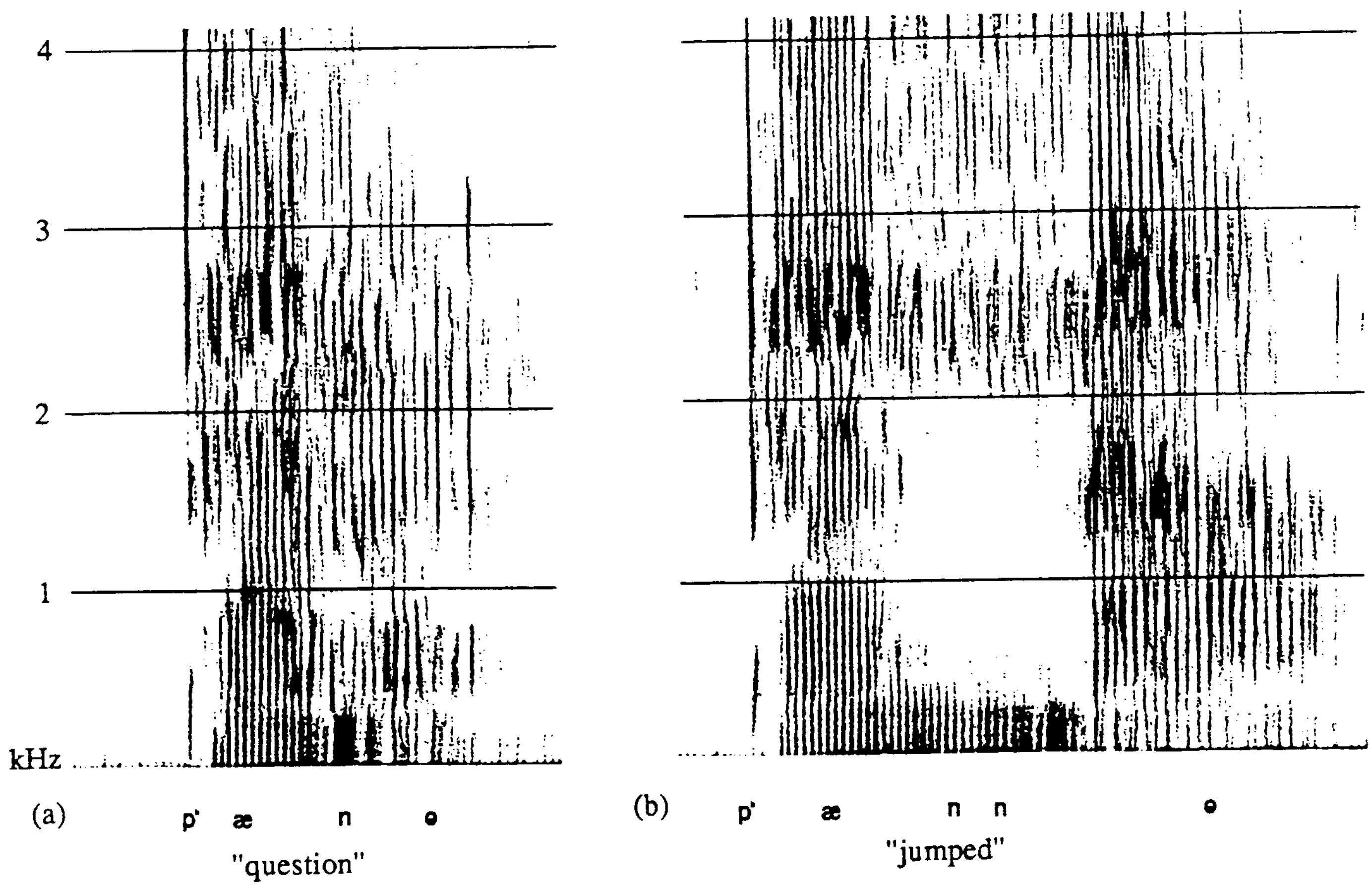


Figure 4.5. Spectrograms of words illustrating (a) single and (b) geminate nasals in Sinhalese.

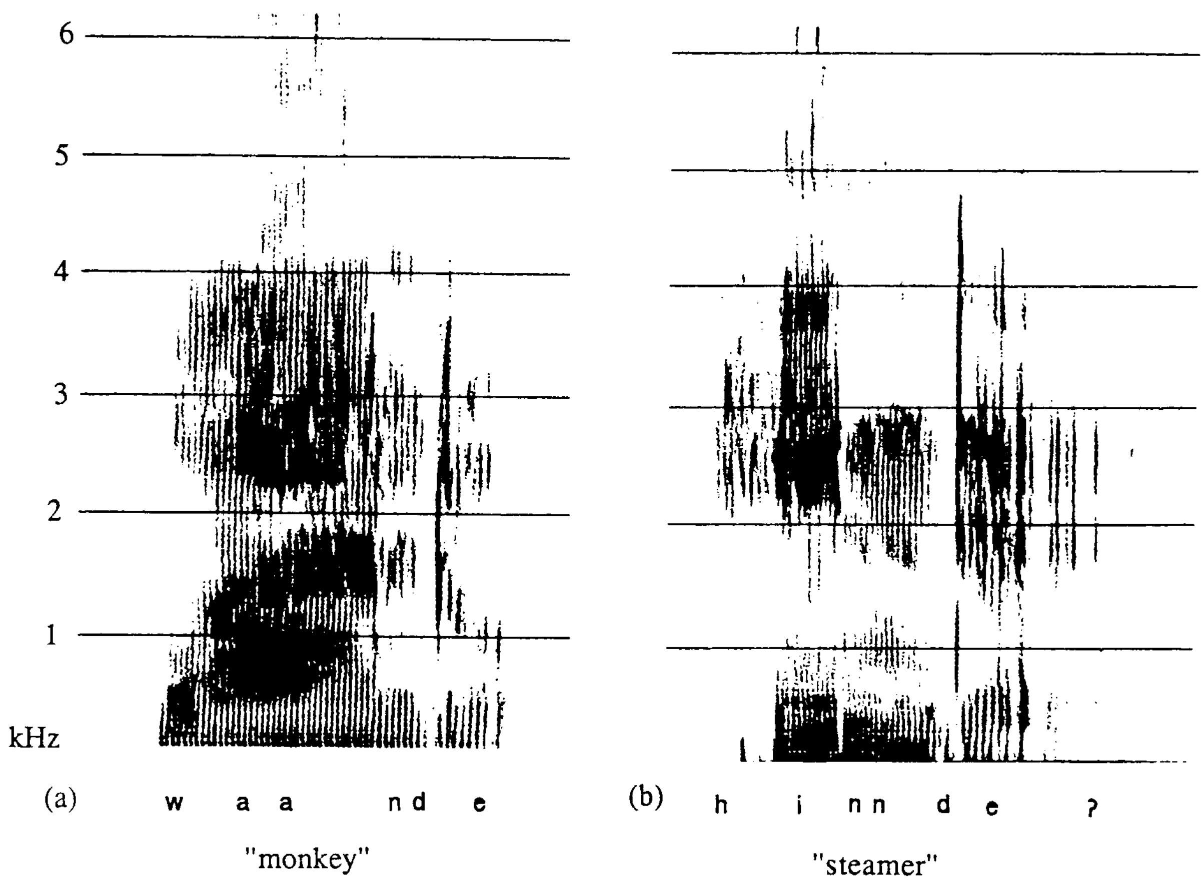


Figure 4.6. Spectrograms illustrating (a) 'prenasalized stop' and (b) nasal+stop in Fula.

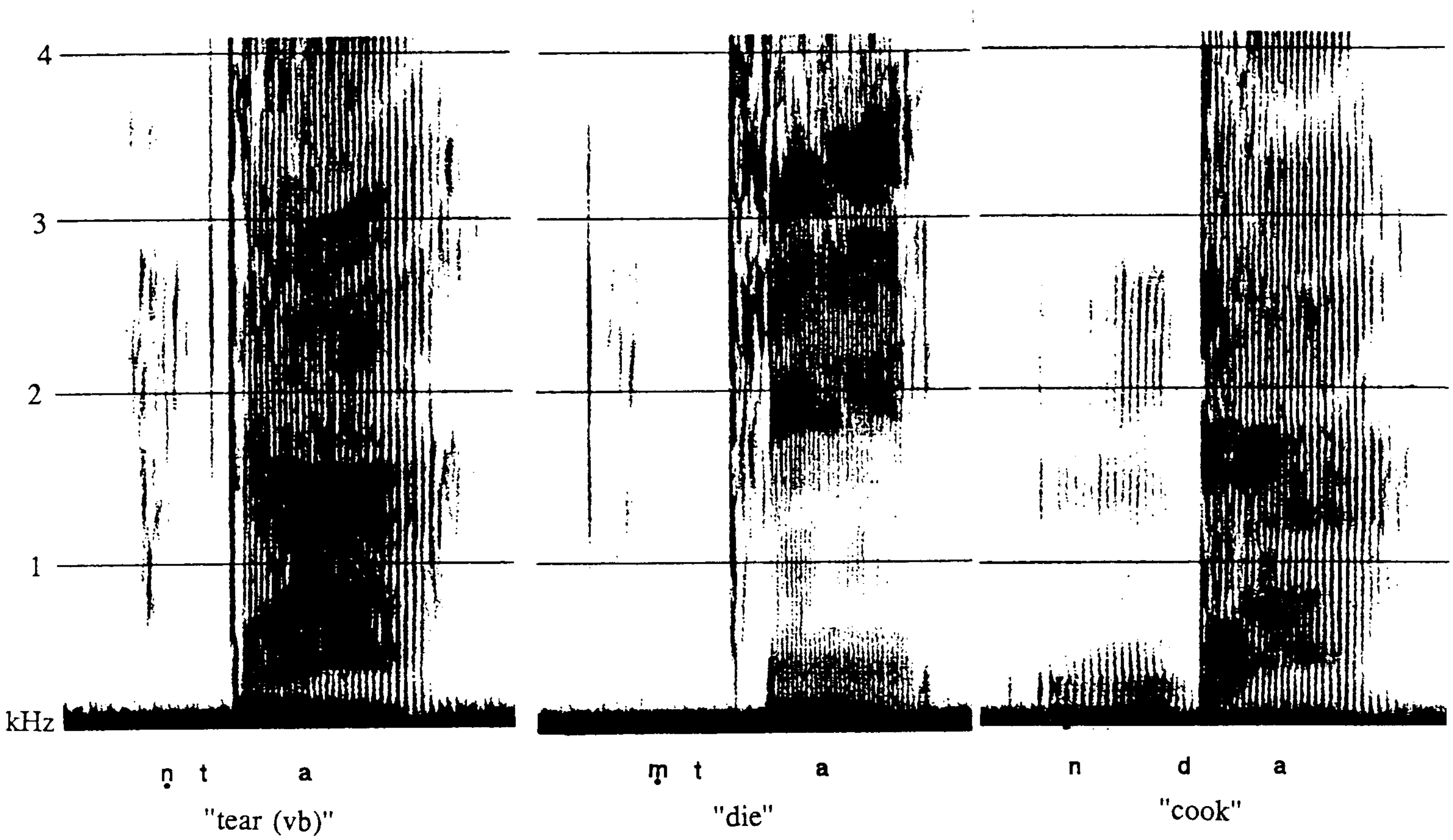


Figure 4.7 Spectrograms illustrating voicing assimilation in homorganic and heterorganic nasal + stop sequences in Bura.

word-internally, Fula prenasalized stops may appear word-initially. However, the longer nasal + stop sequence does not occur in initial position. Fula examples are illustrated in Figure 4.6. As in Sinhala, we feel that the phonetic difference between these examples is best described as one between single and geminate nasals preceding a homorganic stop. The phonological patterns of the language certainly support such an analysis: for example, when a suffix beginning with a prenasalized stop is added to a stem with a final consonant the resulting form has a longer nasal portion (Arnott 1970, McIntosh 1984). Examples of this suffixation process are given in table 4.4.

Table 4.4 Fula single and geminate 'prenasalized stops'

No final consonant in stem	
waandu / baaɗi	'monkey / monkeys'
stem + noun class suffixes	-ndu / -ɗi
Final stem consonant	
biŋŋga / bikko	'big child / children'
stem + noun class suffixes	-ŋga / -ko

In our recordings of Fula these 'geminate prenasalized stops' do not have much greater duration than might be expected from concatenation of a single nasal and a stop in some other language. And our measurements on a number of words with nongeminated prenasalized stops from two speakers showed that the total duration of the nasal and stop portions was in the range 100-45ms, with a mean close to 60ms.

It might be argued that the shortness of this duration is evidence for a distinction between prenasalized stop and nasal + stop sequence. Herbert (1986), in his monograph on prenasalization, suggests that the phonetic characterization of a prenasalized consonant is precisely that it is a sequence of homorganic nasal and non-nasal elements that are approximately equivalent to the duration of 'simple' consonants in the same language. We feel that this view does not take into account the variability in timing of segments. As Browman and Goldstein (1986) have shown, the sequences [mp, mb] in English do not necessarily have any longer acoustic or articulatory durations than the single segments [p, b, m]. They also show that the timing of these English bilabials is very similar to that which they find in word-initial [p, m, mb] in the KiVunjo dialect of Chaga, where [mb] is usually analyzed as a prenasalized stop.

Instead, it seems more appropriate to regard the brevity of homorganic nasal + stop sequences as due to a process of gestural economy. Two adjacent segments which require homologous articulatory gestures may be produced with a single combined gesture. In the present case the two oral closure gestures may be pictured as overlapping, with both the release of the first and the closure

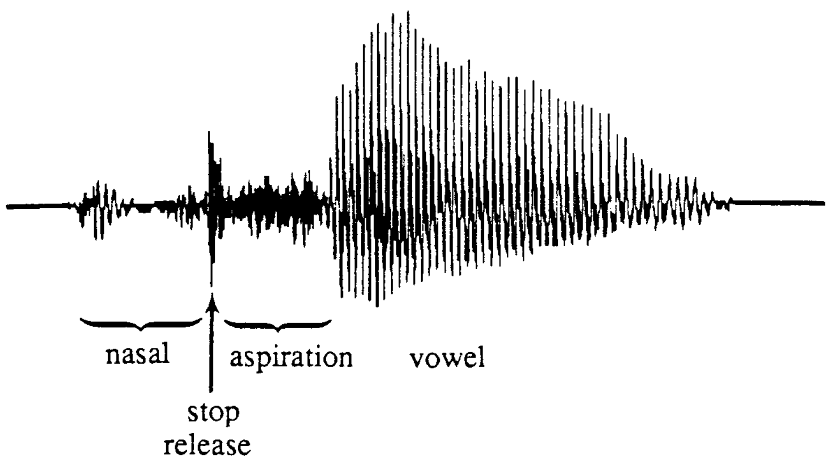


Figure 4.8 Waveform illustrating weak vocal cord vibration in devoiced nasal preceding aspirated stop in the Bondei word /n̥taa/ 'tilapia fish'.

formation of the second suppressed in the interests of economy. The degree to which potential gestural economy is exploited varies from language to language, and within languages varies according to linguistic environment and speech style. With a phonetic theory that includes a better understanding of dynamic aspects of phonetics, it will be possible to provide a full account of such relative timing properties.

Voicing control in nasal + stop sequences

Another reason, apart from the durational considerations discussed above, for not treating 'prenasalized' segments as unitary elements from the phonetic point of view is the independent control of voicing within the sequence. In most languages that have been said to have prenasalized stops only voiced sequences occur. However, in those languages where the stop component may be either voiced or voiceless the nasal component of the sequence is generally voiced regardless of the voicing state of the stop (Herbert 1986). Thus, in Rundi (Meeussen 1959) there are both 'voiced' and 'voiceless' prenasalized stops, but in phonetic terms the voicing difference lies not in the nasal but solely in the stop. In other words, the voicing state is actively changed in the middle of sequences such as / mp, nt, ŋk /. Although nasal segments themselves are usually voiced, a change of voicing within a unitary segment is quite exceptional.

On the other hand, voicing assimilation is not unusual in clusters; and some languages do have voicing assimilation in nasal + stop sequences under some conditions. Thus, in Bura, utterance-initial nasals preceding stops share the voicing category of the stop that follows them. This occurs in both homorganic and heterorganic nasal + stop sequences. Spectrograms exemplifying the three-way phonetic contrast of [m̥t, n̥t, nd] are shown in Figure 4.7. When these devoiced nasals are preceded by a voiced segment in context they are voiced, and there is no reason to assume that Bura has underlying voiceless nasals (Maddieson 1983).

Devoicing of nasals before voiceless stops also occurs in a number of Bantu languages in southwestern and northeastern parts of Africa, such as Ndongo and Kwambi (Baucom 1974) and Pokomo, Pare, Shambaa and Bondei (Hinnebusch 1975). We have heard examples from Bondei and note that the phenomenon is different from that in Bura. Bura has a completely open glottis and a high volume of airflow in its voiceless preconsonantal nasals so that they sound similar to the voiceless nasals in Burmese. In Bondei there seems to be a less forceful airflow and the vocal cords, though apart, are vibrating weakly. The result is that a very low amplitude periodic component can be observed for all or part of the duration of the nasal. This phenomenon can be shown more clearly in a waveform display, as in figure 4.8, than in a spectrogram. In this token the nasal is acoustically noisy throughout, but at its beginning and end a weak periodic wave can be observed, indicating vocal cord vibration. The differences between Bura and Bondei suggest that the manner of the voicing assimilation cannot be quite the same in these two languages. In Bondei, unlike in Bura, the stop releases are aspirated. This fact is perhaps related to the differences in the devoicing process, in that the peak of the glottal opening gesture is presumably later in relation to formation of the oral closure in

Bondei than in Bura.

Whatever the facts concerning articulatory timing and voicing may be, the motivation for talking of prenasalized stops, rather than of a nasal + stop sequence, is often phonological rather than phonetic (in languages which do not have a within-language contrast of the type found in Sinhala and Fula). A unitary analysis may be preferred because the language has no other consonant sequences in any position, as in Fijian (Milner 1956), or has no other consonant sequences in initial position, as in Gbeya (Samarin 1966). We note that the unitary analysis also avoids recognizing a syllable onset with the structure nasal + stop. Syllable onsets with this structure violate the expectation that more sonorous elements (in this case nasals) appear closer to the syllable nucleus than less sonorous ones (stops), in conformity with well-established ideas of the sonority hierarchy (cf. Jespersen 1897-9, Hooper 1976, Steriade 1982). In fact, violations of this particular kind seem to be rather prevalent.

The final question on prenasalization concerns whether any distinction is implied by the use of both transcriptions like [ᵐb, ⁿd] and [mᵖ, nᵈ], which have sometimes been distinguished as 'prenasalized stops' versus 'poststopped nasals'. The latter were noted by Y. R. Chao in Zhongshan (Chao 1948) and Taishan (Chao 1951), two Yue dialects of Chinese. More recently, Chan (1980) explicitly distinguishes between the two possibilities in her account of Zhongshan phonology. The basis for the proposed distinction lies in the perception that sometimes the nasal and sometimes the stop portion is more prominent. We do not know if this reflects a difference in relative durations of the components, or a difference in the amplitude of the burst for the stop in one case as opposed to the other. Historically, the Chinese poststopped nasals derive from simple nasals, in whose production, as Chao comments "the nasal cavity closed too early and the oral cavity opened too late" in the transition from the nasal to the following vowel. Given this historical origin, it seems quite likely that the poststopped nasals would have a relatively weak burst, but no comparative study has yet been carried out.

Prestopped nasals

Similar questions to those raised in the discussion of prenasalized stops arise in connection with the possibility of a phonetic distinction between a sequence of a nasal preceded by a stop and a unitary segment which might be called a prestopped nasal or a nasally-released stop. In some languages a syllable-initial homorganic sequence of a stop and a nasal is noncontroversially treated as a sequence of two separate segments. Russian is one such language. In Russian, many different syllable-initial consonant sequences occur, and nasal + stop sequences are just one of the possible types. Moreover, many of the words with initial stop + nasal sequences appear in paradigms along with forms which have a vowel separating the stop from the nasal. Some examples are given in table 4.5 ('palatalized' stops and nasals are represented as laminal postalveolars, transcribed as / d̠, n̠ /). From these considerations, the separate status of the nasal and stop elements is clear.

Table 4.5 Partial paradigms of Russian nouns with stop + nasal sequences

	'bottom'	'day'
nom sg.	dno	ge□
gen sg.	dna	g□a
nom pl.	do□ja	g□i
gen pl.	do□jev	g□ej

Elsewhere, particularly in Australia, languages have been described as having 'prestopped nasals'. In the case of the Australian languages there is often a close connection between a simple nasal and a stop + nasal sequence. In Diyari (Austin 1981), intervocalic apical alveolar and laminal dental nasals following primary stress may optionally alternate with a stop + nasal sequence, provided that the initial consonant is not a nasal. In other positions simple nasals occur. In Arabana and Wangganuru (Hercus 1972) there is a similar, but apparently not optional, rule that also applies to bilabial nasals. Finally in Olgolo (Dixon 1970, 1980), because the initial consonants which controlled the distribution have been dropped, simple nasal and stop + nasal are in contrast in intervocalic position. A similar process has occurred in Aranda (Dixon 1980). Nothing in the descriptions of these languages suggests to us that there is anything phonetically remarkable about the 'prestopped nasals' in these languages, or that they are different in kind from the sequences that occur in Russian. The phonetic problem is again one of stating the timing relationship between oral and velic articulations, and relating the phonetic facts to appropriate phonological structures.

4.3. Nasalized consonants

There are two major types of nasalized consonants. One type is a nasalized click. Since the click-producing mechanism of the velaric airstream operates in front of the velic opening, pulmonic air may quite freely pass through the nasal passage simultaneously with the production of a click, resulting in a nasalized click. A variety of different laryngeal settings may also be employed, so that this nasal accompaniment to the click can be voiced, voiceless, breathy, and so on. Because of the complexity of the subject a separate chapter is devoted to clicks, and the nasalized clicks will be discussed in chapter 8 together with clicks of other types.

The second major type of nasalized consonants are oral continuants (fricatives and approximants) produced with a lowered velum so that air is also free to pass out through the nasal passage. These types of segments occur most often as allophonic variants of their non-nasalized counterparts in positions where nasality spreads from a nasal consonant or a nasalized vowel in the neighbourhood. The segments involved are usually voiced ones. For example, standard accounts and our own observations of Yoruba agree that the voiced approximants / **w** / and / j / are nasalized when they precede a nasalized vowel. Guarani (Gregores and Suarez 1967, Lunt 1973) is one of a number of languages in which a nasal segment is accompanied by anticipatory nasalization, potentially of several preceding syllables. (Guarani also has been variously analyzed as having inherently nasalized morphemes or a set of nasalized vowels and nasalization also spreads from these. The facts are phonologically complex and a full presentation will not be attempted here). In the course of this spreading of nasalization, nasalized voiced continuants and approximants are phonetically derived. Gregores and Suarez note that the nasalized counterparts of the voiced fricatives / v / and / ɣ / are the voiced approximants [ṽ] and [ɣ̃].

Languages clearly differ in the degree to which nasalization spreads to and through adjacent segments and the direction of the spread, and hence in the number and kind of surface nasalized segments that occur. The acoustic consequences of a lowered velum are also not uniform for segments of different types. There is very little auditory difference between nasalized and non-nasalized voiceless fricatives and approximants; perhaps articulatory assimilation of voiceless sounds to adjacent nasal or nasalized segments is more common than is usually reported. We believe that in Yoruba, for example, the voiceless approximant / h / is usually also nasalized before a nasalized vowel, although this is not noted in descriptions of the language. Nasalization of / h / is clearly demonstrated in Central Igbo in a kymogram tracing published by Carnochan (1948). We are less sure that the reported nasalized voiced and voiceless labiodental and alveolar fricatives in Igbo actually have simultaneous nasal airflow, rather than being elements that occur with nasalization of the following vowel - the device of marking the consonants as nasalized being employed to identify the limited set of consonants that can occur in syllables with nasalized vowels (Williamson 1969).

Nasalized continuants have been claimed to be contrastive segments in a number of languages apart from Igbo. Boyeldieu (1985) argues for interpreting [w̃] as a phoneme in Lua. Stringer and Hotz (1973) describe Waffa as having a nasalized voiced bilabial fricative [β]. This segment contrasts with / β, m / and the sequence / mb / (treated as a single unit by Stringer and Hotz). Examples illustrating these sounds in Waffa, taken from Stringer and Hotz's work, are given in table 4.6. Stringer and Hotz do not comment on vowel nasalization, but they do not report nasalized vowels to be phonemic in Waffa.

Table 4.6. Words illustrating voiced bilabial segments in Waffa

	initial		medial	
mb	mbúumə	'stamens'	jámbáa	'banana'
β	βaíni	'close by'	óoβə	(type of yam)
β	βatá	'ground'	jaáβə	'reed skirt'
m	mátee	'now'	kamə	'round taro'

Ohala (1975) offers persuasive reasons for believing that voiced nasalized fricatives are difficult to produce, since to generate friction at the oral constriction while air is flowing out through the nasal passage requires a high volume of airflow and voicing limits airflow through the glottis. These antagonistic factors presumably account for alternations between non-nasalized fricatives and nasalized approximants such as those reported in Guarani. We do not have direct evidence that Waffa [β̃] is actually fricative, rather than approximant in nature but there is good evidence that a nasalized fricative occurs in Umbundu. According to Schadeberg (1982), Umbundu has a 'voiced nasalized labial continuant' which he symbolizes with [ṽ]. He classifies this segment as an obstruent, and after commenting on Ohala's observation indicates that it is a fricative; additionally he points out that it is distinct from the approximant [w̃], which also appears in the language in certain predictable environments. His analysis of the patterns of nasalization in Umbundu leads him to posit / ṽ / as one of a set of four underlying nasalized consonants, namely / ṽ, h̃, ɾ̃, j̃ /. These occur preceded and followed by phonetically nasalized vowels, but the nasalization of the vowels is treated as the result of a spreading of nasality from the consonants. Underlying nasalized vowels also occur, but the pattern of spreading of nasalization from these is different, and nasalization of consonants cannot be accounted for in this way. Hence / ṽ / is both a phonetic and phonological segment in Umbundu.

A third and minor type of nasalized consonant is a stop produced with a lowered velum. Nasalized stops can only be produced if the oral closure is further back (or lower) than the velic opening, that is, in the pharyngeal or glottal regions. If the closure is in front of the velic opening it will, of course, result in a nasal consonant rather than a nasalized stop. Nasalized glottal stops occur in Sundanese, though in contexts where their nasality is predictable (Robins 1957).

4.4 Conclusion

The aerodynamic and acoustic consequences of a lowered velum vary greatly depending on whether at the same time there is an oral occlusion (and whether it is located in front of the velic opening) as well as on a number of other factors such as the laryngeal setting. In accord with this, traditional phonetics made a strict distinction between nasals and nasalized sounds. Only when a lowered velum is combined with a forward oral occlusion are members of the class of consonants we call nasals produced. Accompanying any other articulation a lowered velum produces a nasalized sound. In traditional phonetic classification the major consonant manner classes consist of those based on degree of stricture, i.e. stops, fricatives, and approximants, plus nasals. In this classification these classes form a mutually exclusive set. A segment cannot be both a nasal and a stop; similarly it cannot be both a nasal and a fricative or a nasal and an approximant. The significance of these classes is shown by the fact that the great majority of the world's languages include members of each class, whereas nasalized consonants are comparatively rare in the world's languages, and frequently are only derived surface segments. In nasalized sounds, the major manner class of the segment is determined by the degree of stricture of the oral articulation. Although nasality is an accompanying feature, a nasalized fricative, say, is still a fricative acoustically as well as in terms of distributional privileges and syllabification. Although what we call nasals have been called 'nasal stops' by others, they are not straightforwardly the nasalized equivalents of plosives in the same way that [ṽ] and [j̃] are the nasalized equivalents of [v] and [j]. Nasals are acoustically continuant, characterized by a steady state. And they are often distributed in a way that is parallel to liquids and other sonorants, rather than to stops.

Nonetheless, the same articulatory property, a lowered velum, distinguishes nasals from plosives as distinguishes nasalized fricatives and approximants (and vowels) from their non-nasalized counterparts. In articulatory terms a single classificatory feature [nasal] is all that a phonetic theory requires to account for both nasals and nasalized segments. Furthermore, this may be a binary feature. At least as far as consonants are concerned, we need to indicate only whether the velic aperture is open or closed, since there is no evidence that degrees of opening are linguistically relevant. (A possible counterexample with respect to nasalized vowels in Palantla Chinantec will be discussed in chapter 10). We recognize that nasals are characterized by the same articulatory feature specification (which we will discuss later) that characterizes stops; they are distinguished from stops by being [+nasal], a specification that applies also to nasalized consonants.

Using the same feature may appear to overlook the differences between nasals and nasalized fricatives, nasalized approximants and nasalized glottal stops that we have stressed above. However, there are very close relationships between nasals and nasalized segments, especially in assimilatory rules, that require expression. Nasalized segments often occur contiguous to nasals, and in a few languages, such as Niaboua (Bentick 1975), nasals occur in place of voiced plosives in the environment of nasalized vowels. Nonetheless, nasalized consonants have the distributional properties of their non-nasalized counterparts, whereas nasals do not pattern in the same way as (non-nasal) stops. The task for a linguistic phonetic theory is thus to express the articulatory and temporal relationships between nasals and nasalized segments while accounting for the differences in their distributional patterns and markedness that are based on their acoustic nature. We feel that the way to represent this important acoustic property is by classifying nasals as [+sonorant]. The similarities between nasals and nasalized segments arise from articulatory considerations, whereas the differences arise from acoustic considerations.

The other major theoretical requirement concerning nasality is to express the relationship between movements of the velum, movements of oral articulators and changes in laryngeal setting. For the most part these are simply matters of relative timing. Although the timing of velic opening and closing movements are often quite closely coordinated with a distinct oral gesture for a consonant (or vocal tract configuration for a vowel), the velic aperture is often held open for the duration of several oral articulatory gestures or configurations. Equally, a single oral configuration (e.g. an oral closure) may be maintained while velic position is changed. We do not see phonetic evidence of any special binding of the components of such gestural sequences in certain cases (i.e. prenasalized stops, etc) as opposed to those cases where contiguous segments which share common articulatory features are adjoined in free combination. In each case, it is simply necessary to express the temporal relationship of the independent movements.

The independence of velic movements has, of course, been recognized in earlier phonological traditions, e.g in the Firthian prosodic school (Robins 1957), but this fact needs to be incorporated into an overall statement of the combinatory possibilities. This can be formally represented by assigning nasality to a separate phonological tier (Halle & Vergnaud 1980) in a multi-tiered representation, or to a separate node in a feature tree (Sagey 1986). These formalisms enable lack of temporal coordination between movements of the velic and other articulators to be directly represented. They also express the fact that nasality can be a component of segments of different manners. This fact is not formally captured by Clements' (1985) proposal to group [nasal] with other manner features in a manner node, since the combinatory possibilities between manners must be stipulated additionally. Besides capturing the formal relationships, a phonetic theory must also provide for an expression of the actual timing and magnitude of velic movements. Phonetic implementation rules of this kind lie outside the scope of this chapter, but work by Moll and Shriner (1967) and Vaissiere (n.d.) indicates that timing patterns of velic movement in English can be generated from underlying binary specifications of nasality and information on prosodic and segmental context.

5.

Fricatives

Descriptive framework

Fricative sounds are those in which a turbulent airstream is produced within the vocal tract. We will restrict the discussion in this chapter to the articulatory gestures required for central fricatives. Lateral fricatives will be discussed in the chapter on liquids. Variations in fricatives due to glottal gestures will be discussed in the chapter on laryngeal activity; and secondary articulations will be discussed in the chapter on consonant modifiers. Forms of h,ɦ in which a turbulent airstream is produced at the glottis are also sometimes classed as fricatives (e.g. by Jones 1956, Bronstein 1960), but it is more appropriate to consider them in the chapters on vowels and on phonation types.

The gesture controlling the constriction in many fricatives has a greater degree of articulatory precision than that required in stops and nasals. Making the articulatory closure for a stop involves simply moving one articulator so that is held against another. It does not make much difference to the sound if the target position, which is above the upper surface of the vocal tract, is a few milllimeters higher so that there is a tight closure, or lower so that the closure is formed more gently. A stop closure will produce more or less the same sound as long as it is complete, irrespective of whether there is firm or light articulatory contact. But in a fricative a variation of one millimeter in the position of the target for the crucial part of the vocal tract makes a great deal of difference. There has to be a very precisely shaped channel for a turbulent airstream to be produced. Moreover, in a stop closure the strength of the closure does not have to be constant throughout the gesture. But in many fricatives, particularly sibilants, an exactly defined shape of the vocal tract has to be held for a noticeable period of time. These demands result in a fricative such as s having a greater constancy of shape in varying phonetic contexts, in comparison with the corresponding stops t,d and nasal n (Bladon and Nolan 1977, Subtelny et al 1972, Lindblad 1980).

Fricative sounds may be the result of turbulence generated at the constriction itself, or they may be due to the high velocity jet of air formed at a narrow constriction going on to strike the edge of some obstruction such as the teeth. We will distinguish between these two classes of fricatives by calling them sibilant vs. non-sibilant fricatives. In defining the difference between the two classes of fricatives in this way we are following Shadle (1985), who uses the terms obstacle vs.

non-obstacle fricatives. Sibilant or obstacle fricatives are those such as s,z, in which the constriction at the alveolar ridge produces a jet of air that hits the obstacle formed by the teeth. In non-obstacle fricatives, such as θ,ð, the turbulence is produced at the constriction itself.

Further exemplification of the distinction is given in table 5.1, which provides an overview of the terms and symbols we will use in this chapter. Some of the terms are used in slightly unconventional ways that will be explained when they are introduced. The table includes a number of non-IPA symbols. We have distinguished between dental and interdental fricatives by the use of a diacritic to indicate a more forward articulation in the case of the latter sounds. We have used ɹ̂ and ʝ for the fricative varieties of ɹ,j (the IPA uses the latter pair of symbols for both approximants and fricatives). Following Catford (1983) and the practice of Soviet phoneticians we have added ŝ,ẑ for what we will describe as closed postalveolar sibilants, and ʜ,ʢ for the epiglottal fricatives. We have also included within the table the IPA symbols ɕ,ʑ, which are traditionally called alveolopalatal fricatives (but which we will regard as palatalized post-alveolar sibilants). As a result of all these additions, the terms for the "places of articulation" are not exactly the same as those listed in the previous chapter in figure 2.1. We are still using the notion place of articulation to describe the direction of the principal movement involved in the gesture. At the end of the chapter we will discuss how the data we will be examining suggest a more elaborate descriptive framework.

Table 5.1 Terms and symbols for rough descriptions of fricatives.

(1) Non-central region

bilabial	labio-dental	linguo-labial	inter-dental	‖ ‖	palatal	velar	uvular	pharyngeal	epiglottal
ɸ β	f v	v̼	θ̟ ð̟	‖ ‖	ç ʝ	x ɣ	χ ʁ	ħ ʕ	ʜ ʢ

(2) Central region, sibilants and non-sibilants

	dental	alveolar	flat postalveolar (retroflex)	domed postalveolar (palatoalveolar)	palatalized postalveolar (alveolopalatal)	closed postalveolar (hissing-hushing)	sublaminal palatal (retroflex)
non-sibilant	θ ð	θ̠ ð̠	ɹ̂				
sibilant	s̪ z̪	s z	ṣ ẓ	ʃ ʒ	ɕ ʑ	ŝ ẑ	ʂ

As in the previous chapter, we will begin by considering gestures made with the lips, and then those involving the tip and blade of the tongue in the dental and alveolar regions. We will next discuss all the sibilant gestures that can be made, starting with those in which the constriction is near the upper teeth, and then considering alveolar and postalveolar sibilants. We will then continue with the non-sibilants, working back through the possibilities within the mouth to those within the pharynx. During the course of the chapter we will also discuss the acoustic structures of fricatives.

The acoustic structure of fricatives seems to vary widely from individual to individual, but this really reflects only the unfortunate fact that we do not yet know what it is that we ought to be describing. We do not know how to sum up what is constant, and what is linguistically and perceptually most relevant in acoustic terms. As we do not yet have an adequate model for the acoustics of fricatives, we are in a position comparable to having to describe vowels without having the notion of formants, or at least peaks in the spectrum. Our best guess is that what matters for fricatives (more especially for sibilant fricatives) is the overall intensity, the frequency of the lower cut off point in the spectrum, and something corresponding to the center of gravity and dispersion of the spectral components above a certain threshhold. We will follow Lindblad's (1983) suggestion that "the cut-off frequency is a correlate of the shade of auditory brightness along the scale of sibilance," and we will also take note of the spectral width associated with different fricatives.

Non-sibilant anterior fricatives

Several languages spoken in West Africa contrast bilabial and labiodental fricatives. Examples from Ewe, which contrasts voiced and voiceless sounds of this kind, are shown in table 5.2. Figure 5.1 shows spectrograms of the Ewe phrases in the first line of table 5.2, illustrating the differences between voiceless bilabial and labiodental fricatives in minimal pairs. The speaker was conscious of the reason for recording these phrases, and consequently the fricatives may be somewhat longer than usual. Nevertheless the differences between the two sounds are very small. The second formant transition has a slightly lower origin for the bilabial fricative; and the overall intensity of the fricative noise is higher for the labiodental fricative.

Photographs illustrating the difference between bilabial and labiodental fricatives in a neighboring language, Logba, are reproduced in figure 5.3. Both lips are tensed and almost touching for the bilabial fricative; in the labiodental not only is the lower lip drawn back so that it actually touches the upper front teeth, but also the upper lip is actively raised up from its rest position. This raising of the upper lip is even more noticeable in side view photographs of some of our other language consultants. All the speakers of Ewe, Logba and Avatime (Siya) that we recorded pronounced these sounds in essentially the same way. The same processes can be seen in a video recording of our principal Ewe consultant, the Ghanaian linguist Gilbert Ansre (to whom many thanks). It is clear that the retraction of the lower lip and the raising of the upper lip are necessary parts of the gestures for labiodental fricatives in these languages. These components of the gesture for a labiodental fricative are, however, absent in the majority of languages with labiodental fricatives, and are absent even in such languages as Spanish, which has the voiced bilabial fricative **β** as an allophone of **b**, in addition to the labiodental fricative **v**.

Table 5.2. Ewe bilabial and labiodental fricatives.

éɸá	'he polished'	éfá	'he was cold'
ɛ̀βɛ̀	'the Ewe language'	ɛ̀vɛ̀	'two'
éɸlè	'he bought'	éflẽ́	'he split off'
èβló	'mushroom'	évló	'he is evil'

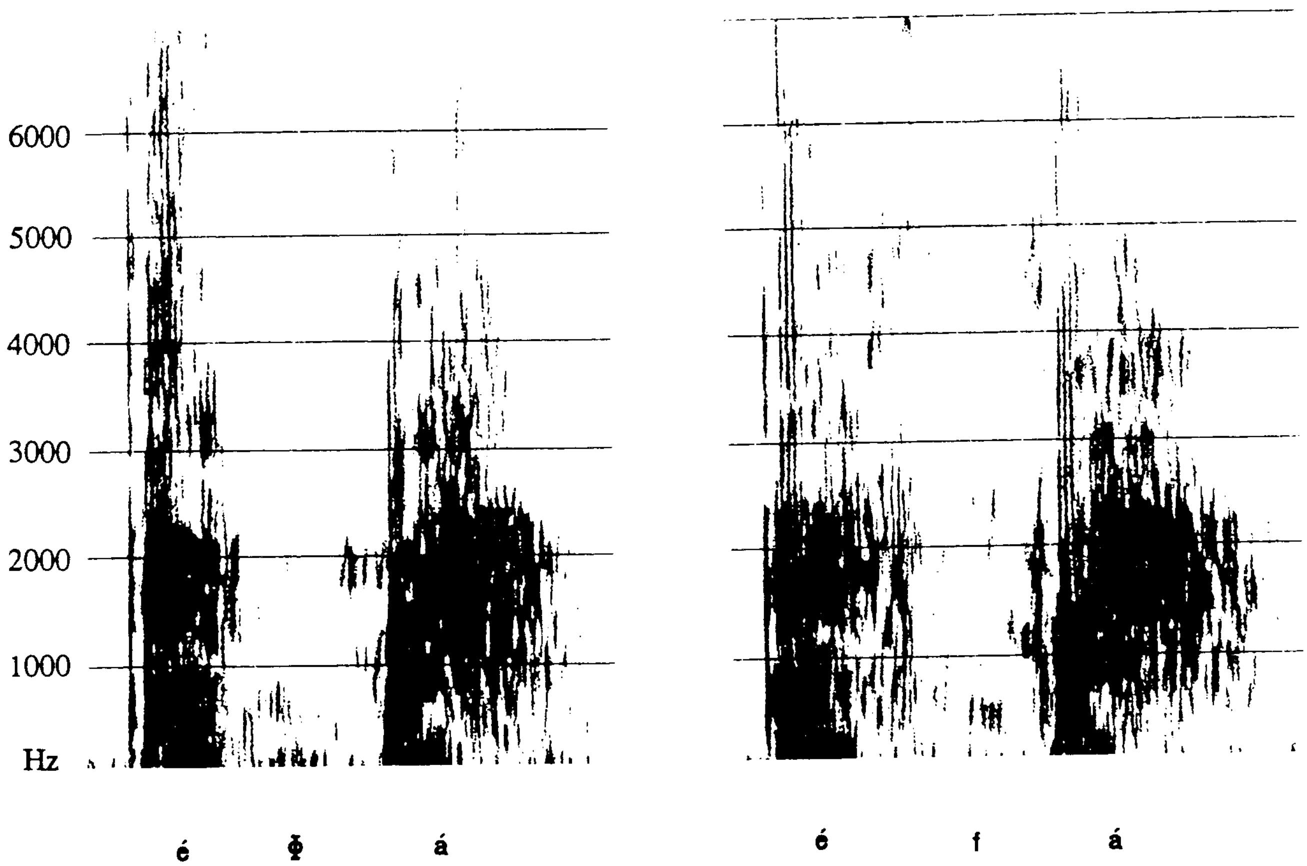


Figure 5.1. Spectrograms of Ewe bilabial and labiodental voiceless fricatives in éɸá 'he polished' and éfá 'he was cold'.

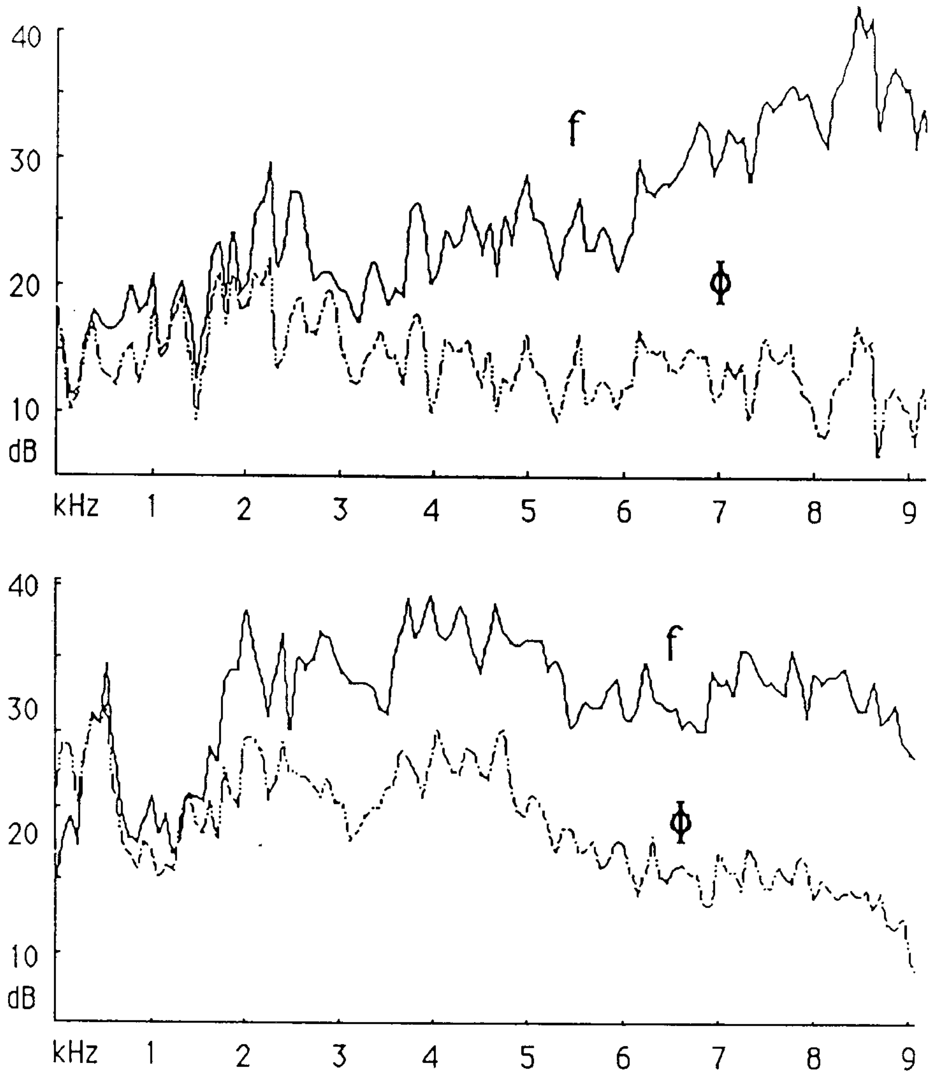
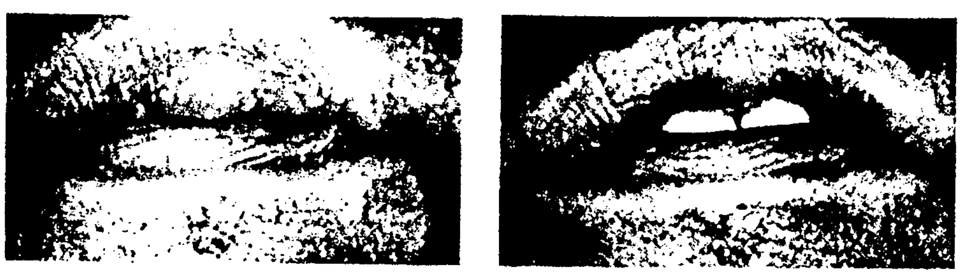


Figure 5.2. Means of 30 FFT spectra made at 5 msec intervals throughout the Ewe fricatives ɸ and f as produced by two speakers during the words in the first row of table 5.1. The mean noise on the part of the recording immediately adjacent to each word has been subtracted from each spectrum.



β v

Figure 5.3. Photographs of the contrasting lip positions in the bilabial β and the labiodental v in Logba (from Ladefoged, 1968).

The existence of linguolabial gestures in some of the languages spoken in Vanuatu was pointed out in Chapter 2. Linguolabial fricatives in Thenen Taut were exemplified along with the stops in table 2.2. We do not know of any languages other than those in Vanuatu that use linguolabial articulations for fricatives.

Non-sibilant dental and interdental fricatives occur in many languages, but we do not know of any that contrast them. Nevertheless some languages consistently use one, and others the other, so we have separated the two possibilities in table 5.1, using the symbols θ̟,ð̟ for the interdental gestures. Examples of differences between languages are provided by Navarro Tomas (1968), who describes (and diagrams) Spanish θ̟ as in θ̟iŋko *cinco* 'five' as being interdental with the tongue "beneath the edges of the teeth", and Balasubramanian (1972), who provides palatographic data showing that Tamil ð̪ as in pʰaːð̪ɯ 'half' is dental.

Figure 5.4. The tip of the tongue protruded between the teeth in θ as in *thief* as pronounced by a speaker of Californian English.

There is evidence that dialects of English differ in this respect. Textbooks teaching the pronunciation of British (RP) English (e.g. Jones 1956, Gimson 1970) typically describe θ, ð as dental, whereas those teaching American English (e.g. Prator and Robinett 1985) describe these sounds as interdental. We investigated 28 native Californian college students and 28 British university students and staff speaking with a wide variety of English and Scottish accents. Nearly 90% of the Californian speakers produced θ as in *think* as shown in figure 5.4, with the tip of the tongue protruded between the teeth so that the turbulence is produced between the blade of the tongue and the upper incisors. Only 10% of the British speakers made this sound in this way; instead 90% of them used an apical articulation with the tip of the tongue behind the upper front teeth.

Interdental fricatives are, of necessity, laminal; the constriction is between the blade of the tongue and the lower edges of the upper incisors. Dental fricatives can be apical or laminal, but we do not know of any consistent linguistic use of these two possibilities. Jespersen (1897-1899) considered the difference to be partially determined by dental idiosyncrasies. He suggests that if there are spaces between the teeth the tip of the tongue will be raised so that there is a closure between the tongue and the upper teeth, and the friction will occur in the spaces between the teeth; but if the teeth are close together, the tip of the tongue will be down so that a laminal fricative is produced. It is interesting that in the early days of the development of phonetic theory our forerunners considered anatomical differences among speakers in the production of these fricatives to be noteworthy. We will ourselves need to note the role of individual differences of a similar kind at other points in this chapter.

In our survey of British speakers we tried to find whether the gestures for the dental fricatives were made with the tip or the blade of the tongue. This was often a difficult question to answer, but it seemed that the constriction was usually between the edge of the tip of the tongue and the upper teeth. As we will note at other points in this chapter, the distinction between apical and laminal articulations is less important for many fricatives than it is for similar stops and nasals. It may be much more of an individual matter, as Jespersen suggested.

A similar difference to that between British and American dialects has been observed between several Shandong dialects of Chinese by Sung (1986). Where the majority of dialects in this group have sibilants, Rongcheng and Qingdao have developed dental nonsibilant fricatives, and Jiaonan has taken the change still further and uses interdental fricatives. The speakers of this latter dialect are well known for the way in which they actually protrude the tongue between the teeth.

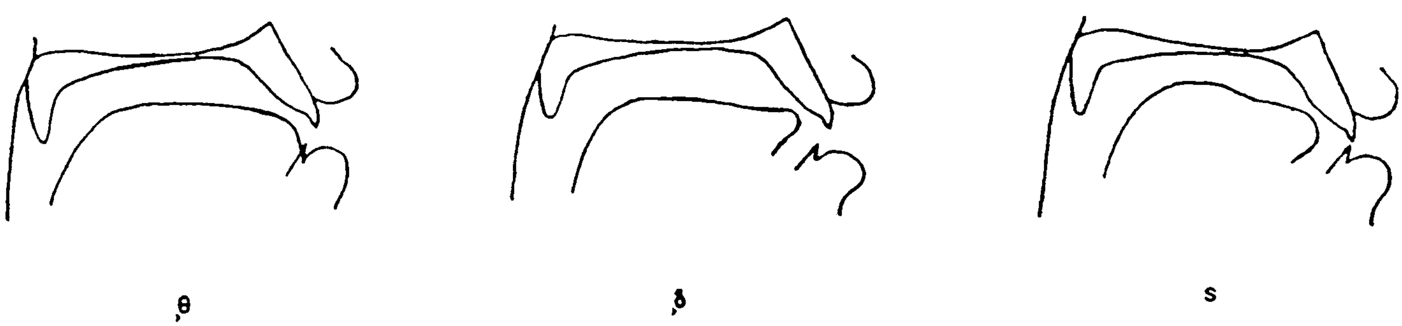


Figure 5.5. Icelandic non-sibilant alveolar fricatives θ̦ as in θ̦akɪ̥ð 'roof', and ð̦ as in vað̦an 'whence', compared with the sibilant alveolar s as in sunnar 'proved'.

Both the American and British varieties of θ and ð are non-sibilant fricatives, with the turbulence being produced at the interdental or dental constriction. Non-sibilant fricatives of this kind can also be made further back, with the tongue near the front part of the alveolar ridge.The IPA does not provide a symbol specifically for non-sibilant alveolar fricatives. Following the principles used in the previous chapter, we will use θ̦, ð̦ with the diacritic indicating a more retracted articulation. In Icelandic both θ̦ and ð̦ are definitely alveolar non-sibilant fricatives, the former being laminal, and the latter usually apical. Figure 5.5, based on data in Petursson (1971), shows the pronunciation of θ̦ as in θ̦akɪ̥ð 'roof', and ð̦ as in vað̦an 'whence'. In each case the constriction is in the alveolar region., and the teeth are fairly far apart so that it is clear that they do not form an obstruction. A voiced alveolar fricative ð̦ sometimes occurs as an allophone of the alveolar stop /d/ in formal Danish, in words such as 'læ̦ðəfoɣɪ̦ð (proper name:

'Ladefoged'). Jespersen (1897-1899) describes this Danish sound as a laminal alveolar fricative, made with the tip of the tongue behind the *lower* front teeth. However the constriction in present-day Danish ð is often so weak that there is little audible friction, and the sound might be better classified as an approximant. Bauer et al (1980) note that "only in very distinct Danish - as from the stage of the Royal Theater - do we get a fricative."

It is possible to form a non-sibilant fricative using the teeth themselves as the only constriction. Passy (1899) describes a fricative in the Shapsug dialect of Adyghe, a Circassian language, which has "the lips fully open, the teeth clenched and the tongue flat, the air passing between the teeth; the sound is intermediate between ʃ and f." (Passy 1899: 110, our translation.) This sound was noticed independently by Catford who comments that "the Adyghe (Circassian) bidental fricative is, in fact, a variant of x, occuring for the x in such words as xə 'six' and daxe 'pretty' in the Black Sea sub-dialect of Shapsug" (Catford personal communication) .

Sibilants

The more usual fricatives in the alveolar region are the sibilant fricatives s, z. In these fricatives the principal source of the sound is the turbulent airstream produced when the jet of air created by the alveolar constriction strikes the teeth, which form an obstacle downstream from the constriction itself. We see, therefore, that at some points within the vocal tract it is possible to form two different constrictions, one that will produce a sibilant fricative, and one that will produce a non-sibilant fricative. Icelandic, in fact, has both a sibilant and a non-sibilant alveolar fricative. The righthand part of figure 5.5 shows the Icelandic sibilant fricative s. Petursson (1971), describing the difference between what we have called the non-sibilant and sibilant voiceless alveolar fricatives says: "The first important difference is that θ̦ is articulated with the blade of the tongue, but for s the tip is raised. The place of articulation is more advanced for θ̦ than for s. The shape of the tongue is different for the two consonants; for θ̦ it is flat, for s it has a characteristic curve. The alveolar constriction is also different: for θ̦ it is large, for s it is a narrow channel." (Our symbols and translation.) Note also that all these fricatives have constrictions near the alveolar ridge, but in the sibilant fricative the teeth are also close together.

It is also possible to produce sibilant fricatives with a dental constriction, in the same region as that used for the non-sibilant θ sounds. Indeed, the sibilant s is regularly described as a voiceless dental fricative in many well known languages (e.g. Cantonese: Hashimoto 1972; Standard Chinese: Chao 1968; Swedish: Elert 1968). As we will note, it is often difficult to be sure whether sibilants in this area are dental or alveolar. But Bright (1978) has pointed out that a considerable number of the languages of California contrast s̪ with s (using our symbols, not his). He notes that Karok has minimal word-pairs like s̪úːf 'creek' vs. súːf 'backbone', describing the sound at the beginning of the first of these words as being "a very far-forward, apico-dental sound ... pronounced by younger speakers as θ." The sound at the beginning of the second word is described as being "apico-alveolar." This contrast also appears in Luiseño in words such as s̪úkat 'deer' vs. **sukmal** 'fawn'.

We do not ourselves have any articulatory data on contrasts between dental and alveolar sibilants. We will begin our account of sibilants with a discussion of English **s**. This sound usually has a constriction in the middle of what we refer to as the alveolar region (i.e. the forward part of the alveolar ridge). It can be formed either by the tip of the tongue, or by the blade with the tip behind the lower front teeth. Bladon and Nolan (1977) point out that there is considerable disagreement among authorities as to which is the most common articulation. In their own video fluorographic study of eight speakers of different forms of British English, they found that seven of these speakers had a laminal **s**. In a recent survey we found that 8 out of 16 Californian English speakers used an apical constriction, raising the tip of the tongue so that the tip of the tongue was above the level of a thin toothpick inserted between the upper and lower incisors. The differences in the part of the tongue used are probably due to individual anatomical characteristics. The amount of protuberance of the alveolar ridge, and the relation between the lower jaw and the upper teeth, affect the gesture that is required to produce the acoustic structure necessary for **s**. Indeed, McCutcheon, Hasegawa and Fletcher (1980) have shown that even the location of the rugae (the ridges on the roof of the mouth) have an effect on how an individual chooses to form the constriction for **s**. There are, of course, articulatory regularities that are constant. All speakers of English pronounce this sound with the upper and lower teeth close together, making it an obstacle fricative; and there is always a narrow groove in the tongue directing a jet of air towards the teeth. For many speakers the lower lip is also involved in directing the airstream towards the edge of the upper teeth. The constriction must be close to the teeth, but the precise channel location, and the apical-laminal distinction are not of particular importance in the characterization of the general, cross-speaker, properties of English **s**.

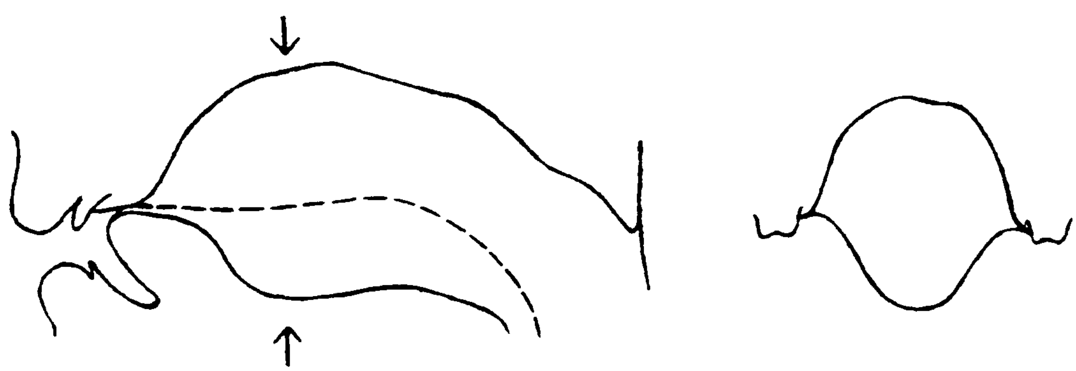


Figure 5.6. The articulatory gesture for **s** as in *saw,* as pronounced by the first author. The solid line indicates the position of the center of the tongue as known from x-rays; the dashed lines indicate the positions of the side of the tongue as indicated by palatograms. The coronal section on the right gives a transverse view of the shape of the tongue at the point indicated by the arrows on the sagittal section on the left. (Based on data in Ladefoged, 1957.)

Perhaps the most remarkable but least remarked feature of the articulatory gesture for English s is the deep pit which may occur in the center of the tongue. The articulatory constriction forming the jet of air consists of a groove, 5-10 mm. long, running in the posterior anterior direction. Behind this groove there is often a wide pit, extending out to the sides of the tongue. Some English speakers produce **s** in a word such as *saw* with the center of the tongue depressed several millimeters below the level of the sides of the tongue, as can be seen in figure 5.6, which is based on x-ray and palatographic data reported by Ladefoged (1957). For this speaker (the first author) at a point about 20 mm behind the tip of the tongue the midline is 12 mm below the sides. This particular utterance may have had a slightly exaggerated articulation in that the x-ray picture was taken during a very slow pronunciation of the word *saw*.; but it neither sounded nor felt in any way atypical.

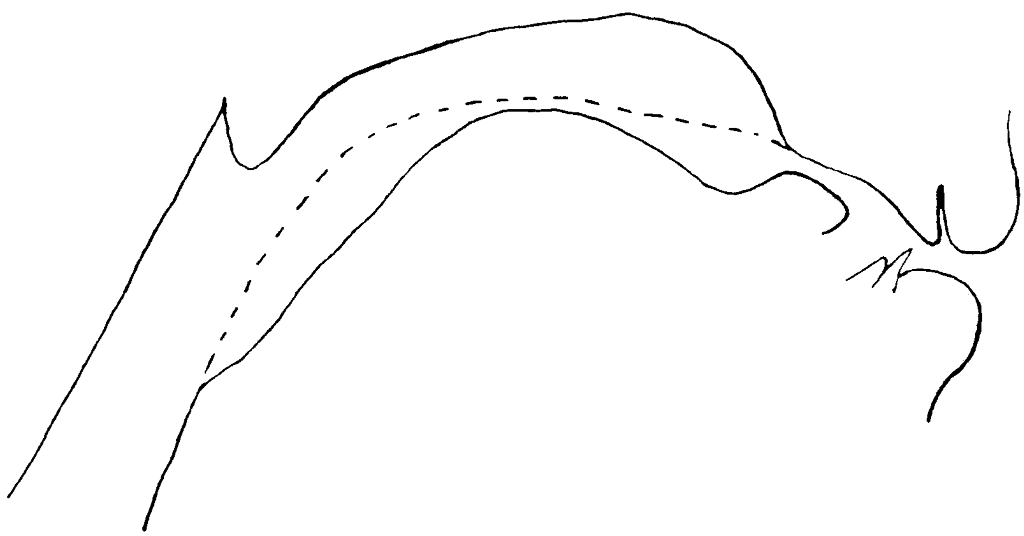


Figure 5.7. Tracings from an x-ray photograph of a speaker of British English (RP), taken during the pronunciation of **s** as in *saw*. The dashed line indicates the position of the sides of the tongue. The solid line shows the center of the tongue, as outlined by a radio opaque marker.

The fact that there is a deep hollow in the center of the tongue is often hard to determine from x-ray pictures in which the midline of the tongue has not been explicitly marked. Bladon and Nolan (1977) do not comment on the possibility, perhaps because they chose to mark the sides rather than the center of the tongue, fearing that a strip down the center of the tongue might affect the pronunciation. We did not notice anything unusual in the speech of any of our subjects who were being photographed while they had a thin line of barium sulphate down the midline of the tongue. Figure 5.7 shows the gesture used by another speaker, David Abercrombie, whose dentition is such that the crucial part of the tongue could be clearly seen. This speaker produces s with a more laminal articulation than that shown in figure 5.6, and with the center of the tongue approximately 10 mm below the sides of the tongue. Hardcastle (1974), in his survey of instrumental investigations of lingual activity in speech, notes that "if the central line of the tongue is outlined, it is possible to measure the depth of a groove, for instance in the articulation of [s]." His "simplified tracing from an X-ray photograph taken during the author's articulation of [s]" does not have a scale, but it appears that at a point below the soft palate there is a groove which is at least 17 mm deep. Similar gestures have been observed in other languages. From other comments in the text, it is likely that the "characteristic curve" mentioned by Petursson (1971) in his description of Icelandic **s** quoted above is a hollowing of this kind. We do not know the proportion of all **s** sounds that involve a hollowing of the tongue just behind the constriction, but it is probably more common than has been previously reported.

The more posterior sibilant in English, symbolized ʃ in the IPA tradition, has been variously described. Jones (1956), Abercrombie (1967), Ladefoged (1982), and Prator and Robinett (1985) call it a palatoalveolar fricative. Bronstein (1960) describes the tongue position in much the same way as Jones, but uses the term alveolo-palatal. Most of the authors note that the constriction in ʃ is wider as well as being further back than in **s**. Both Jones and Bronstein say that most people make this sound with the tip of the tongue up, but that some speakers have the tip of the tongue down behind the lower front teeth. Borden and Harris (1980) describe English ʃ as palatal. Hockett (1958) describes it as a lamino-alveolar or lamino-domal surface spirant, involving "a close approximation of a whole area, from side to side and from back to front".

English ʃ is similar to **s** in that for both sounds the teeth are close together, making them obstacle fricatives. The crucial differences between them are in the location and width of the constriction, which is further back and wider for ʃ, the raising (or doming) of the part of the tongue immediately behind the constriction for ʃ as opposed to the hollowing of this part of the tongue for **s**, and the added lip rounding or protrusion in ʃ. It should be noted that the secondary articulation of lip rounding is a feature of ʃ in some languages, such as English , but it is not found in many other languages such as Telugu.

Figure 5.8. The articulatory position for ʃ as in *shaw*, as pronounced by the first author. The solid line indicates the position of the center of the tongue as known from x-rays; the dashed lines indicate the positions of the side of the tongue as indicated by palatograms. The coronal section on the right gives a transverse view of the shape of the tongue at the point indicated by the arrows on the sagittal section on the left. (Based on data in Ladefoged, 1957.)

The apical articulation of ʃ as in 'Shaw' as produced by the first author, who was at that time a speaker of British (RP) English, is illustrated in figure 5.8. The constriction is in what we have called the postalveolar region, that is, on the center of the alveolar protruberance. It is clearly further back than the alveolar **s** illustrated in figure 5.6, in which the constriction is on the flat part of the alveolar ridge, just behind the upper incisors. The front of the tongue is raised, with the center being above the level of the sides.

In a palatographic survey of 164 students at the University of Edinburgh, Ladefoged (1957) reported that "for every speaker the articulation of the voiceless fricative in *sip* involves the formation of a narrower channel (which is usually also further forward) than that in *ship*." The wider channel in ʃ results in the jet of air striking the teeth at a lower velocity in ʃ than in **s**. In addition, all the speakers described in Ladefoged (1957) produced ʃ with the sides of the tongue raised higher up towards the hard palate than for **s**, with, presumably, concomitant raising of the center of the tongue as shown for the speaker in figure 5.8. The degree of lip rounding was not recorded for these subjects, but, as we have noted, English ʃ is typically somewhat rounded. The acoustic structure of sibilant fricatives will be considered later, but we may note here that both the lower velocity of the airstream, and the lengthening of the vocal tract by added lip rounding, will cause ʃ to have a lower apparent pitch than **s**.

Consideration of the articulatory characteristics that we have observed lead us to define ʃ as a postalveolar domed sibilant. By domed we mean to denote the raising of the front of the tongue that occurs, irrespective of whether an apical or laminal articulation is used. This doming is equivalent to a small amount of palatalization. We will regard the phrase palatoalveolar sibilant as an exactly equivalent specification, denoting a comparatively wide constriction in the postalveolar region near the center of the alveolar protruberance, with concomitant raising of the front of the tongue. Bronstein notwithstanding, we will distinguish between palatoalveolar and alveolopalatal sibilants, using the latter term as an alternative specification for the postalveolar palatalized sibilants that we will describe in Standard Chinese. We will avoid Borden and Harris's use of the term palatal, reserving that for sounds made further back in the mouth.

English ʃ is also like **s** in that both sounds can be made with the tip of the tongue up or down. In our survey of 16 speakers of Californian English we found that 8 of them raised the tip of the tongue above the plane between the upper and lower incisors when saying the word 'Shaw' (or 'Shah', the two words are homophones in Californian English). These 8 speakers were not the same as those who had an apical articulation for **s**. The remaining 50% produced what we would judge to be laminal articulations. Again, as also noted by the authors cited above, it appears that the apical-laminal distinction is not relevant in the formation of English sibilants.

There have been surprisingly few studies of the acoustics of English fricatives. The most comprehensive work is still that of Hughes and Halle (1956). In their discussion of the English fricatives **f,s,ʃ** as spoken by three speakers, they note that there are great discrepancies among the spectra of a given fricative as spoken by different speakers, but the differences among the spectra are consistent for a single speaker. Hughes and Halle found only very varied spectral characteristics for f,v, but more specific spectral properties for the sibilants, with s,z being characterized by spectral peaks at higher frequencies than ʃ,ʒ. This result, as we will see, has now become firmly established in a wide variety of languages. Equally, the lack of well determined analyses of f,v,θ,ð remains. It seems that in the case of these and other anterior non-sibilant fricatives, the inconsistencies between speakers are so great that it may be profitless to try to characterize the acoustics of the fricatives themselves. The perceptual cues may be almost entirely in the varied acoustic structure of the surrounding sounds. Consequently trying to describe different spectra for this subset of fricatives is like trying to describe different silences during the stop closures of p,t,k.

We will now consider Standard Chinese (Pekingese), which has a number of obstacle fricatives made in the alveolar and postalveolar regions. Relevant examples are given in Table 5.3 . The glosses shown are appropriate when these forms have a high level tone (55). We have given standard IPA transcriptions, with the initial consonants each followed by just the vowel a. From a phonetic point of view there is nothing other than a normal transition between the intitial consonant and the following vowel in all these cases. But the usual Chinese Pinyin orthographic forms have *ia* where we have a in the palatalized postalveolar (alveoloplatal) column. This reflects the underlying phonology, and therefore has some relevance to the phonological classification of the alveolopalatal sounds.

Table 5.3 Contrasts among Standard Chinese fricatives and affricates.

labiodental		alveolar		flat postalveolar (retroflex)		palatalized postalveolar (alveolpalatal)		velar	
fa	'to issue'	sa	'three'	ʂa	'sand'	ɕa	'blind'	xa	'sound of laughter'
		tsa	'take food with tongue'	tʂa	'to pierce'	t̠ɕa	'to add'		
		tsʰ	'to wipe'	tʂʰa	'to stick in'	t̠ɕʰa	'to dig finger nail into'		

Figures 5.9 and 5.10 show data for alveolar s, postalveolar (retroflex) ʂ, and palatalized postalveolar (alveolopalatal) ɕ as produced by three speakers of Standard Chinese (based on Ladefoged and Wu, 1984). The first point to note is that for all three sounds for all three speakers the upper and lower teeth are fairly close together, so that these three sounds are all clearly sibilant fricatives. In each of the sounds the tongue forms a differently shaped channel for the air; but the main source of acoustic energy is always the turbulence that arises when this air passes between the nearly clenched teeth.

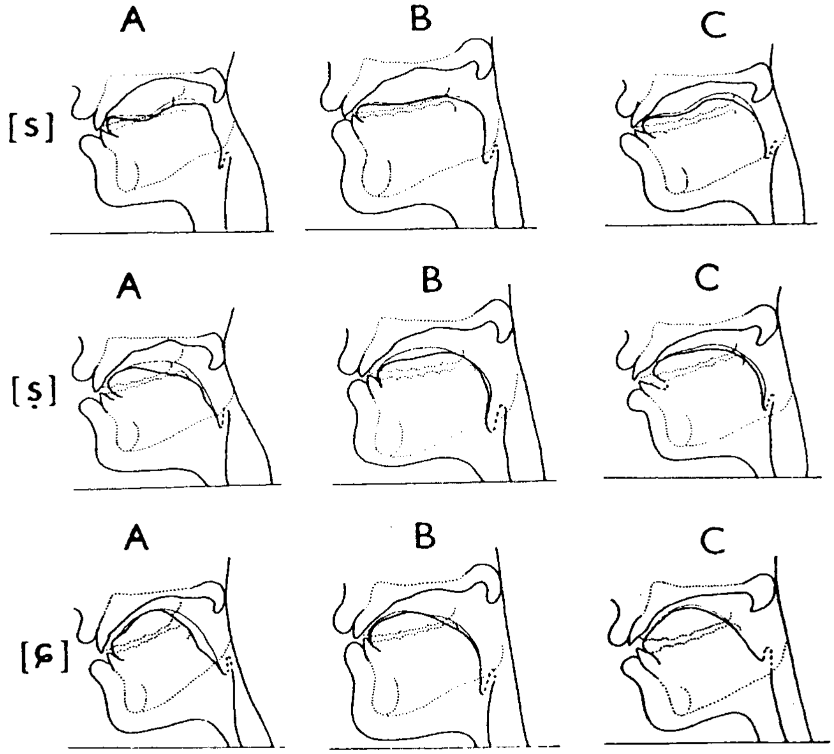


Figure 5.9. Tracings from x-rays of three speakers producing Pekingese sibilant fricatives. Where there are two lines drawn for the tongue, the lighter line represents the positions of the sides of the tongue. (Based on Ladefoged and Wu, 1984.)

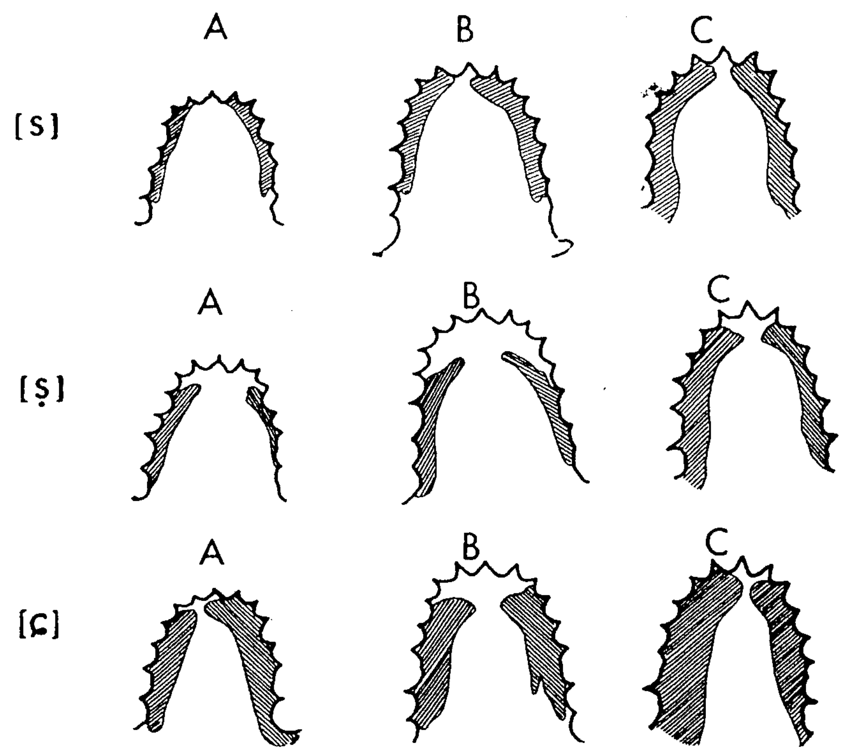


Figure 5.10. Palatograms of the data in figure 5.10. (Based on Ladefoged and Wu, 1984.)

As the top row of figure 5.9 shows, all three speakers produced **s** with the tip of the tongue; in all three cases there is a hollowing of the tongue such that the tongue is concave with respect to the roof of the mouth, although the hollow does not appear to be as deep as that for the English speakers reported above. The palatograms show that speakers B and C make this sound with a narrow slit, with a width of 4.5 mm for speaker B and 3.75 mm for speaker C. Speaker A made this sound with the narrowest channel on the teeth, so palatographic data is not available for this measurement. The height of the slit is about 1 mm for speakers A and B, and even less for speaker C. These measurements of the width and height of the constriction are similar to those for English reported by Subtelny et al. (1964, 1972).

The position of the point of greatest constriction is slightly different for each speaker. For speaker A it is on the teeth, for speaker B slightly behind the teeth, and speaker C still further back, so that it is on the front part of the alveolar ridge. Given these data, it seems that these sounds do not have a very exact place of articulation (in the sense of the precise location of the constriction in relation to the anatomical features of the roof of the mouth). This again agrees with the data for English **s** as reported by Subtelny et al (1964, 1972), and as described above. In Chinese, as in English, s must have a constriction located close to the teeth; and this constriction must form a narrow channel directing air towards the teeth at a high velocity. But the speaker's individual dentition and mouth shape will determine where the constriction is in relation to the alveolar ridge. For each of the speakers in figure 5.9 the constriction is at a similar distance from whatever narrowing provides the obstacle -- the gap between the lower and upper teeth for speakers A and C, but probably the gap between the lower lip and the upper teeth for speaker B.

The Standard Chinese so-called retroflex ʂ is shown in the middle rows of figures 5.9 and 5.10. This gesture is plainly very different from that in the retroflex stops discussed in the previous chapter. It does not involve the tip of the tongue being curled up and backwards into the palatal region, as in the Dravidian sublaminal retroflex stops, nor does it have the apical postalveolar shape that occurs in the Hindi retroflex stops shown in figure 2.5. In our Standard Chinese data, all three speakers produce the constriction for this sound with the upper surface of the tip of the tongue, making it a laminal rather than an apical postalveolar. The constriction is at about the same place for all three speakers, further back than in **s**, so that it is nearer to the center of the alveolar ridge. Both the height and the width of the channel are greater than in **s**, but the width varies considerably, from 18.5 mm for speaker A to 5 mm for speaker C. The location and width of the constriction are thus very comparable with those for English ʃ. The front of the tongue is fairly flat for speakers A and C, and slightly hollowed for speaker B, rather than being slightly raised towards the hard palate as it is in ʃ. Because the part of the tongue immediately behind the constriction is not domed as it is for ʃ, we have termed this sound a flat postalveolar sibilant. A further point to note about this gesture is that the tongue tip does not touch the lower teeth, as it does in the articulation of **s**. Instead it is drawn slightly back, so that there is a sublingual cavity. Perkell et al (1979) have shown that this cavity has a significant acoustic effect, producing a comparatively low frequency spectral peak. Additional x-ray data in other publications (Zhou &Wu

1963, Ohnesorg & Svarny 1955) all show substantially the same gesture, confirming the notion that Standard Chinese ʂ is a (laminal) flat postalveolar sibilant.

The third sibilant in Standard Chinese is usually termed an alveolopalatal sound. The tongue has a very different position in this sound from that in any of the other sounds we have been considering, as may be seen from the data in the bottom rows of figures 5.9 and 5.10. There are some similarities to English ʃ, but both the blade and the body of the tongue are higher in the mouth, forming for each speaker a comparatively long, flat, constriction. The extent of this constriction may be estimated from the palatograms in figure 5.10. For all three speakers there was contact between the sides of the tongue and the palate high in the mouth all the way back to the molar teeth. It is possible that some of the turbulence may be formed along the wall of this long constriction, as suggested by Shadle (1985) for palatal and velar fricatives. But it is also apparent that these speakers raise the lower jaw so that the upper and lower teeth are close together, making the Standard Chinese ɕ an obstacle fricative.

From a comparison between the palatograms and the x-ray tracings in Figure 5.9 it is apparent that the narrowest channel occurs near the front part of the alveolar ridge for speakers A and C, and notably farther back for speaker B. For none of the speakers is the constriction in exactly the same place as in either of the other two Chinese sibilants. The palatograms show that it is consistently farther back than in s but not quite as far back as in ʂ. The difference between ʂ and ɕ is small, so that it might be possible to consider both of them as having constrictions in the postalveolar region, as in English ʃ. However, phoneticians who are familiar with both English and Chinese invariably note that English ʃ is not the same as Chinese ɕ, the major difference being in the degree of raising of the front of the tongue. We referred to ʃ as a domed postalveolar (palatoalveolar). It is therefore appropriate to refer to ɕ as a palatalized postalveolar, with the IPA term alveolopalatal being a possible alternative. We are thus making a distinction between three postalveolar sibilant gestures: flat postalveolar (retroflex) ʂ; domed postalveolar (palatoalveolar) ʃ; and palatalized postalveolar (alveolopalatal) ɕ.

There are a number of other fricatives that have to be compared with these English and Standard Chinese sounds. The Polish fricatives exemplified in table 5.4 have many similarities but also some differences from the Standard Chinese sibilants. A great deal of data on the acoustic structure of the Polish fricatives has been given by Kudela (1968). Additional data can be found in Jassem (1962). We will concentrate here on the articulatory gestures required for these sounds, relying largely on the descriptions by Puppel et al (1977). They use the symbols /s z ś ź š ž/ for sounds which we symbolise by s̪ z̪ ʂ ʐ ɕ ʑ. Their diagrams of these sounds are shown in Figure 5.11 Again it is clear that these three pairs of sounds are all obstacle fricatives with the teeth close together.

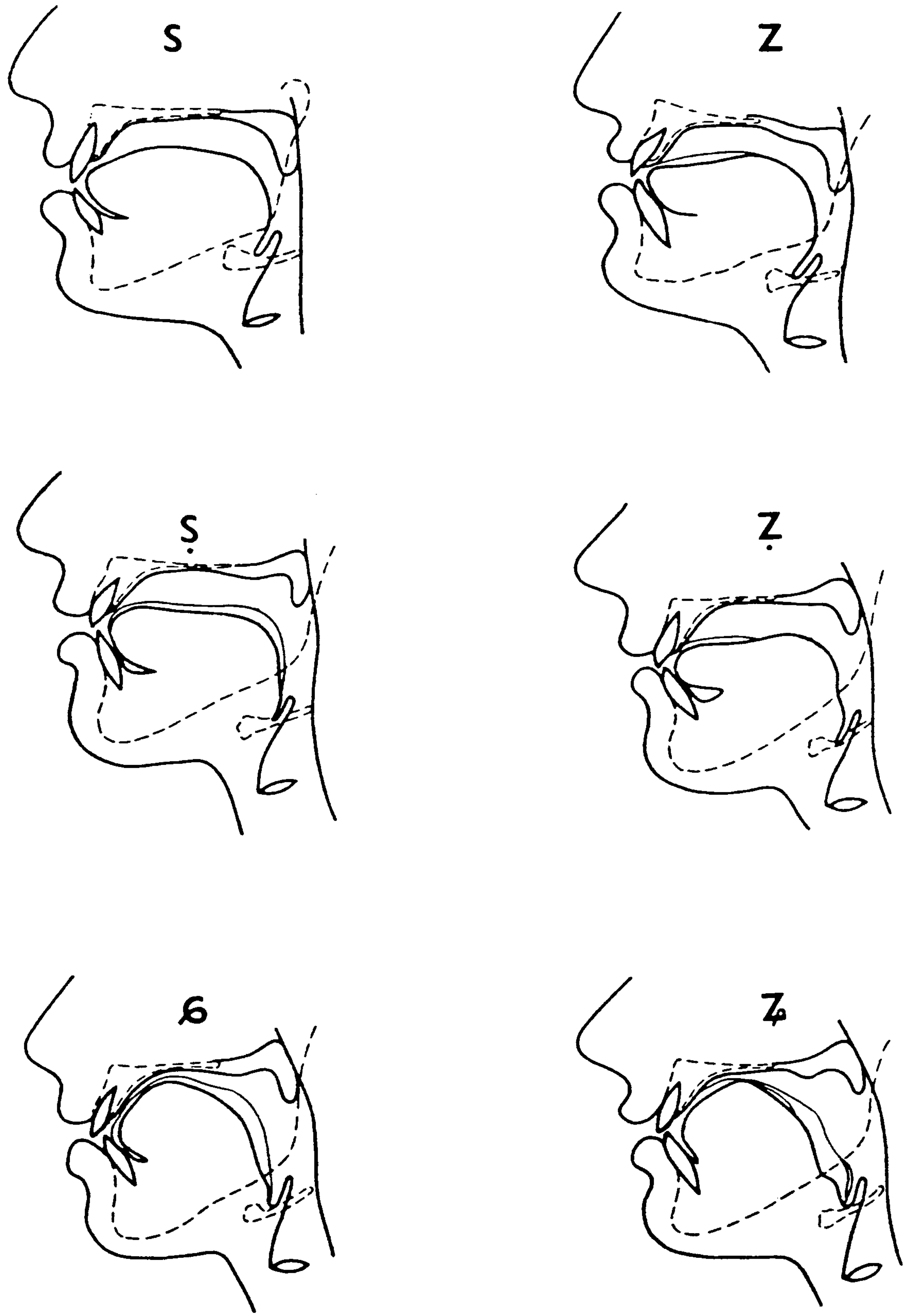


Figure 5.11. The articulatory gestures involved in Polish fricatives, based on x-ray data given by Puppel et al (1977).

The authors note that: "The Polish sounds /s/ and /z/ belong to dentalized sounds, i.e. those which are articulated in the alveolar region but with the blade of the tongue being very close to the inner side of the upper front teeth. Thus, the hissing effect is very strong. However, the English counterparts are articulated more in the purely alveolar region. Thus, in English, the tongue is more retracted for the articulation of these sounds." From their diagrams it is clear that their voiceless sound is s̪ and not s, and thus differs from the corresponding sounds in English and Standard Chinese. But, despite their comment, it is not quite so apparent that the voiced counterpart is dental z̪ rather than alveolar z.

Table 5.4 Contrasts among Polish sibilants.

alveolar			flat postalveolar (retroflex)			palatalized postalveolar (alveolpalatal)		
kosa	*kosa*	'scythe'	koʂe	*kosze*	'baskets'	baɕa	*Basia*	'Barbara' (dim.)
koza	*koza*	'goat'	koʐe	*korze´n*	'root'	baʑa	*bazia*	'catkin'

In describing ʂ and ʐ Puppel et al say (using our symbols, not theirs): "The narrowing is made by the tip of the tongue and the blade of the tongue, and the alveolar ridge. The narrowing, as compared with that for s and z, is a bit more open. The lips are protruded and slightly rounded. ... The Polish ʂ and ʐ consonants are articulated more in the alveolar region. They also belong to those sounds which are slightly dentalized." We would also point out the more complex obstruction caused by the close approximation of the upper lip with both the lower lip and the lower teeth in these sounds, making them somewhat rounded.

We do not know what Puppel et al mean when they say that these sounds are "slightly dentalized." Nor, judging from the illustrations, do we consider the tip of the tongue to be involved in making the constriction. But the tip of the tongue is slightly retracted from the lower teeth, so that there is a small sublingual cavity. These sounds seem to us to be produced in a similar way to the Standard Chinese laminal postalveolar (retroflex) sibilants. They differ in that Standard Chinese ʂ is not rounded (except before rounded vowels and semivowels) and has a larger sublingual cavity. These two differences tend to cancel one another, in that the addition of lip rounding or the introduction of a larger sublingual cavity both have very similar effects, thus making these Polish and Chinese sounds auditorily very similar.

The third pair of Polish fricatives, ɕ and ʑ, involve an articulatory gesture which is very similar to that in the Standard Chinese sound for which we have used the symbol ɕ. Puppel et al describe the Polish sounds as follows: "The sounds are produced with the body of the tongue in the front position. The tongue is tense and the lips are spread. The air escapes through a very narrow channel made between the post-alveolar region of the palate and the middle of the tongue ... the lips are slightly spread." When Puppel et al specify "the body of the tongue in the front position" they presumably mean that the sound is palatalized. From the illustrations in figure 5.11 it is clear that the gestures for Polish ɕ and ʑ are very similar to those for Chinese ɕ (at least for speakers A and C in figure 5.9).

Figure 5.12. The articulatory gesture involved in Tamil ʂ in paʂa as indicated by x-ray data given in Svarny and Zvelebil (1955).

Another sound which is acoustically similar to those we have been discussing is a sibilant made with the underside of the tongue, the retroflex (sublaminal postalveolar) ʂ. Balasubramanian (1972) describes Tamil as having a sublaminal ɖ that differs from the Chinese and Polish ʂ in much the same way as the sublaminal alveolar stop ʈ in Tamil and other Dravidian languages differs from the apical postalveolar stop ʈ in IndoAryan languages. But Balasubramanian provides no x-ray data to substantiate this point; and it seems that he is somewhat confused in that there is no way in which the articulatory contact shown in his palatograms could have been produced by the sublaminal retroflex articulation which he diagrams. Ladefoged and Wu (1984) accepted Balasubramanian's account of Tamil as having sublaminal ʂ. But we are now more doubtful. The well known Dravidian and Indo-Aryan languages of India seem to have apical rather than sublaminal retroflex sibilants. An example of the Tamil sibilant, which we would rather symbolize as ʂ is shown in figure 5.12 (based on x-ray data in Svarny and Zvelebil 1955). The articulation is clearly apical or laminal rather than sublaminal. It appears to be further back than the postalveolar sibilants in Standard Chinese and Polish. But, as we have remarked before, there are no absolute landmarks in the vocal tract, so it is difficult to compare articulatory data from one person with that from another, just as it is difficult to compare acoustic data from different individuals. We will classify Tamil ʂ as a laminal postalveolar, but reserve judgment on whether it really is equivalent to the Standard Chinese and Polish sounds that we have symbolized in the same way.

As far as we can tell from the description given by Emenau (1984), Toda contrasts sublaminal and laminal postalveolar sibilants. Toda has four different articulatory gestures for sibilant fricatives, whereas the other Dravidian languages have only three. Emenau (1984) describes a pair of voiced and voiceless fricatives that have "strong retroflexion like the voiceless stops," which would presumably make them sublaminal. We included ʂ and ʐ in table 5.1 so as to be able to symbolize these sounds. The other voiceless sibilant fricatives in Toda include s, which is described as being "not distinguishable from an English *s*" and two other sounds, both of which are made further back, and have "the edge of the tongue exactly at the alveolar ridge" (i.e. in what we would call the postalveolar region). One of these sounds is described by Emenau as "palatalized (hence classification as an alveolopalatal)." He does not say whether this sound is the same as English ʃ, but he symbolizes it by š́, which verifies our conclusion that he is describing the postalveolar region. The other sound made at this place of articulation is said to be "made with the tongue surface flattened as for *s*." This might therefore be similar to the Chinese and Polish flat postalveolar ʂ. Furthermore, in accordance with the comments made above on Tamil, it would also be similar to the retroflex fricatives in this and other Dravidian languages. It is the presence of an additional sibilant in Toda in comparison with these other Dravidian languages that leads us to suspect that Toda might have sibilants (as well as stops) made with an apical postalveolar retroflex gesture contrasting with sibilants (and stops) made with sublaminal palatal (retroflex) gestures.

The situation in Caucasian languages is also very complex, although for these languages Catford (1983 and personal communications) has given excellent accounts of the phonetic data available. Catford (in progress) has described what we would call five different primary articulatory gestures (i.e. without considering secondary articulations, or different states of the glottis) for sibilant fricatives in North West Caucasian languages. Four of these sounds, **s ʃ ʂ ɕ**, are similar to sounds that we have symbolized this way in other languages. The fifth sound, which Catford symbolizes as **ŝ**, he describes as "acoustically and physiologically between a typical **s** and a typical **ʃ**," calling it a "hissing-hushing sound." He goes on to say: "In its production the tip of the tongue rests against ... the lower teeth (as for a laminal **s**), but the main articulatory channel is at the back of the alveolar ridge (as for a lamino-postalveolar **ʃ**)." It is therefore like **ʃ** (and **ʂ** and **ɕ**) in that its constriction is in the postalveolar region; but it is like **s** in that the tip of the tongue rests against the lower teeth so that there is no sublingual cavity. Figure 5.13 shows the four contrasting gestures in the Bzyb dialect of Abkhaz, based on x-ray tracings in Bgazba (1964) and the interpretive comments in Catford (in progress). The constriction for **s** (at the top left of the figure) is in the alveolar region, on the front part of the alveolar ridge. The three other sounds all have constrictions on the middle of the alveolar ridge, in what we are calling the postalveolar region. **ɕ** has the front of the tongue raised, making it a laminal palatalized postalveolar (alveolopalatal) sibilant. **ʂ** in this case is made with the tip of the tongue, so it is an apical postalveolar (retroflex) sibilant. Both these sounds on the right of the figure have a sublingual cavity that is not present in **ŝ**. Because of the absence of the sublingual cavity in **ŝ**, we have termed this sound a laminal closed postalveolar sibilant.

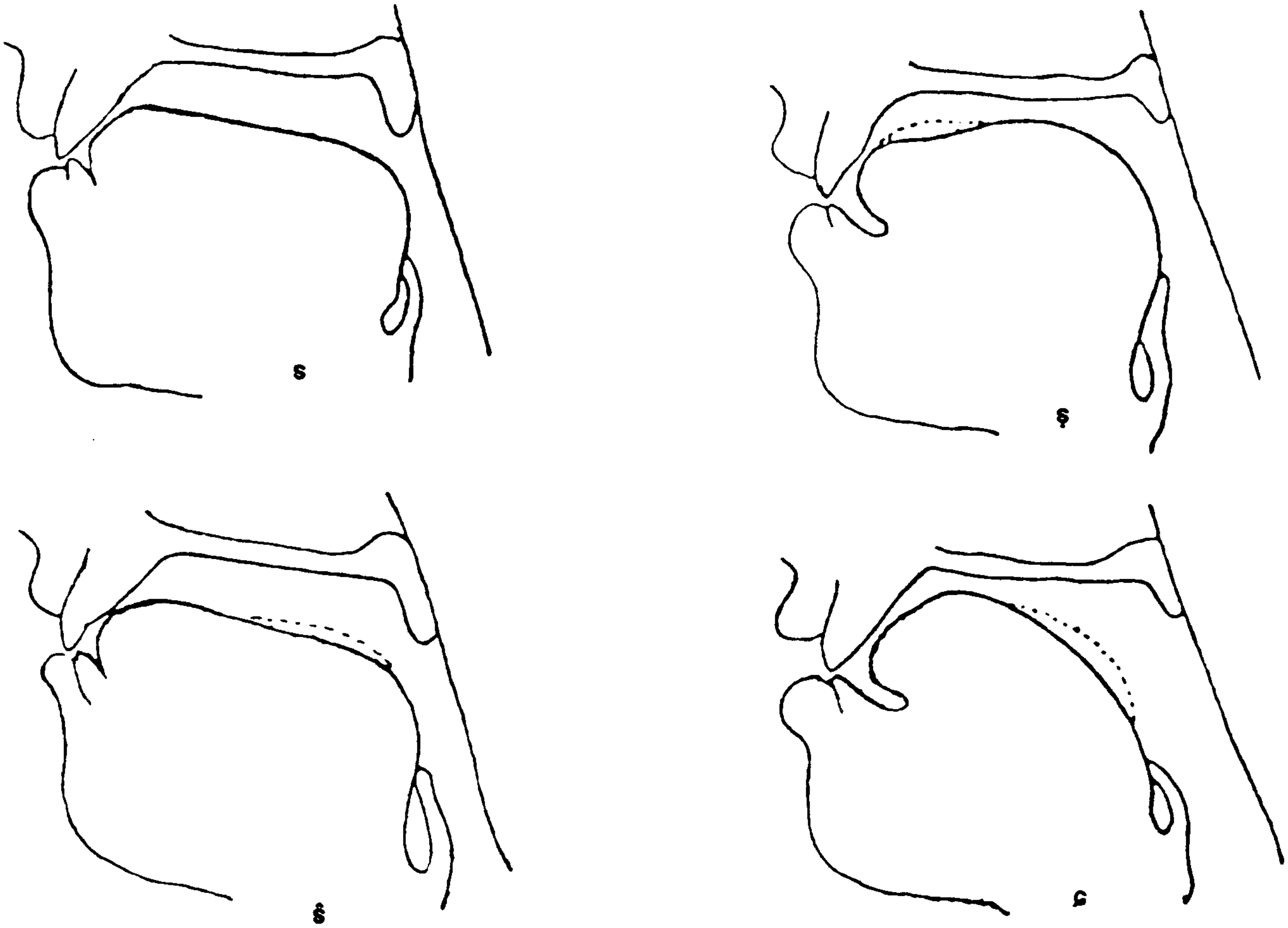


Figure 5.13. The four contrasting gestures for the sibilant fricatives in the Bzyb dialect of Abkhaz. Based on X-ray tracings from Bgazba (1964) and interpretive comments by Catford (in progress).

Catford (in progress) also has a good summary of the acoustic data for a number of the Caucasian languages, reproduced here (with many thanks) as figure 5.14. The general pattern is one in which the lower cut off frequency gets lower as the cavity in front of the constriction gets bigger. The only major exception is Adyghe s, which looks like the kind of artefact that occurs when a speaker is too close to the microphone. For each language ŝ has a higher cut off frequency and (apart from Ubykh) a higher range than the other postalveolars. The data suggest that ʃ may be distinguished from ʂ and ɕ by having a more extensive range and perhaps by an intermediate cut off frequency. Among the unrounded fricatives, ʂ has the lowest cut off and the lowest range. The rounded sibilants have both lower cut off frequencies, and considerably smaller ranges.

There may be sibilant fricatives in which the primary articulatory constriction is as far back as the palatal region. The descriptions are not completely clear, but what might be regarded as voiceless palatal sibilants may occur in Gununa-Kena (Gerzenstein 1968), and voiced palatal sibilants in Muinane (Walton and Walton 1967) and Cofan (Borman 1962). We neither have nor know of instrumental data on these languages. Although some palatal fricatives may, like the sibilants, have a high pitched sound, they are not obstructed fricatives and are therefore not what we would call sibilants.

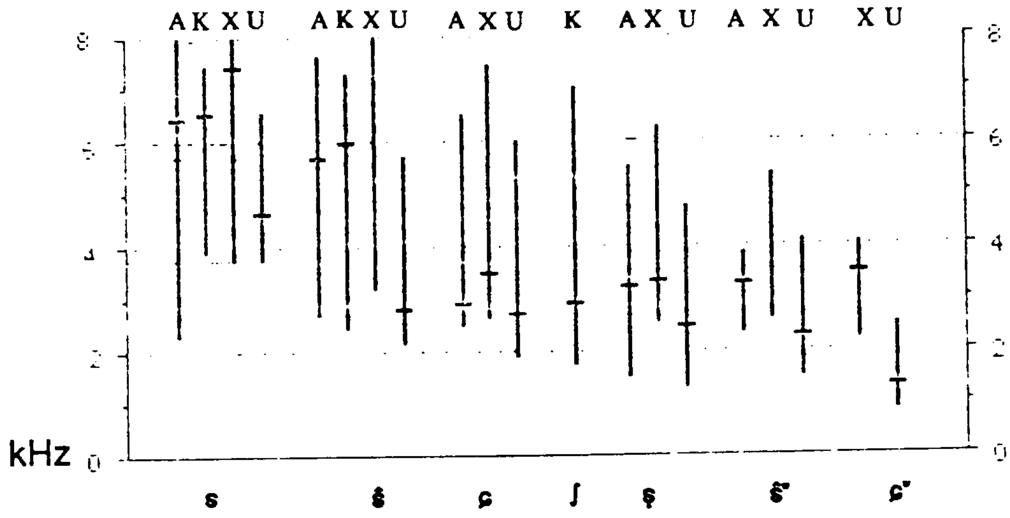


Figure 5.14. Acoustic data for a number of Caucasian languages: A = Adyghe (literary); K = Kabardian; X = Abkhaz; U = Ubykh. Reproduced (with kind permission) from Catford (in progress).

In summary, there are at least seven articulatory gestures for sibilants, as shown in table 5.5. The first two of these sounds, s̺,s, present no problem. The next four, ʂ,ʃ,ɕ,ŝ, all have a constriction in the post-alveolar region. The first three of these, ʂ,ʃ,ɕ, differ from one another by increasing amounts of raising of the part of the tongue immediately behind the constriction. Also note that separating apical from laminal articulations does not seem to be as useful in the case of sibilants as it is when distinguishing among stop consonants or liquids. Dental sibilants are always apical, but alveolar sibilants, and two of the four possible postalveolar sibilants can be made with the tip or the blade of the tongue. As we saw, about 50% of Californian English speakers have an apical s, and 50% a laminal one; and the same is true for Californian English ʃ.

Table 5.5. Basic types of sibilants.

Symbol	"Place of articulation"	Exemplifying languages
s̺	apical dental	Luiseño, Polish
s	apical or laminal alveolar	Luiseño, English
ʂ	apical or laminal flat postalveolar (retroflex)	Chinese, Polish, Toda?
ʃ	apical or laminal domed postalveolar (palatoalveolar)	English
ɕ	laminal palatalized postalveolar (alveolopalatal)	Chinese, Polish
ŝ	laminal closed postalveolar ("hissing-hushing")	Kabardian, Adyghe
ʂ̩	sublaminal palatal (sublaminal retroflex)	Toda

Posterior non-sibilant fricatives

Most of the fricatives in the dental, alveolar and postalveolar regions are of the sibilant, obstacle, type. But, in addition to the non-sibilant alveolar fricatives of the ð type that we described earlier, there are also non-sibilant fricatives further back in this region. A non-sibilant apical postalveolar (retroflex) fricative occurs in some forms of English. This sound, which we symbolize by ɹ̝, is the fricative form of the approximant ɹ. It is the form of South African English common in the Eastern Cape pronunciation of 'r' in words such as *red roses*. Note that in this dialect the postalveolar non-sibilant ɹ̝ contrasts with the postalveolar sibilant component of the affricate dʒ in words such as *jive* vs *drive*. The non-sibilant fricative ɹ̝ differs from the sibilant fricatives z and ʒ in the position of the jaw and the shape of the articulatory constriction. The non-sibilant fricative does not have the lower jaw raised so that the teeth are close together; and the constriction is wider so that it does not produce a high velocity jet of air which strikes an obstacle. A postalveolar non-sibilant fricative ɹ̝ also occurs in some forms of Edo, where it contrasts with an approximant ɹ (Ladefoged 1968).

Table 5.6. Margi palatal and velar stops, fricatives, and approximants.

	Palatal		Velar	
	Voiceless	Voiced	Voiceless	Voiced
Stop	càŋʷá cat	ɟaʔdí hump of a cow	kákádɔ̀ book	gàlí spear
Fricative	çà moon	ʝaʝaʔdɔ̀ picked up	xá big water pot	ɣàɾɔ́ arrow
Approximant		jà give birth		

Phonological contrasts involving voiceless palatal fricatives are fairly rare; less than 5% of the languages of the world include ç in their inventory (Maddieson 1984a). The voiced palatal fricative ʝ is even more rare (which perhaps explains why the IPA does not have a separate symbol for this sound). But the Chadic languages Margi and Bura have not only both the voiced and voiceless palatal fricatives ç,ʝ but also contrast these with a voiced approximant j as well as with voiced and voiceless velar stops, and voiced and voiceless velar fricatives. Margi words illustrating all these sounds are shown in table 5.6. The voiced velar fricative ɣ is often more like an approximant than a true fricative.

It is not clear whether the vocal tract shapes in palatal fricatives are equivalent to the overall shapes in the corresponding stops with the difference being simply whether there is a narrow constriction or complete closure in the palatal region. We do not have any physiological data on these Margi sounds; but x-ray data for other languages indicate that palatal stops and fricatives may differ considerably in the position of the root of the tongue. Figure 5.15, based on x-ray data in

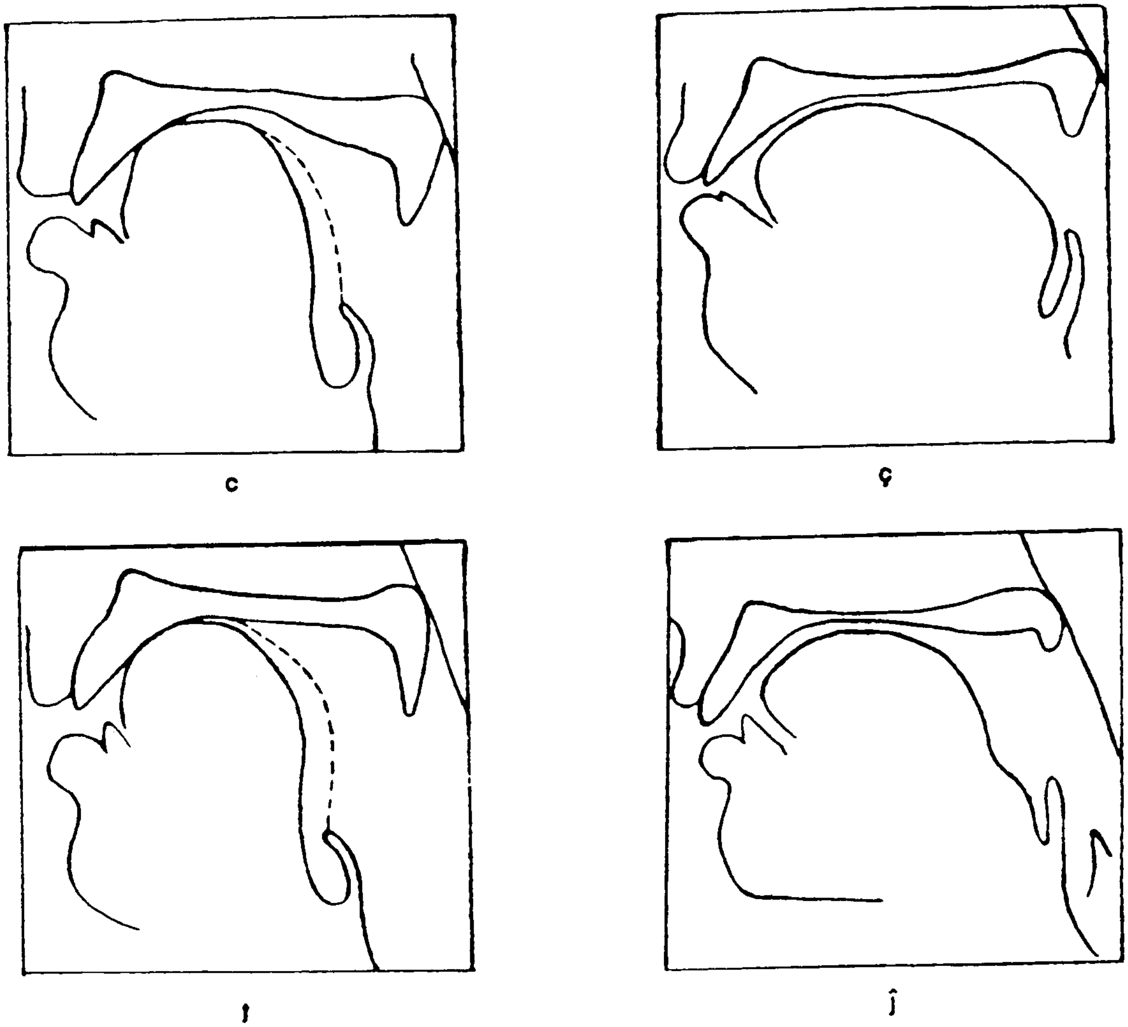


Figure 5.15. Hungarian palatals (after Bolla, 1980). Note that the root of the tongue is more advanced for the stops and nasal on the lefthand side.

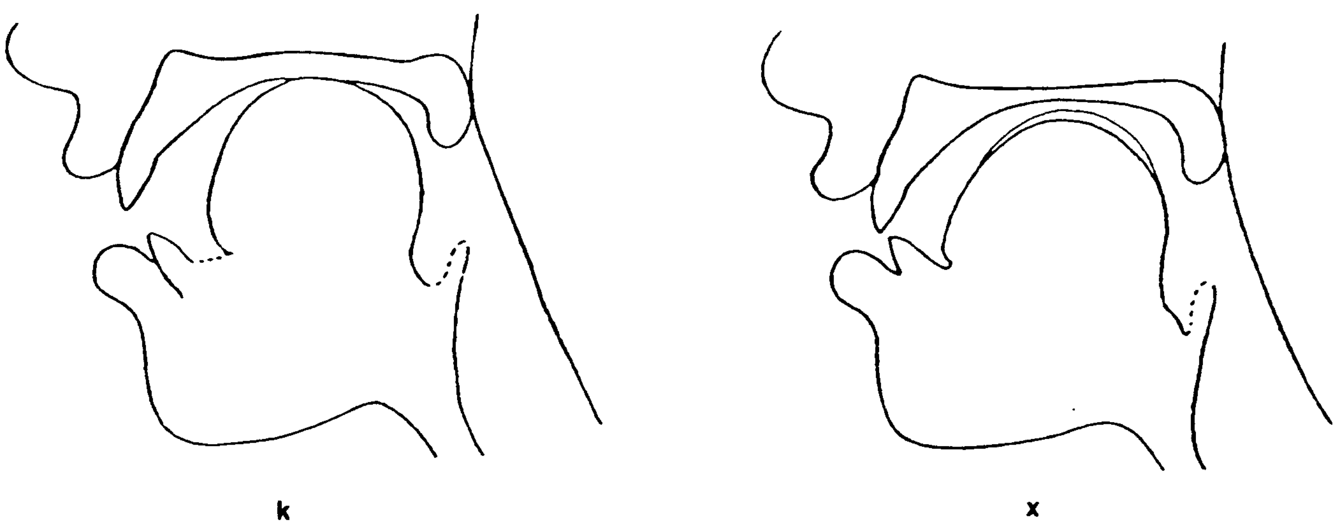


Figure 5.16. A comparison between a voiceless velar stop and a fricative in Standard Chinese (based on data in Wu et al 1962).

Bolla (1980), shows that Hungarian c,ɟ,ɲ, all have the root of the tongue more advanced than ç,j. This may be because j is an approximant, and what Bolla calls ç is simply the voiceless counterpart of j; but it is more probably because the stops require an articulatory gesture in which the tongue has to be raised considerably higher, as if the aim were to push the tongue through the roof of the mouth, as we noted in the previous chapter.

There are data on several languages containing velar fricatives, indicating that the vocal tract shape is much the same in the stops and in the fricatives. The differences in the overall vocal tract shape are less dramatic than those for the palatal gestures, perhaps because the gesture for a velar stop requires a less extreme tongue movement than that required in palatal stops. A comparison between Standard Chinese x and k (based on data in Wu et al 1962) is shown in figure 5.16.

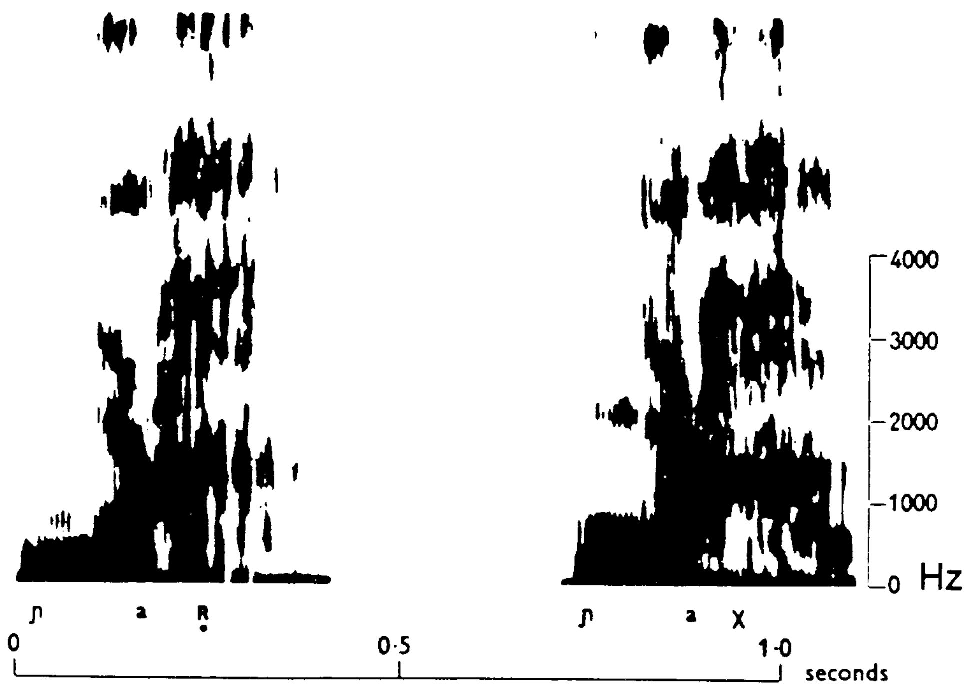


Figure 5.17. Voiceless uvular fricative trill ʀ and voiceless uvular fricative χ in Wolof (after Ladefoged 1968).

Velar fricatives contrast with uvular fricatives in a number of languages (e.g. in the Amerindian languages Haida, Tlingit, Wintu and Pomo, and in many Caucasian languages). We do not have any phonetic data of our own on any of these languages. It seems that uvular fricatives may also have much the same vocal tract shape as uvular stops. There is, however, a complication in the case of uvular fricatives in that the shape of the vocal tract may be such that the uvula vibrates. An example of a contrasting trilled and an untrilled uvular fricative in Wolof is presented in figure 5.17. The first of these two sounds is usually classified as being a uvular fricative, and the second as an allophone of a phoneme that is usually called "fortis", and which in initial position is a voiceless uvular stop (Ladefoged 1968).

Pharyngeal fricatives are rare. We will consider at this point the sounds in Semitic languages that are usually symbolized ħ, ʕ, although we recognize that these sounds are often approximants rather than fricatives. Arabic contrasts voiceless (or perhaps murmured) with voiced (usually laryngealized) gestures of this kind, in words such as **ħammaam** 'bath' and **ʕamm** 'uncle'. There seem to be at least two different ways of forming these Semitic fricatives, one of which might be more properly called epiglottal rather than pharyngeal. Catford (1977b) describes a gesture that we regard as truly pharyngeal in which "the part of the pharynx immediately behind the mouth is laterally compressed, so that the faucal pillars move towards each other. At the same time the larynx may be somewhat raised." He considers this to be "the most common articulation of the pharyngeal approximants ħ and ʕ." Sounds pronounced in a similar way but with a narrower constriction forming a turbulent airstream we would consider to be pharyngeal fricatives.

Note that Catford describes these sounds as approximants; in fact he goes on to say that they are "often wrongly described as fricatives." He is clearly correct in saying that in much, if not most, casual colloquial Arabic (as opposed to citation forms produced for the benefit of linguists) these sounds are not fricatives. In our experience there is audible local turbulence in ħ, but it is very seldom apparent in ʕ.

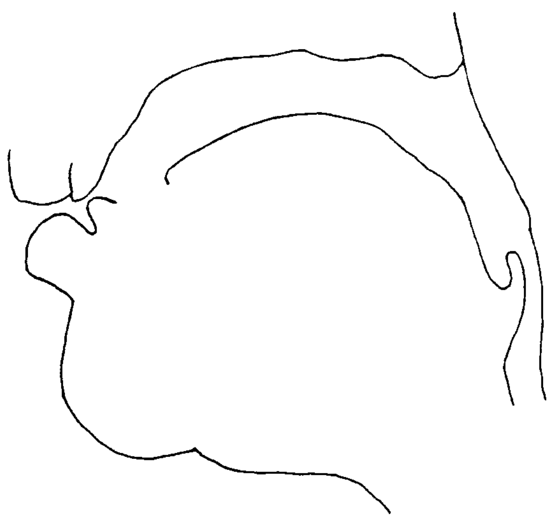


Figure 5.18. A voiceless epiglottal fricative ħ (before uː) in Arabic. (From data in Bukshaishai 1985.)

There are several instrumental records indicating that these gestures are more usually made in the epiglottal region, rather than in the upper part of the pharynx. The diagrams based on x-rays in Al-Ani (1970) for Iraqi Arabic and Ghazeli (1977) for Tunisian Arabic show that there is a constriction near the epiglottis. A typical gesture as indicated by x-rays is as shown in Figure 5.18. Laufer and Condax (1981), using fiberoptic data, describe a gesture in which the epiglottis has a more active role. In their work on Hebrew (and in later work on Palestinian Arabic, Laufer, personal communication) they conclude that the constriction "in no way involves the tongue." Instead it is "made between the epiglottis and the posterior pharyngeal wall, and may involve contact between the epiglottis and the arytenoids." However, as a result of a more recent x-ray study, Boff Dkhissi (1983) concludes that the movement of the epiglottis is not independent from that of the root of the tongue; rather the two elements work together in forming the constriction. In so far as these sounds are epiglottal rather than pharyngeal fricatives, they might better be symbolized ʜ,ʢ, rather than ħ,ʕ.

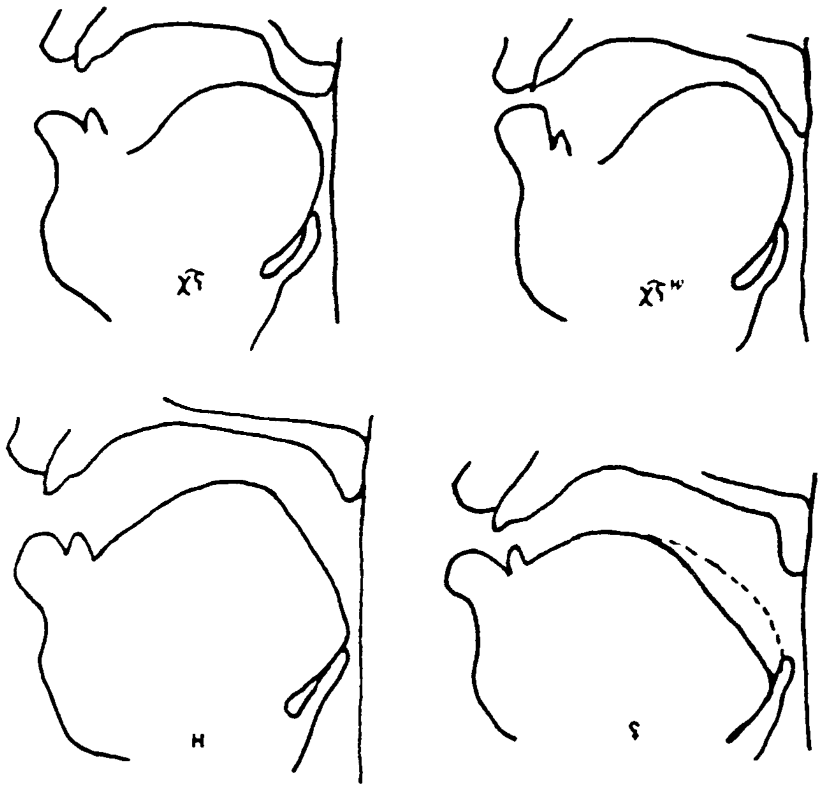


Figure 5.19. Pharyngeal plus uvular constrictions in Abkhaz (top row, based on Bgazba 1964), and epiglottal constrictions in Dargi (bottom row, based on Gaprindasvili 1966).

Gestures involving the epiglottis occur in a number of other languages, in addition to the Semitic languages discussed above. Catford (1983) has described Caucasian languages in which both pharyngeal and epiglottal fricatives occur, so that ʜ,ʢ contrast with ħ,ʕ. He notes that the Burkikhan dialect of Agul mentioned in the previous chapter in relation to the epiglottal stop ʡ, "has no fewer than seven pharyngeal and laryngeal sounds: pharyngeal ħ and ʕ, 'deep pharyngeal' [which we would call epiglottal. P.L. & I.M.] or 'emphatic' ʜ,ʢ, and the corresponding stop ʡ and glottal h and ʔ." There are x-ray studies of some of these fricatives in other Caucasian languages. Figure 5.19 shows tracings (also reproduced by Catford) from x-rays by Gaprindashvili (1966) and Bgazhba (1964) showing the difference between fricatives in the epiglottal region in Dargi and in the middle or upper part of the pharynx in Abkhaz.

It may be that, instead of two distinct regions, pharyngeal and epiglottal, there is actually a range of possible gestures made in this one general area. The most anterior of these would be the gestures described by Catford (1977b) as involving the faucal pillars and the part of the pharynx immediately behind the oral cavity. A slightly more retracted gesture can be exemplified by Danish "r". This sound is sometimes considered (e.g by the IPA 1949) to be a form of uvular ʁ, but it actually involves a weak constriction much nearer to the middle of the pharyngeal continuum. In contemporary Danish these sounds are usually approximants rather than fricatives, but in a very distinct, more old-fashioned, pronunciation a turbulent airstream is formed in the vicinity of the constriction associated with a low back vowel. As may be seen in the chapter on vowels, this is below the constriction near the faucal pillars in the upper part of the pharynx described by Catford (1977b), but it is distinctly above the level of the epiglottis.

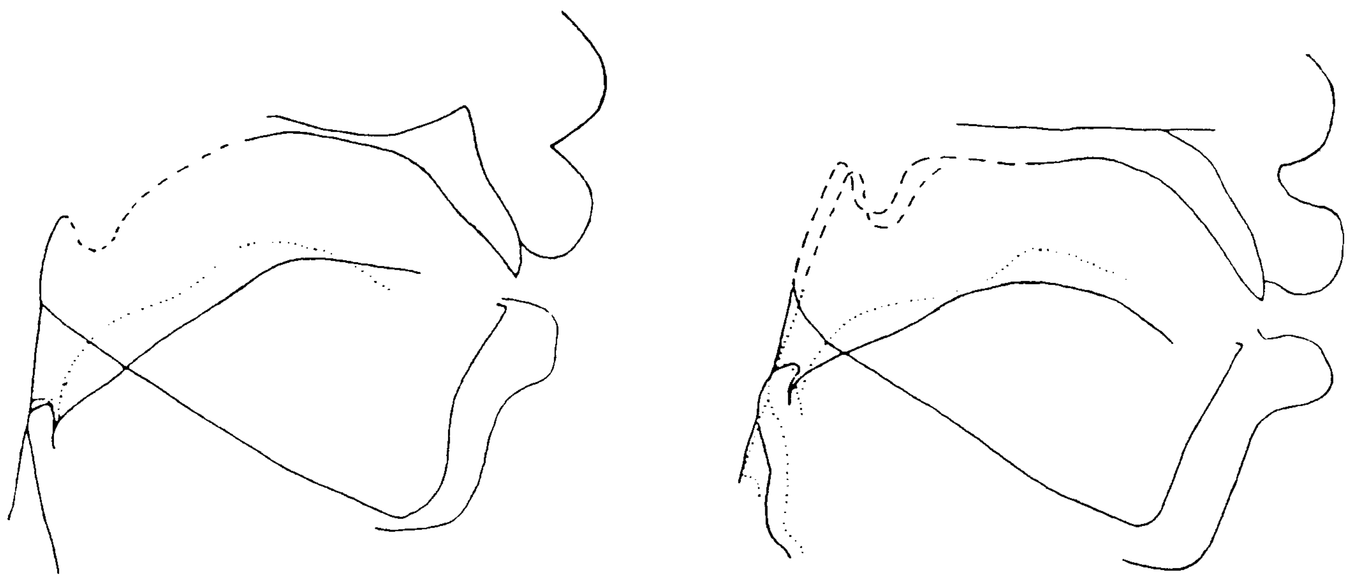


Figure 5.20. Two speakers of !Xóõ producing epiglottal articulations accompanying vowels of an u type (dotted line) and of an a type (solid line). After Traill (1981).

Gestures which involve constrictions that may be even closer to the larynx occur in Khoisan languages, where they are used in the production of strident sounds (Ladefoged and Traill, 1984; Traill 1985). There are phonological and phonetic reasons for considering these Khoisan gestures as phonation types rather than as fricatives of the kind we have been considering in this chapter. They are additive components that affect the vowels rather than forming in themselves a consonantal gesture; and they often involve a concomitant laryngeal gesture. Nevertheless they are definitely fricative sounds, with a turbulent airstream being produced by a constriction within the vocal tract, just above the vocal cords. X-ray photographs (from Traill 1985) showing the articulations used by two speakers of !Xóõ are given in figure 5.20. Traill notes that the epiglottis is hard to specify in these tracings from frames in a cine-x-ray film, as it was usually vibrating. Nevertheless it would be appropriate to describe these sounds as epiglottal fricative trills.

Finally in this survey of possible fricative gestures, we must consider some more complicated possibilities. There are a number of cases of double articulations, such as the labial velar fricative **ŵ**, which contrasts with the labial velar approximant **w** in Bura, Margi and other languages. We will consider this contrast in the chapter on approximants. In Kom and Kutep the labiodental fricatives **f,v** can be superimposed on other sounds. It is more appropriate to discuss these gestures in the chapter on consonant modifiers. But there are also cases in which it is not quite so clear that the gestures should be treated as consisting of a primary and a secondary articulation. Shona, for example, has so-called "whistling fricatives" in which there is extreme lip rounding combined with a laminal alveolar gesture; and some dialects of Swedish clearly have a fricative that has two or even three articulatory constrictions. As there is good data available on the Swedish fricatives, we will consider them in more detail.

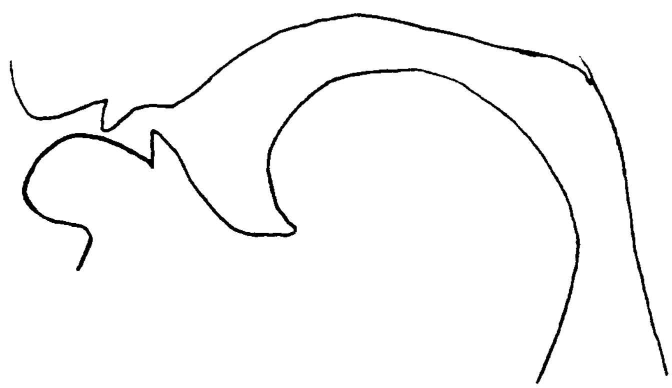


Figure 5.21. Swedish ɧ, a highly rounded, labiodental, velar or velarized fricative. (Based on data in Lindblad 1980).

Swedish has four phonologically distinct fricative gestures. The contrasting sounds are soemteimes symbolized /f,s,ɕ,ʃ/; in addition there is a retroflex fricative ,ʂ, which is, phonologically, the sequence /rs/. The first two of these, f,s, do not need extensive comment; /f/ is labiodental f, and /s/ is dental s̪. The other two, /ɕ,ʃ/, are more difficult to describe. The basic descriptive problem is one of geographical, social, and stylistic variation. Any remark about the Swedish fricative system has to be endlessly hedged with qualifications. According to Lindblad (1983), the most common usage is for ɕ to be a "predorsoalveolar fricative." His further comments and sketches based on x-rays indicate that ɕ is similar to the Polish gesture that we symbolized in the same way, which we called a palatalized postalveolar sibilant. Lindblad notes that variations of this phoneme in Swedish include an affricate tɕ or tʃ, and a palatal fricative ç similar to that in German. It is, however, the fourth Swedish fricative, phonologically /ʃ/, that is the most interesting. Lindblad describes two common variants of this sound. The first is usually symbolized by ɧ and is a highly rounded, labiodental, velar or velarized fricative. Lindblad uses the symbol w for this sound; a simplified version of his composite x-ray tracing is shown in figure 5.21. He suggests that the source of friction is between the lower lip and the upper teeth. He also demonstrates that the upper lip is considerably protruded in comparison with its position with that in the gesture for i. In addition to these anterior gestures, Lindblad notes that the "tongue body is raised and retracted towards the velum to form a fairly narrow constriction. (The presence of this constriction is constant, but not its width or location, which vary considerably.)" The posterior constriction in ɧ may be great enough to be itself a source of turbulence, so that this sound may have three notable constructions, one in the velar region, one labiodental, and a lesser one between the upper and lower lip.

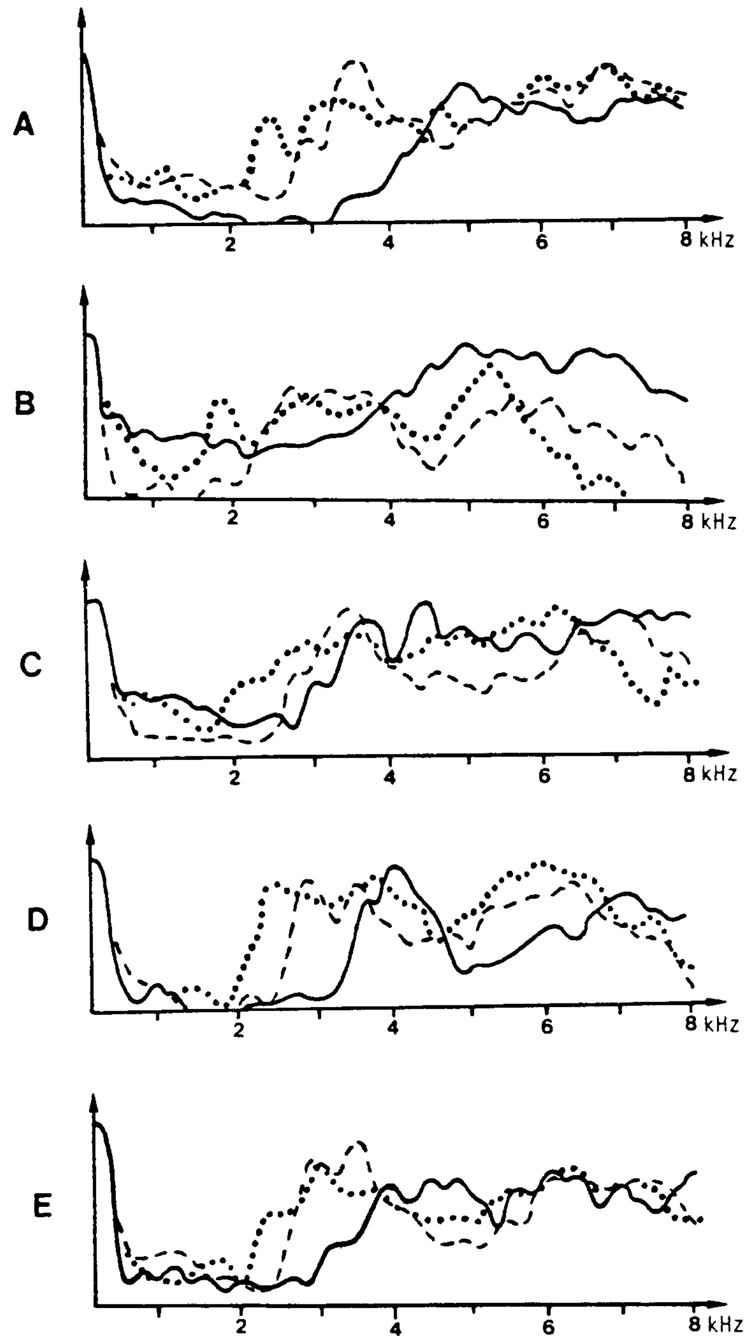


Figure 5.22. Spectra of Swedish s (solid line), ɕ (dashed line), and ʂ (dotted line) before ɑ:, as produced by five speakers A-E. (After Lindblad 1983.)

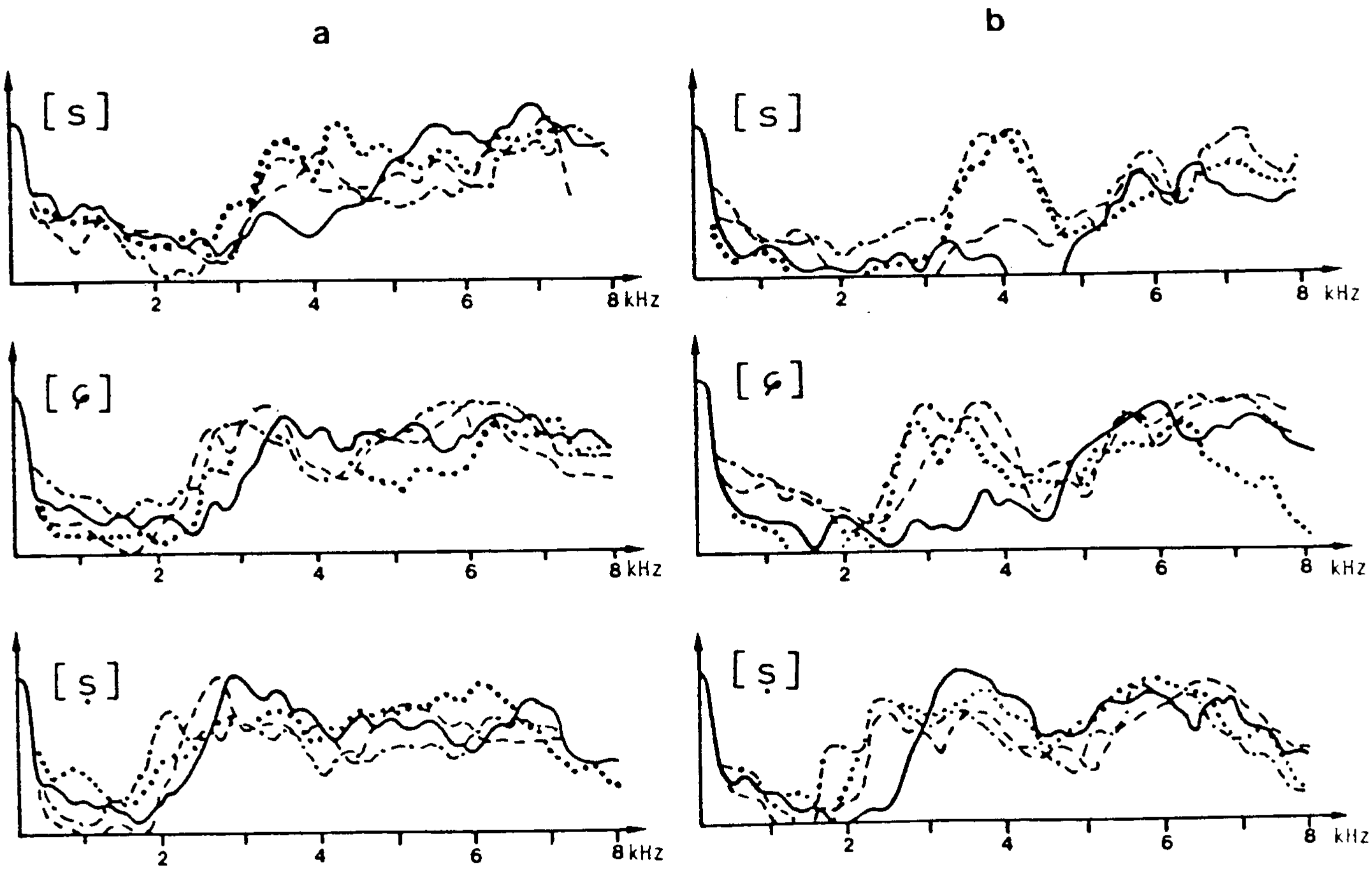


Figure 5.23. Spectra of Swedish s, ɕ and ʂ before iː (solid line), yː (dashed line), ɑː (dotted line), and uː (dashed and dotted line), as produced by two speakers A and B. (After Lindblad 1983.)

The second common variant of Swedish /ʃ/, which we will symbolize by χ, is described by Lindblad as a "dorsovelar voiceless fricative" pronounced with the jaw more open and without the lip protrusion that occurs in ɧ. Lindblad suggests that the difference between χ (which he, somewhat confusingly, transcribes as ɧ) and the more usual velar fricative x is that the latter "is formed with low frequency irregular vibrations in the saliva at the constriction" (Lindblad 1983, our translation). We infer from his descriptions and diagrams that the Swedish χ variant has less friction, and may be slightly further forward than the velar fricative x commonly found in other languages. Lindblad claims that between the extreme positions of the labiodental ɧ and the more velar χ, "there are a number of intermediate types with various jaw and lip positions, including some with both anterior and posterior sound sources. He suggests that there are many varieties of Swedish /ʃ/ pronunciations along this scale, noting that "traditional descriptions have ascribed separate points of articulation to individual sound types rather than describe the entire scale."

Lindblad provides two different kinds of acoustic data on Swedish fricatives. One is the analysis of a subset of these fricatives as they occur in different phonetic contexts, and as spoken by different individuals. The other is an analysis of a wider range of Swedish fricatives as spoken by himself as an illustration of archetypal productions ("cardinal" versions) of these sounds. His analysis of s,ɕ,ʂ as spoken by five different speakers is reproduced here in a slightly modified form in figure 5.22. There are large variations among the speakers, but it is true that for each of them ʂ has the lowest cut off frequency, ɕ the next, and s the highest. There are also very considerable contextual effects, as may be seen from figure 5.23, which shows these same fricatives as pronounced by two of the speakers in a variety of vowel contexts. For any one vowel context the spectral relations among s, ɕ, ʂ are similar to those described above when they occurred before a. But the variations in the spectrum of each of these fricatives before different vowels are enormous. Figures 5.22 and 5.23 provide good evidence of the difficulty of characterizing fricatives in acoustic terms. (As we noted above, many years ago Hughes and Halle (1956) reported similar cross-speaker differences and within speaker consistencies in their analysis of English fricatives.)

Discussion of the second kind of acoustic data provided by Lindblad moves us closer to the final kind of acoustic data we will discuss in this chapter. All the acoustic analyses of fricatives that we have discussed so far have used real language data. Data of this kind has the advantage that it reflects what is important for making a contrast within a particular language. But it has the disadvantage that when we use it for comparing sounds in different languages or dialects we are inevitably comparing different speakers as well. An alternative technique for comparing a wide range of fricatives is to analyze samples produced by phoneticians making what they consider to be typical examples of each different fricative. Samples of this kind are inevitably suspect unless the phoneticians are trying to mimic what they hear in each of a number of diferent languages, and even then they may not reflect what native speakers of different languages might make. Phoneticians who imitate, for example, β as in Ewe, and v as in English, will not be making the contrast between β and v that occurs in Ewe, in that they will not be raising the upper lip in v as is necessary in Ewe. But we may presume that this kind of problem will not arise when a phonetician such as Lindblad produces the sounds that occur in different contexts and dialects in Swedish.

Lindblad's demonstrations of his own pronunciations of some of the fricatives that occur in different Swedish dialects are shown in figure 5.24. He notes that these sounds may be characterized to a great extent by the frequency of the lower edge of the band of fricative noise. For the three sibilants s, ʂ, ʃ on the left of the figure, this frequency gradually descends. (It is somewhat surprising that it should be lower in ʃ, than in ʂ.) In the palatalized postalveolar sibilant ɕ in the lower left of the figure there is a less sharp lower frequency cut off, as there is in the palatal fricative ç opposite it on the lower right side; ɕ differs from ç by having a higher mean spectral energy. The rounded fricatives in the upper right part of the figure have a strong low frequency peak. Both ʃw and ɧ also have a low frequency peak, as well as a considerable amount of energy in the region just above 4 kHz.

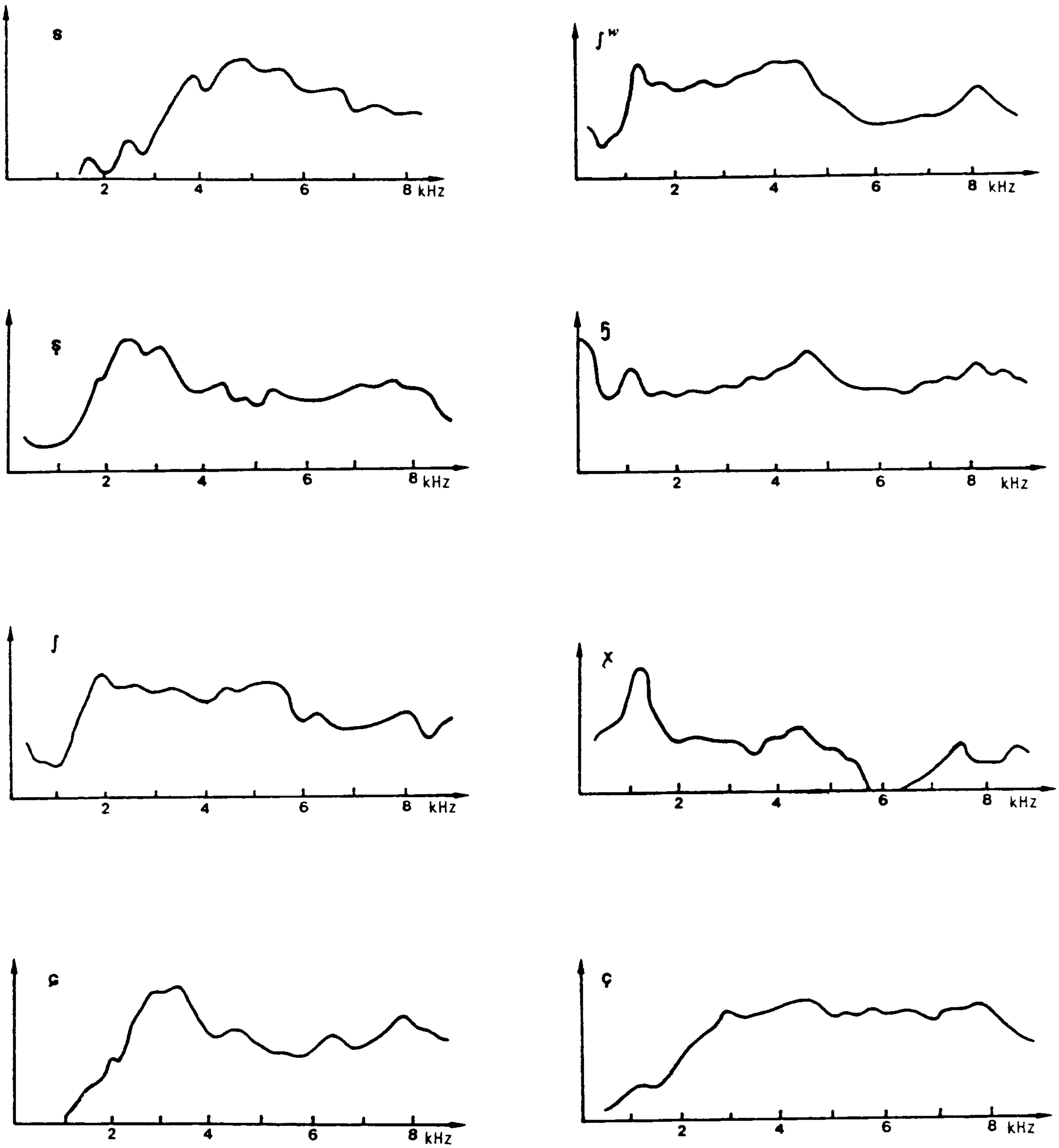


Figure 5.24. The fricatives that occur in different Swedish dialects as prononounced in their "cardinal" versions by Lindblad (1983). Note that Lindblad uses different symbols, substituting ɰ for the sound which we, following the more usual Swedish literature, have symbolized as ɧ, and using ɧ for the more nearly velar fricative which we symbolize by χ.

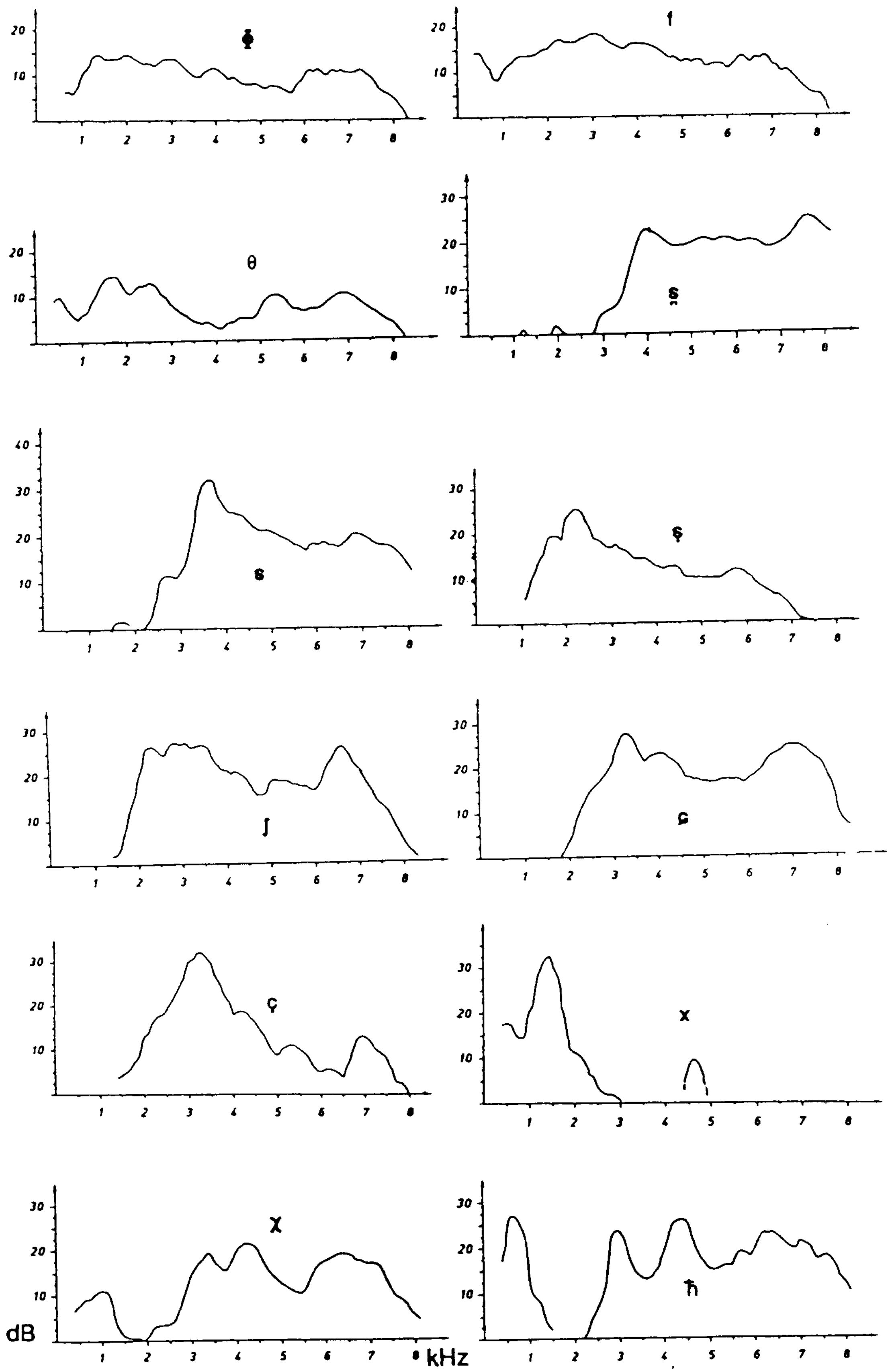


Figure 5.25. Spectra of 12 fricatives as produced by Jassem (1968).

Other examples of the study of fricatives as produced by phoneticians include Strevens (1960) and Jassem (1962). More recently Shadle (1985) has analyzed sustained productions of the fricatives ɸ,θ,f,s,ʃ,x as spoken by three male and three female "phoneticians or speech researchers familiar with the phonemes." She again found "tremendous variation in spectral shape " between speakers. A comparison of a larger range of sounds is presented by Jassem (1968), who considered the acoustic structure of a number of fricatives in different languages. Spectra of 12 of these sounds are reproduced in figure 5.25. When considering Jassem's findings, it must be remembered (as he himself emphasizes) that the data represent fricatives as produced by only a single speaker; but, nevertheless, this speaker (Jassem himself) is "well acquainted with these sounds through contact with languages in which they occur and/or through exhaustive phonetic training" (Jassem 1968). There is little more that we need say about ɸ,f,θ, apart from noting their comparatively flat spectrum. All the sibilants have a relatively sharp low frequency cut off that is higher in frequency in proportion as the sibilant is more front in articulation (as we have seen in other analyses, such as Catford, in progress, and Lindblad 1983).The palatal fricative, ç, is marked by a particularly large spectral peak, which is much more localized in Jassem's data than Lindblad's data shown in figure 5.24. The more back fricatives, x,χ,ħ, have a spectral peak that decreases in frequency as the place of articulation approaches the glottis, and additional peaks in the higher part of the spectrum.

Phonological features for fricatives

We will now consider how all these fricatives can be classified within each language in terms of features. We will start by considering the features that are necessary to classify fricatives as distinct from other sounds. Then, assuming the validity of the distinction between sibilants and non-sibilants within the class of fricatives, we will go on to assess the adequacy of the place features discussed in the previous chapter for making further distinctions among fricatives.

Chomsky and Halle (1968) distinguish fricatives from oral and nasal stops by means of the feature continuant. Fricatives are distinguished from other continuant sounds such as vowels, semivowels, and laterals, by other features such as consonantal and lateral. In their system there is no explicit recognition of friction as a phonetic property. An alternative proposal by Ladefoged (1982) divides segments into stops (complete closure in the vocal tract), fricatives (the vocal tract having a constriction such that a turbulent airstream is formed), and approximants (all other sounds). This proposal can be accommodated within the Chomsky-Halle framework by simply adding a binary feature: fricative. There would then be some redundancy in feature specifications, but this would be counterbalanced by it no longer being necessary to include the feature consonantal, as all non-consonantal sounds would be [-stop, -fricative]. Within current CV theory, this feature is in any case regarded as having a different status, so that it is considered to be a marker of a slot that can be filled by certain classes of segments. Thus consonantal is more like a cover feature that has no specific phonetic property but is defined in terms of particular combinations of values of other feaures. We will not pursue this notion further, as discussions of phonological considerations of this sort are outside the scope of this book. However we must note that classifying fricatives by means of a binary feature would not allow a formal way of showing that the process of going from a stop to a fricative is an articulatory weakening that is similar to the process of going from a fricative to an approximant. The ternary system stop-fricative-approximant makes this explicit.

The class of sounds that we call fricative is divided by Chomsky and Halle into two classes by means of the feature strident. Both from a phonological and from a phonetic point of view, the more appropriate division is into sibilant (obstacle) and non-sibilant (non-obstacle) fricatives. We can see no reason for grouping f,v along with s,z,ʃ,ʒ and other obstacle fricatives. It is far preferable to divide fricatives into sibilants and non-sibilants as indicated at the beginning of this chapter in table 5.1. In passing, we should note that this division, which is based on the articulatory distinction of whether friction is generated by a downstream obstacle or not, differs from some previous divisions in which sibilants are defined in acoustic terms (Ladefoged 1971, 1982). Any definition that relies on the fact that sibilants have a comparatively large amount of energy in the upper part of the spectrum will have problems in avoiding classifying palatal (non-obstacle) fricatives along with the sibilants. This seems inadvisable from a phonological point of view. In German, for example, the palatal fricative ç does not pattern with the sibilants s,z,ts,ʃ in forming plurals and singular genitives.

The further differentiation of fricative sounds involves what is traditionally called the place of articulation. As we noted in the last chapter, the place features can be thought of as specifying the direction of the movement, and the shape of the moving articulator. For many non-obstacle fricatives, the direction of the movement and the general cavity shape is much the same as in the corresponding stop. However, the extent of the movement and its temporal organization is always very different, and will require the specification of a separate, intrinsic, timing pattern. It is precisely these aspects of the sound that are taken into account by classifying it as a fricative.

The place of articulation features discussed in the last chapter can be used in a fairly straightforward way for classifying the articulatory gestures in most non-sibilant fricatives. The only additional gesture that we have to take into account is that required for pharyngeal fricatives. Chomsky and Halle distinguish pharyngeal sounds from uvular sounds by means of the feature low. We do not know exactly how they would distinguish pharyngeal from epiglottal fricatives, as may be necessary in some Caucasian languages. For us, pharyngeal is simply an additional member in the set of possible places of articulation.

In the previous chapter we noted the marginal status of labiodental stops. In the case of fricatives there is no doubt that we need to distinguish between bilabial and labiodental gestures. Chomsky and Halle do this by means of the feature distributed. We can see no phonological motivation for this feature, which groups ɸ,s,ʃ together as distributed sounds, and f,θ,ʂ as non-distributed. We think it preferable to simply add the bilabial-labiodental distinction as a new feature, if one is operating within a binary feature system. In a theory in which the notion of phonetic adjacency is more highly valued than the notion of binarity, labiodental would be regarded (as in the previous chapter) as simply a member of the set of possible places.

The distinction between bilabial and labiodental fricatives provides an interesting example of a problem that occurs when we compare sounds in different languages. In what sense can we say that English labiodental f is the same as Ewe f ? There are clear, consistent, differences in their articulation. Speakers of English do not raise the upper lip in the way that is the required norm in Ewe; in fact many speakers of English realize the phoneme /f/ in a way that is very similar to Ewe ɸ. There is a continuum between bilabial and labiodental fricatives, and Ewe f is at a different place from English f on this continuum. The solution to this problem is, of course, explicit within the theory proposed by Chomsky and Halle (1968), who would consider the difference between English f and Ewe f to be a low level phonetic difference in the value of the feature [distributed]. As we have noted, we are not sure of the validity of this particular feature; but, whatever set of features we adopt, it must allow us to distinguish labiodental gestures from bilabial gestures in scalar terms.

We cannot distinguish different sibilant fricatives from one another by means of the places of articulation used for differentiating stops. These place of articulation features are neither sufficient nor appropriate because it is no longer true that the place of articulation necessarily specifies a direction of movement and a cavity shape similar to that in the corresponding stop. In some sibilants such as s there is a deep groove in the tongue, in others such as English ʃ there is a raising of the front of the tongue, and in yet others such as Polish ʂ neither of these tongue shapes occurs. We propose that the phonological classification of fricatives will require, in addition to the feature fricative itself, the feature sibilant, all the place of articulation possibilities discussed in the previous chapter, supplemented by pharyngeal, and a method of separating the four possible postalveolar sibilants. Three of the postalveolar sibilants can be distinguished by a three valued feature indicating whether the tongue is flat, domed, or palatalized. The fourth requires an additional feature specifying that it differs from the other three by being "closed" (i.e. having no sublingual cavity).

These considerations have implications for the notions that we were discussing in the previous chapter. There we were suggesting that the traditional "place of articulation" term could be considered as specifying both the target region and the primary shape of the moving articulator. If we retain this notion, which seems to us to be a very necessary part of any phonetic theory, then the place features have to be given a different articulatory interpretation when they occur in combination with different manners of articulation. The fact that two different fricatives can have the same "place of articulation" shows that the place of articulation terms do not fully specify the articulatory gestures involved. Putting this another way, we can say that a term such as "alveolar" implies one kind of articulatory shape when applied to a sibilant fricative and another when applied to a non-sibilant fricative. We could, as an alternative, say that the term "sibilant" specifies the different articulatory shape that occurs. But, whichever way we do it, we have to use context restricted definitions of the features involved, if we want to specify all the phonetic information.

Alveolar (or [+anterior, +coronal]) does not mean the same thing in conjunction with sibilant and with stop. Similarly, when sibilant occurs in conjunction with alveolar one tongue shape is implied, whereas when it occurs in conjunction with postalveolar it implies another. It is true that all alveolar sounds have some things in common. As an abstract device in a phonological system, a feature such as alveolar can be used for classifying sounds irrespective of how they are classified in terms of other features. Similarly, sibilants can be said to have certain articulatory characteristics: they all have the jaw raised so that the upper and lower teeth are close together, and they all have a narrow articulatory channel that directs the air stream across the edges of the teeth. But the way in which the second of these characteristics is implemented depends on the "place of articulation" category. There is no algorithm that can be applied within a computer model of tongue shapes that will convert a sibilant to a non-sibilant irrespective of which place of articulation is specified. From an analytic point of view one can define the phonetic properties that a sound has to have if it is a sibilant, and those that it has to have if it has a particular place of articulation. But from a generative point of view these properties are not independent of one another.

6.

Laterals

In this chapter we will review all of the various types of segments which have a lateral component. Laterals are usually defined as those sounds which are produced with an occlusion somewhere along the mid-saggital line of the vocal tract but with airflow around one or both sides of the occlusion. We will define laterals slightly differently; they are sounds in which the tongue is contracted in such a way as to narrow its profile from side to side so that a greater volume of air flows around one or both sides than over the center of the tongue. In most laterals there is in fact no central escape of air, but our definition does not require the presence of a central occlusion. The common types of laterals, voiced lateral approximants, have traditionally been grouped with rhotics (r-sounds) under the name of 'liquids'. The core membership of the class of rhotics is formed by segments in which there is a single or repeated brief contact between the tongue and a point on the upper surface of the vocal tract, i.e. principally apical trills, taps and flaps. Laterals and rhotics are grouped together because they share certain phonetic and phonological similarities. Phonetically they are among the most sonorous of oral consonants. And liquids often form a special class in the phonotactics of a language; for example, segments of this class are often those with the greatest freedom to occur in consonant clusters (for more discussion of these similarities see Bhat 1978). We note the validity of the liquid grouping but have chosen to devote separate chapters to laterals and rhotics. Rhotics and related sounds are discussed in chapter 7.

Apart from the general phonetic and phonological similarities between laterals and r-sounds, there is another link between the two groups. Quite a few languages have a single underlying liquid phoneme which varies between a lateral and a rhotic pronunciation. The factors affecting the choice between these variants differ from language to language. When the variation is conditioned by vowel environment, there seems to be a trend for lateral productions to occur in the environment of back vowels, as in Nasioi (Hurd and Hurd 1966), Barasano (Stolte and Stolte 1971) and Tucano (West and Welch 1967). In Chumburung (Snider 1984) the phoneme / l / has a rhotic variant which occurs medially in words with narrowed pharynx (retracted tongue root) vowels. In other languages, for example, Korean (Cho 1967), the different pronunciations depend on position in the word or syllable. In yet others the lateral and rhotic pronunciations vary freely, as in several of the West African languages surveyed in Ladefoged (1968).

In these languages with only one liquid the lateral and rhotic variants often share the same manner of articulation, both being produced as flaps. But the majority of languages clearly

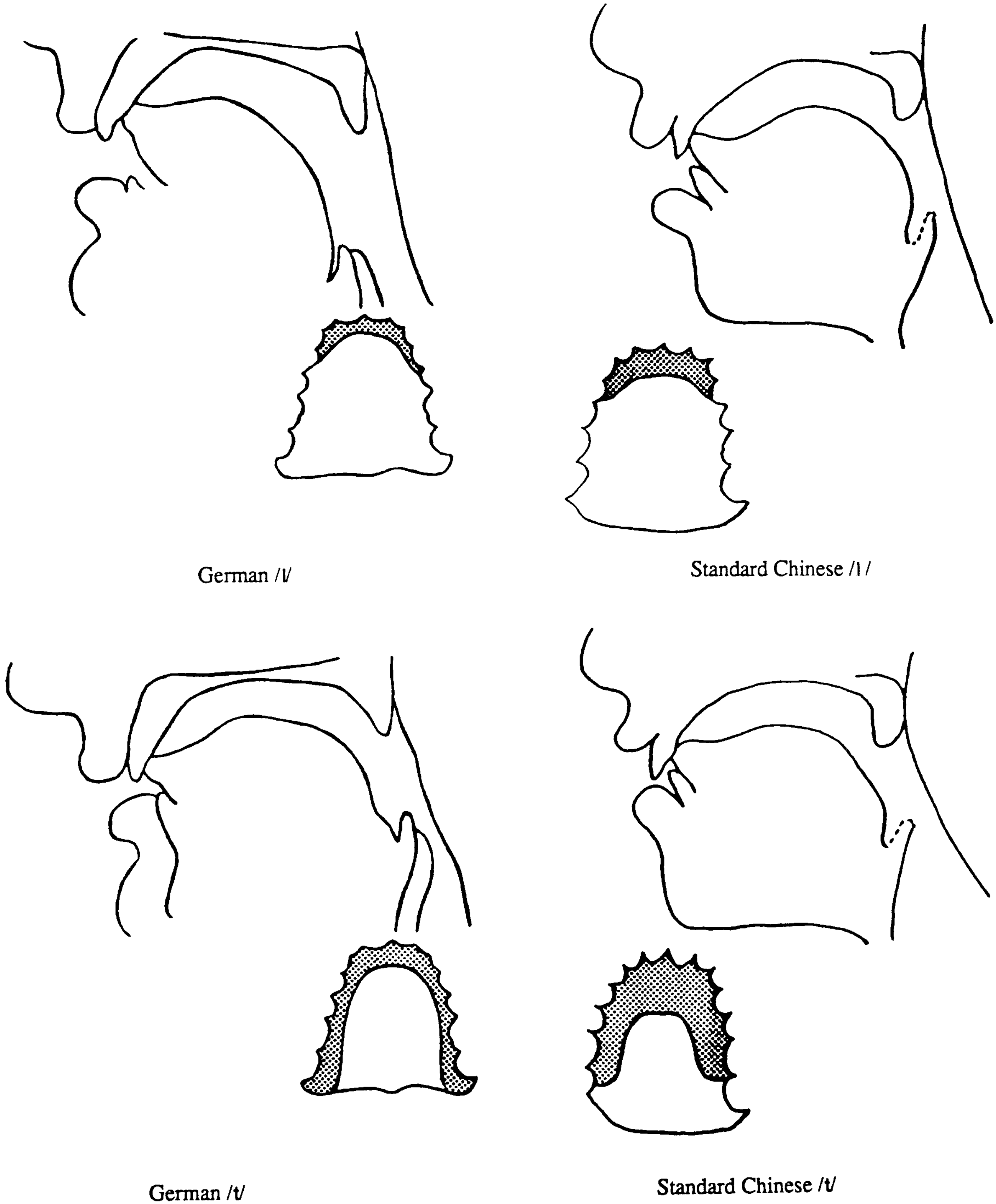


Figure 6.1. Radiograms and palatograms comparing articulatory positions for [l] and [t] in German and Standard Chinese (after Wangler 1961 and Zhou & Wu 1963).

distinguish lateral and rhotic sounds, most typically having one lexical segment in each of these classes. Our review of laterals will begin by discussing the articulatory and acoustic properties of the most frequent type of lateral, a voiced lateral approximant, before turning to other types of lateral segments, such as fricatives. A final section will discuss the issues concerning linguistic representation of laterals that are raised by our analysis of their phonetic nature.

6.1 Voiced Lateral approximants

Most lateral segments in the world's languages are made with an occlusion in the dental/alveolar region (Maddieson 1984). Palatographic and radiographic studies of several languages have shown that in many cases the occlusion is limited to a few mm on the alveolar ridge in the area behind the incisors and perhaps extending to the premolars. It does not extend back to the molar regions but instead the body of the tongue is relatively low in the mouth behind the closure, permitting lateral air escape as far forward as the front of the palatal region. Figure 6.1 compares the articulatory position for / l / with that for / t / for a German and a Standard Chinese speaker by means of palatograms and x-ray tracings from Wangler (1961) and Zhou and Wu (1963) respectively. The contact indicating sealing of the closure around the sides of the palate seen in the palatograms of / t / in the lower half of the figure is missing in the palatograms of / l /. The radiograms indicate that, although the tongue tip makes contact at a fairly similar location for / t / and / l /, the profile of the tongue behind the closure differs, so the tongue is lower in the mouth below the front palate area for the lateral. This low position facilitates the lateral escape of air. Similar differences in the tongue profile can be seen in published data on a number of other languages with dental or alveolar stops and laterals.

Though this articulatory pattern of a quite limited medial closure restricted to the front of the mouth is common for dental and alveolar laterals, it is by no means universal. The area of contact may extend further back in the mouth, meaning that the lateral escape is located further back, or the closure at the front may be incomplete. Balasubramanian (1972) includes palatograms of the long alveolar lateral / lː / of Tamil which show a more extended lateral contact on the right-hand side of the palate. Bolla (1981) shows bilateral contact back to the third molars for a Russian speaker. figure 6.2 shows retracings of three palatograms of a Gonja speaker (from Painter 1970) producing alveolar laterals. In each case, these laterals are produced with a small escape channel at the front to the left of the medial line. The main lateral escape is further back. In figure 6.2 (a) it is on the left in the mid-palatal region. In figure 6.2 (b) and (c) the escape around the oral obstruction is further back in the mouth than the palatogram is able to show. Dynamic palatographic records of a British English speaker published by Dent (1984) show contact maintained along the edges of the palate above the molar teeth and on both sides of the alveolar ridge in most instances of / l /, but during production of an / l / in the cluster / sl / a small central escape channel in the alveolar region remains open. Dent notes that this absence of medial closure occurs sometimes with two out of her three subjects but that the percept remains that of an authentic lateral. So we see that laterals do not always have complete medial closure. However, even when this is the case they have a larger escape channel further back

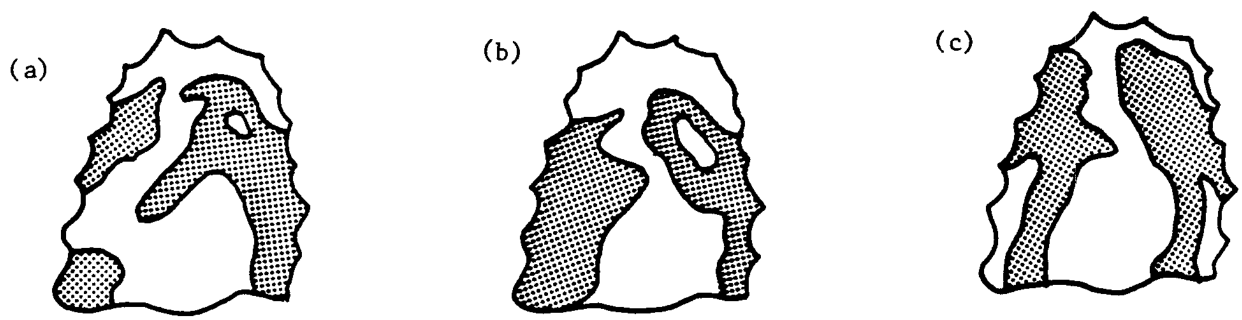


Figure 6.2. Palatograms showing contact area for three repetitions of /l/ by a Gonja speaker (after Painter 1970).

in the mouth. Note that the incompletely occluded laterals we have discussed are in syllable-initial positions, not in final position. We will return to the question of non-occluded laterals below in connection with the vocalization of postvocalic laterals.

First let us review what articulatory gestures are used in the production of laterals of the common voiced approximant type. We will do this by reference to the point of most forward contact of the tongue (more or less the traditional place of articulation) and to the part of the tongue that is involved. We will also discuss some questions concerning the shape of the remainder of the tongue where this is known. As in chapters 2, 4 and 5, we will begin by examining the differences between typical productions of contrasting lateral segments within a language and then building a composite picture of the range of contrasts that seems possible. The terminology for places of articulation will be that developed in these earlier chapters.

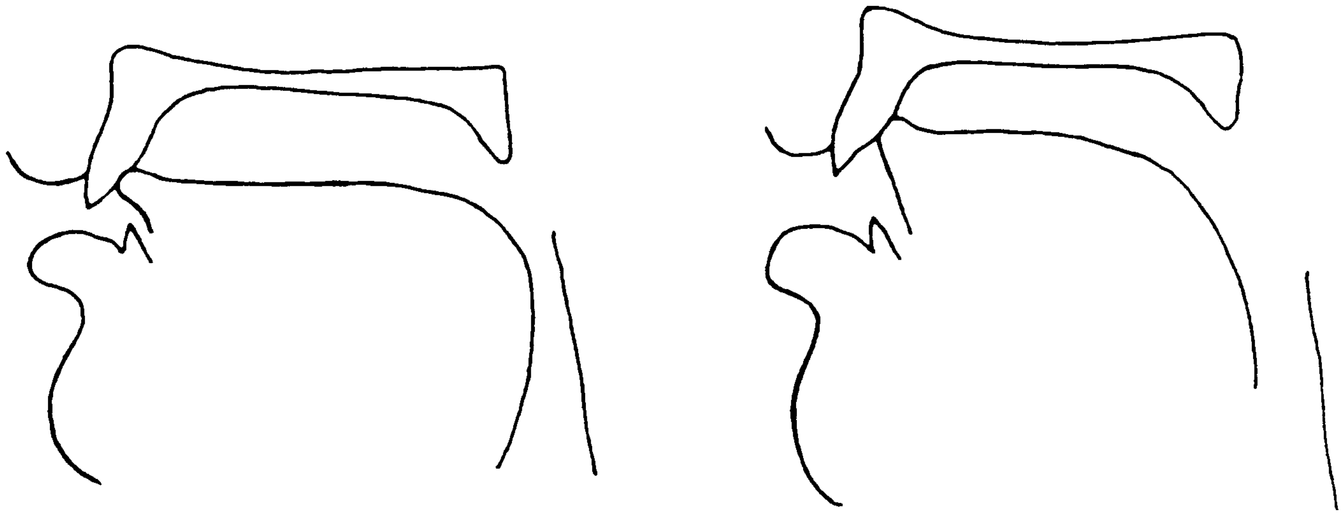
There are fewer places at which laterals are produced and fewer contrasts between laterals than is the case with stops or fricatives. The largest number of contrasting simple voiced lateral approximants known to occur in a language is four, as found in our own work on Kaititj (see below) and reported from several other Australian languages such as Pitta-Pitta (Blake 1979), Diyari (Austin 1981) and Arabana (Hercus 1972). Kaititj has laminal dental, apical alveolar, apical post-alveolar and laminal post-alveolar laterals. Examples of words containing these are given in table 6.1.

Table 6.1 Words illustrating contrasting laterals in Kaititj

	laminal dental		apical alveolar		apical post-alveolar		laminal post-alveolar	
	l̪		l		ḷ		l̠	
initial	l̪inp	'armpit'	lubiụ	'thigh'	ḷaɹ̣iŋk	'hit'	l̠ukuŋk	'light (fire)'
medial	al̪uŋ	'burrow'	aluŋk	'chase'	aḷat	'sacred board'	al̠ilk	'smooth'
final	aḷbal̪	'smoke'	irmal	'fire saw'	aldimaḷ	'west'	kural̠	'star'

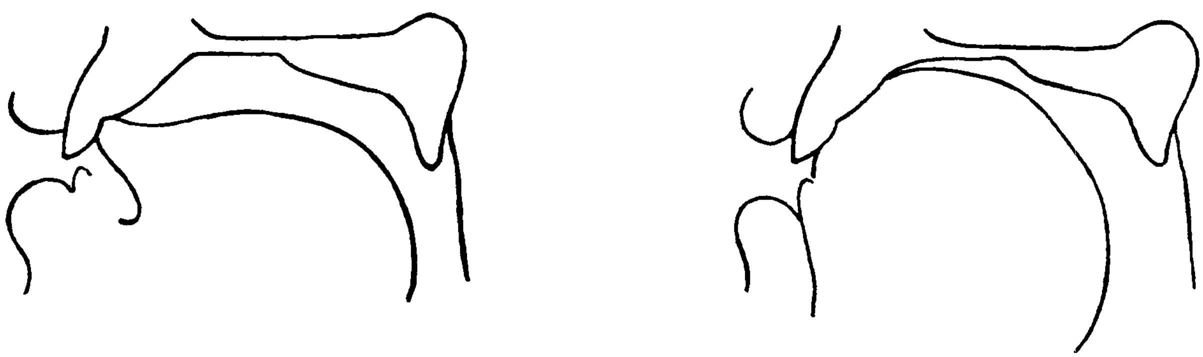
The number of languages which contrast simple voiced lateral approximants at three places of articulation is also relatively small, and many of these are also languages of Australia. Examples are Nunggubuyu, Alawa and Bardi. These languages lack the palatal lateral found in languages like Pitta-Pitta. The Papuan language Mid-Waghi, which will be discussed below, also has three places for laterals, as do a number of languages from other parts of the world, including the Argentinian language Mapuche (Araucanian) (Key 1978), and Eastern Ostyak (Gulya 1966). Languages with two laterals are much more frequently encountered; detailed articulatory phonetic information is available on some of these languages. Several of these throw interesting light on the role of tongue profile in contrasting articulatory gestures.

Radiographic studies (Bothorel 1970) indicate that Albanian has a distinction between what



(a) [l̪] in [hal̪a] "aunt"   (b) [l] in [pala] "pair"

Figure 6.3. Radiograms of (a) apical dental and (b) apical alveolar laterals in Albanian (after Bothorel 1970).



(a) [l] in [sala:n] "salads"   (b) [l̠] in [butal̠adu] "bottles"

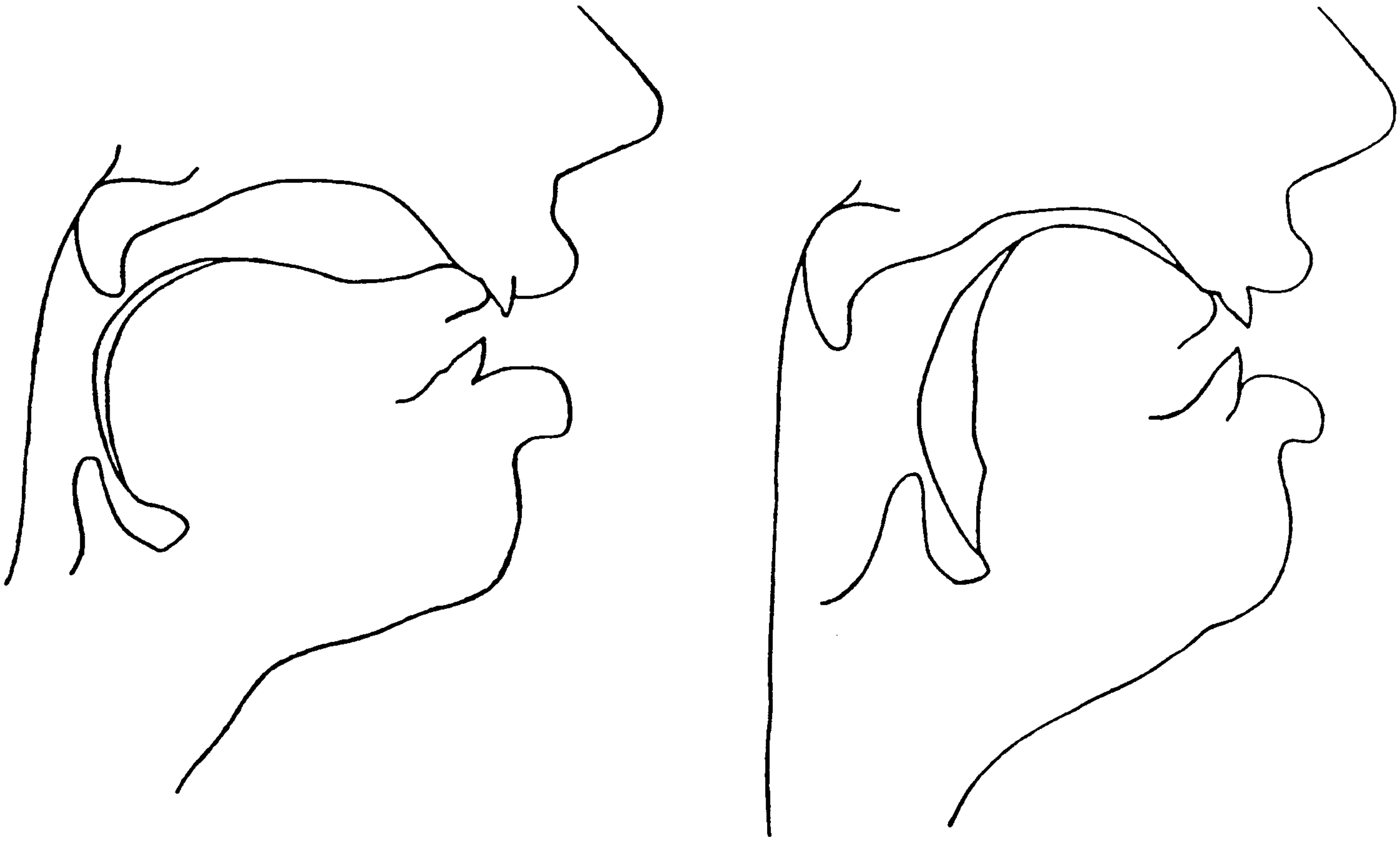
Figure 6.4. Radiograms of (a) apical dental and (b) laminal post-alveolar (palato-alveolar) laterals in Breton, Argol dialect (after Bothorel 1982).

might be labeled apical dental and apical alveolar laterals. Tracings of these are given in figure 6.3. Note that besides the different location of the 'place of articulation' there are several other differences between [l] in *pala* and [l̪] in *halla* in this figure. The back of the tongue is retracted for [l̪] so that a narrowed pharynx results, and the body of the tongue lies lower in the mouth than for [l]. The speaker represented in Dodi (1970) seems to have less of a place difference than the two speakers examined by Bothorel, but does show the difference in tongue profile. Stevens, Keyser and Kawasaki (1986) suggest that there is a general tendency for languages with a contrast of dental and alveolar segments to have a backed tongue position for the dental. They propose viewing the difference in tongue position as an "enhancing feature" for the phonological feature [distributed], whose values correspond in part to the distinction we are drawing between laminal ([-distributed]) and apical ([+distributed]). The Albanian laterals indicate that the dental vs alveolar place contrast can occur with the "enhancement" of different tongue positions but without differing by one being laminal and the other apical.

Laminal post-alveolar (palato-alveolar) laterals occur in limited surface contrast with apical alveolar laterals in the dialect of Breton spoken at Argol (Bothorel 1982). Sample radiograms of these sounds are shown in figure 6.4. The particular token of the apical lateral shown in this figure has a somewhat more forward position than those before other vowels and the tongue partly contacts the teeth. It was selected in order to show the two contrasting laterals of the language in similar vowel environments. The laminal postalveolars only occur after an actual or historical / i / and consequently have some similarities of tongue position to the high front tongue position for / i /. However, they cannot be regarded as simply the result of coarticulation since they do not necessarily occur next to an actual / i / vowel, as the example we have chosen shows.

The Breton laminal post-alveolar lateral tongue shape is in some respects quite similar to that seen in radiograms of the Russian "soft l" (Koneczna and Zawadowski 1956, Fant 1960, Jazic 1977, Bolla 1982, 1981), although in the Russian sound the contact is further forward. This Russian laminal lateral is commonly referred to as a palatalized version of the apical "hard" l, but as the example in figure 6.5 shows, the primary articulation itself differs for many speakers from that seen in the non-palatalized counterpart. For some speakers of Russian, the contrast can be described as between an apical and a laminal alveolar. For others, the contrast is between an apical alveolar and a laminal dental. In addition, there are differences in the position of the body of the tongue. The apical lateral in figure 6.5 (a) has some raising of the back of the tongue and considerable narrowing of the pharynx. For the laminal lateral in figure 6.5 (b) the highest point of the tongue is under the back of the palate and the pharynx is wide. In this case, tongue backing occurs with the segment that Stevens et al (1986) would call [-distributed], that is, with the one we would classify as [+laminal].

There is also a difference in primary place of articulation between the two laterals of Bulgarian. These are normally also treated as differentiated by presence or absence of palatalization, but in our view, the difference is really in the primary articulation, as in Russian. In the Bulgarian case, both the laterals are laminal. The radiograms and palatograms we have seen (Stojkov 1942, 1966), as well



(a) [l̺] in /lak/ "varnish"   (b) [l̻] in /l̻ina/ "line"

Figure 6.5. Radiograms of (a) apical alveolar and (b) laminal alveolar laterals in Russian (after Koneczna & Zawadowski 1956). The laminal articulation is the palatalized lateral phoneme /lʲ/.

(a) /l/   (b) /ʎ/

Figure 6.6. Palatograms of (a) apical alveolar and (b) laminal palatal laterals in Spanish, Standard Peninsular Castilian dialect (after Navarro Tomas 1968).

as the verbal descriptions by Stojkov, make it clear that Bulgarian / ɫ / is a laminal dental. Except before front vowels, the front of the tongue is low behind the occlusion and the back of the tongue is raised toward the velum. Its palatalized counterpart is laminal post-alveolar (palato-alveolar), and the body of the tongue is generally higher in the mouth, particularly in the front (although it seems less high than in the Breton case cited above).

The radiographic study by Jazic (1977) contrasts Russian and Serbo-Croation / ɫ /'s and their palatalized counterparts. For Serbo-Croation / lʲ / the occlusion is palato-alveolar, with the tongue body high and the pharynx wide. Serbo-Croatian / ɫ / has a low tongue profile but still a relatively wide pharynx, similar to that seen in the German and Breton radiograms in figures 6.1 and 6.4. Thus, phonological palatalization is not always accompanied by a big difference in pharynx width.

The extent to which different tongue profiles of the types seen in the contrasting laterals of Albanian, Breton, Russian, Bulgarian and Serbo-Croatian can be chosen independently of the tongue tip and blade activity is unclear. It seems reasonable to suppose that the choice of laminal or apical articulation restricts the freedom of position for the tongue body to some degree, and, conversely, that raising the front of the tongue favors laminal articulation, whereas lowering it favors apical articulation. The data we have seen suggests that wide pharynx and raised tongue front usually accompanies the laminal articulations, but Bulgarian shows that this is not invariably the case. The tongue profile may be more variable when the articulation is apical, but raising of the back of the tongue and/or narrowing of the pharynx are not uncommon. But there is unfortunately too little data available from too few languages to be sure how generally these observations apply. It would be nice to know, for example, if the tongue profile differences in Russian laterals are replicated in Diegueno (Langdon 1970). This is also a language with laterals with two types of articulation, in one of which "the apex [of the tongue] is raised to touch the alveolar ridge" while in the other "it is lowered to touch the back of the lower teeth with the blade contacting the alveolar ridge." However, Diegueno lacks the general phonological division of consonants into plain and palatalized classes which characterizes Russian and several of the other languages we have discussed here. We do not know if laminal alveolar or post-alveolar laterals occur without an accompanying raising of the tongue front which might be characterized as some form of 'palatalization'. Our examination of spectrograms of the Diegueno laminal lateral suggest that it is a palato-alveolar articulation, with a raised tongue position.

In any case, the pre-palatal laminal laterals we have been discussing so far can be distinguished from dorsal palatal laterals of the type found in, say, Italian in contrast with apical alveolars. In palatal laterals, contact is made between the tongue dorsum and the hard palate. Bladon and Carbonaro (1978) show the occlusion for Italian / ʎ / being made about two-thirds of the way back on the hard palate. In those dialects of Spanish which have a palatal lateral (principally those of European Spanish), the articulation seems to be a little further forward. The contact area is quite extended, as may be seen in figure 6.6 reproducing palatograms of Spanish / ɫ / and / ʎ / from Navarro Tomas (1968). A tracing of a radiogram of Spanish / ʎ / in Straka (1965) shows the tongue tip not making any contact with the teeth (as in the palatogram in fig 5.6), whereas one in Quilis (1963) shows an extension of the contact area all the way from the palate to the teeth.

Contrasts involving sublaminal post-alveolar (retroflex) laterals appear in Tamil, Malayalam, Toda and other Dravidian languages in which stops at this place of articulation occur. But most Dravidian languages have only two places of articulation for laterals, instead of the 6 or 7 places they have for stops. Svarny and Zvelebil (1955) publish palatograms and radiograms documenting the fact that Tamil and Telugu contrast apical alveolar and sublaminal retroflex laterals, with a tongue shape for the retroflex lateral very similar to that for the corresponding stops shown in figure 2.7. The contact for the retroflex lateral is on the hard palate, hence these sounds could be considered as produced with the 'apical' variety of the palatal place of articulation. Outside the Dravidian language family contrastive sublaminal retroflex laterals are not known for certain to occur, but, to judge from a sketch of the articulators in Gulya (1966), this type of retroflex lateral may occur in Eastern Ostyak, in contrast with both palatal and alveolar laterals. The retroflex laterals of the Australian languages are, as noted above, apical post-alveolars, as are those of the Indic languages with retroflex laterals, such as Panjabi.

The final place of articulation at which laterals are known to occur contrastively is velar. Velar laterals, not always of the voiced approximant type, appear in Melpa and Mid-Waghi in contrast with laterals at other places of articulation (Ladefoged, Cochran and Disner 1977), and in Kanite (Young 1962) and Yagaria (Renck 1975) as the only lateral segments. These are all languages of New Guinea, but velar laterals are reported also in Kotoko and possibly other East Chadic languages (Paul Newman, p.c.) and Hagege (1981) reports a voiced velar lateral in Comox. The description of this sound by Hagege is quite specific. He notes that the back of the tongue makes quite firm contact with the back of the velum and the sides of the tongue are lowered so that there is only weak friction and the sound is an approximant. Trager and Smith (1956) claim that velar laterals also occur in certain varieties of American and Scottish English, but no other observers have agreed with this claim. Words illustrating the 3 contrasting laterals which appear in Mid-Waghi, laminal dental, apical alveolar and (dorsal) velar, are shown in table 6.2. We use the symbol [ǥ] for a velar lateral approximant as suggested by Ladefoged et al. (1977). The acoustic character of these examples is discussed below.

Table 6.2. Words illustrating laterals in Mid-Waghi.

laminal dental	apical alveolar	(dorsal) velar
al̪a al̪a	alala	aǥaǥe
"again and again"	"speak incorrectly"	"dizzy"

The precise location of the contact and of the lateral escape channel for the velar cannot be recorded by direct palatography since the closure is too far back, but with an open vowel before and after a velar lateral it is possible to see both the central velar closure and the lateral opening simply by looking into the speaker's mouth. For the Mid-Waghi speaker we recorded, it was possible to see that the tongue was bunched up in the back of his mouth with the tip retracted from the lower front teeth. The body of the tongue was visibly narrowed in the central region, and presumbaly also further back where it could not be seen. The only articulatory contact was in the back of the velar region in much the same position as for a velar stop and, according to the speaker, air escaped around both sides of this contact in the region of the back molars. In addition, the auditory impression created by the brief stop closure which sometimes occurs before the lateral is clearly velar.

Production of uvular or epiglottal (pharyngeal) laterals by narrowing the tongue and using a medial occlusion formed with the uvula or the epiglottis respectively is not inconceivable; however, no such sounds are known to occur in any natural human language. Bilabial and labiodental approximants can be produced with a central occlusion and lateral airflow, but these seem to be indistinguishable from the corresponding central approximants. (In fact, for many English speakers the labiodental fricatives / f / and / v / are produced as what might by some definitions be lateral segments, since they have a closure in the midline.) Note that since we define laterals as involving narrowing of the tongue, these labial articulations are not laterals by our definition. On the other hand, laterals can be produced by an articulation involving the tongue and the upper lip. Linguo-labial laterals sound quite distinctive, but none of the languages that has developed this place of articulation has employed it in the production of lateral segments as far as we know.

We therefore have indications that there are nine 'places of articulation' used for laterals, as summarized in table 6.3. Of these nine places, eight participate in pairs that can be distinguished by the apical/laminal feature operating independently of other aspects of the place feature system, as described in chapter 2. Distributional facts concerning laterals in Australian languages (Dixon 1980) provide good evidence for treating the apical/laminal distinction as a separate feature. For example, in those languages with four laterals only the two apical laterals may appear as the first element of a medial consonant cluster.

Table 6.3. Places of articulation for laterals and examples of languages using them.

dental		alveolar		post-alveolar		palatal		velar
apical	laminal	apical	laminal	apical	laminal	sublaminal	laminal	
1	2	3	4	5	6	7	8	9
Albanian		Albanian		Panjabi		Malayalam		Mid-Waghi
	Kaititj		Russian		Bulgarian		Italian	

Voiced approximant lateral segments seem to be prone to considerable variation in their production. In English, for example, / l / is subject to considerable assimilatory effect from adjacent voiceless consonants (especially from preceding stops), considerable coarticulatory effect of adjacent vowels, and considerable variation attributable to effects of position in the syllable and morpheme (Lehiste 1964, Giles and Moll 1975, Bladon and Al-Bamerni 1976, Dent 1984, Gartenberg 1984). Large variation in the articulatory position for French / l /, including sublaminal palatal (retroflex) productions in various consonant sequences are documented by Rochette (1973). The resonant nature of laterals and their somewhat vowel-like acoustic structure seems to make coarticulated variation in their production quite noticeable, more so than might be the case with other classes of segments. However, just as we observed that apical laterals seem to have more cross-language variation in their articulation than laminal laterals do, there is also evidence that apical laterals are more subject to within-language coarticulatory variation than laminal ones. For example, Italian / l / shows much more variation, measured acoustically by variation in F2, with respect to both following and preceding vowel context than does / ʎ / (Bladon and Carbonaro 1978). Somewhat similarly, the laminal post-alveolar (palato-alveolar) lateral in Catalan varies less than the apical alveolar lateral, according to both dynamic palatographic and acoustic studies carried out by Recasens (1984a, b).

As we mentioned earlier, laterals may also be produced without a complete medial occlusion. Extremes of this process may be seen in languages such as English and Portuguese where completely unoccluded "laterals" occur in postvocalic positions. In some forms of British English, such as that spoken in London and much of southeast England, two quite different types of laterals must be distinguished. For syllable initial / l / the tip of the tongue touches the alveolar ridge and the tongue is narrowed so that there is no contact at one or both sides. In syllable-final / l / there is no alveolar contact and the tongue tip may be behind the lower front teeth. But there is still a narrowing of the tongue so that, by our definition, this segment is still a lateral. It seems as if the situation is similar in Portuguese. Feldman (1972) shows that the final allophone of / l / in certain varieties of Brazilian Portuguese is produced with no occlusion but with a marked raising of the tip of the tongue towards the alveolar ridge, where initial allophones of / l / would have a contact. This vestigial tongue-raising gesture, together with raising of the back of the tongue produces a segment which is acoustically very similar to [ɷ], and for some speakers of Brazilian Portuguese merges with that segment. Laterals of this type are likely to become simply vowels with the passage of time, but as long as the tongue narrowing gesture remains they are still correctly classed as laterals.

Acoustic characteristics of voiced lateral approximants

Canonical voiced lateral approximants are characterized acoustically by well-defined formant-like resonances. The first formant is typically rather low in frequency. The second formant may have a center frequency anywhere within a fairly wide range depending on the location of the occlusion and the profile of the tongue. The third formant has typically a relatively strong amplitude and high frequency; and there may also be several closely spaced additional formants above the frequency of F3. When a lateral is adjacent to vowels an abrupt change in formant location can often be observed both when the medial closure for the lateral is formed and when it is released, particularly if the articulation is apical. Laminal and dorsal laterals may have somewhat slower transitions from and to adjoining vowels. These properties can be seen by examining the spectrograms in figures 6.7 (Kaititj) and 6.8 (Mid-Waghi).

The first formant of lateral segments seems to remain quite uniformly low--typically below 400 Hz for male speakers. Fant (1960) and Bladon (1979) have suggested that F1 varies inversely with the cross-sectional area of the lateral passage. Accordingly, higher F1 for laminal and dorsal laterals is to be expected (since the body of the tongue is raised and the lateral passage consequently more constricted) than for apical and sublaminal laterals. Note that this proposed grouping of laterals on acoustic grounds has no parallel with the groupings established by acoustic properties of stops or nasals. We find at best partial confirmation of these theoretical claims in real language materials. We have data from two speakers of the Arandic languages with four laterals, one male speaker of Kaititj and one female speaker of Alyawarra. Both show a lower F1 in the laminal dental than in any of the other laterals, which appears contrary to Bladon, and it is difficult to be certain of the ranking of the other three laterals. Spectrograms of our Kaititj speaker are shown in figure 6.7. However, some other instances confirm the predictions. The laminal post-alveolar lateral of Breton has a lower range of F1 than the apical alveolar (Bothorel 1982), and the palatalized lateral of Bulgarian has an F1 100-150 Hz lower than the plain (apical) lateral (Tilkov 1979). Vages, Ferrero, Magno-Caldognetto and Lavagnoli (1978) show a mean F1 of 500 Hz for / l / and of 280 Hz for / ʎ / for ten speakers of Italian. The two laterals of Russian are, however, shown as having the same F1 by Zinder, Bondarko and Berbitskaja (1964), contra Fant (1960).

We would anticipate a high F1 for velar laterals following Bladon and Fant. And, in fact, in our materials from Mid-Waghi (one speaker) and Melpa (two speakers) the highest F1 in a lateral segment is observed in the velar lateral. The relatively high F1 for the velar lateral can be seen in the spectrograms of the three contrasting laterals in Mid-Waghi given in figure 6.8. It may also be noted that the velar laterals in Mid-Waghi are occasionally 'prestopped'. There is a brief velar stop closure preceding the first velar lateral in figure 6.8 (c), but the second is entirely approximant in nature.

For laterals without a secondary constriction involving the back of the tongue, the frequency of the second formant seems to be inversely related to the volume of the oral-pharyngeal cavity behind the articulatory occlusion (Bladon 1979). Measurements of F2 for the four laterals of Kaititj and Alyawarra, given in table 6.4, confirm this pattern. The pattern of relative height of F2 is similar for both speakers. It is lowest in the apical alveolar, approximately equal in the laminal dental and apical post-alveolar (retroflex) cases, and substantially higher in the case of the laminal post-alveolar (palato-alveolar) laterals, which have the smallest cavity behind the closure. The laminal dental and apical post-alveolar are presumably distinguishable by the decidedly lower F1 of the dental, as well as by different transitional characteristics.

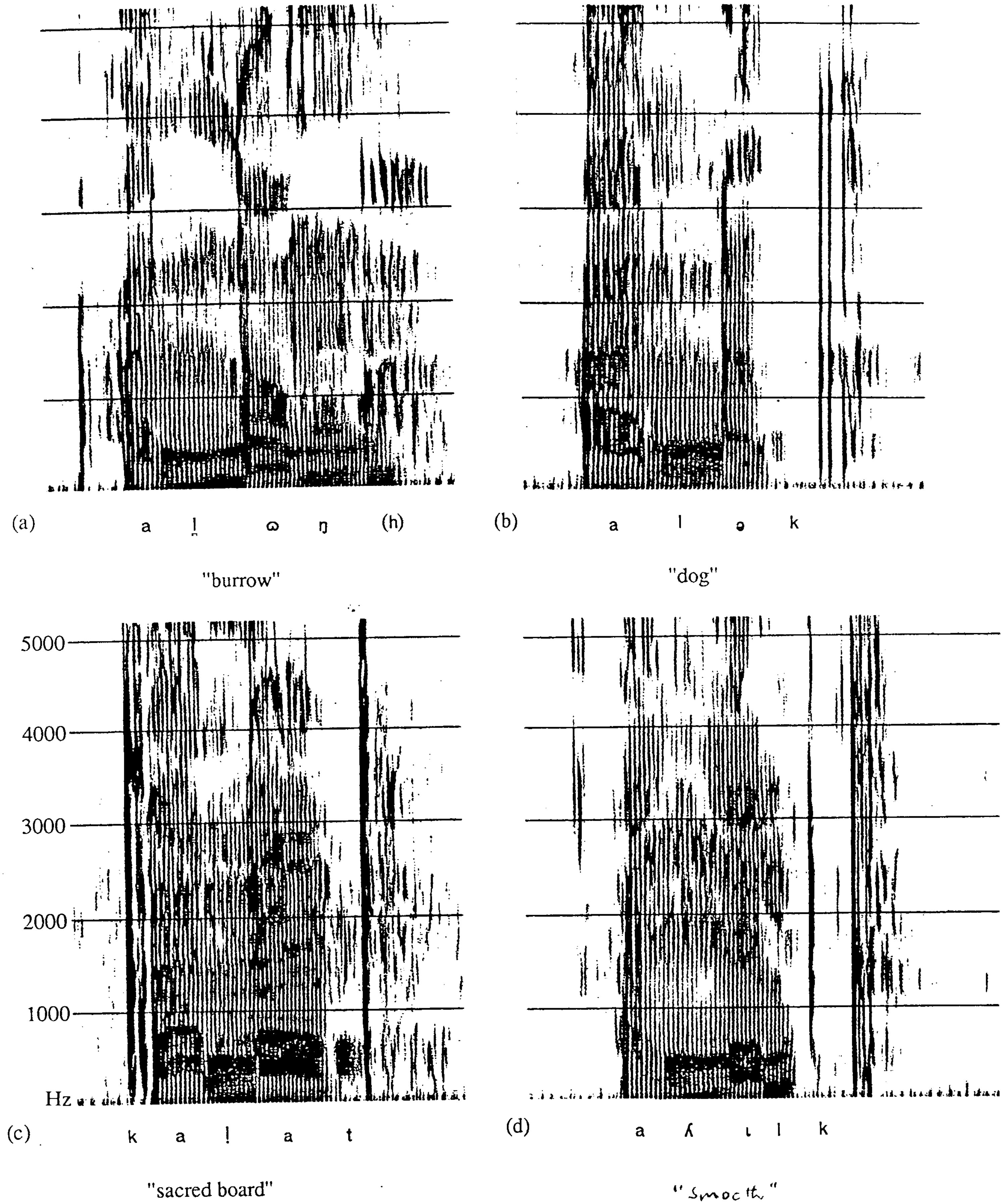


Figure 6.7. Spectrograms illustrating (a) laminal dental, (b) apical alveolar, (c) apical postalveolar and (d) laminal palatal laterals in Kaititj.

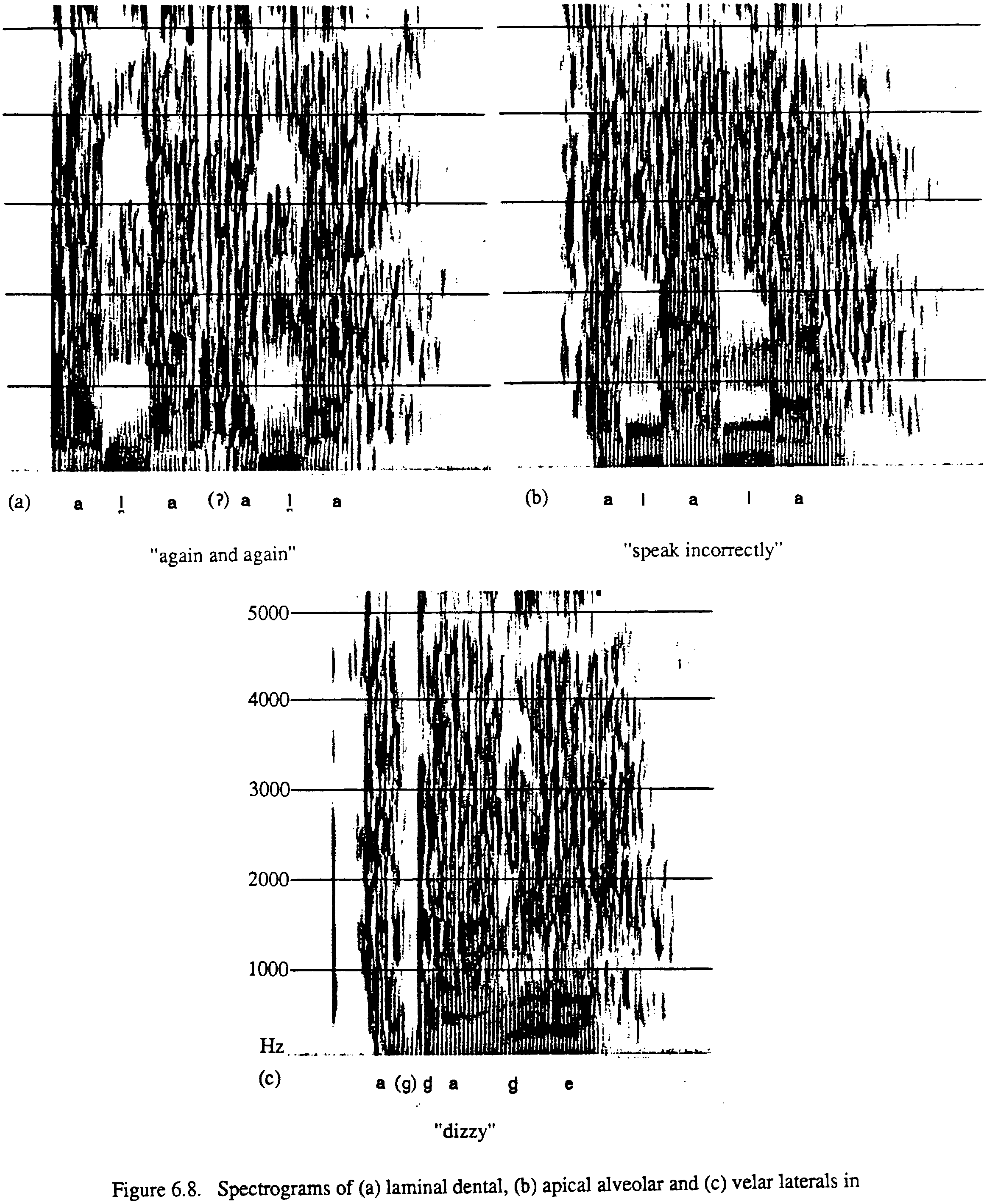


Figure 6.8. Spectrograms of (a) laminal dental, (b) apical alveolar and (c) velar laterals in Mid-Waghi.

Table 6.4. F2 in laterals of two Australian languages

	Kaititj (male)	Alyawarra (female)
apical alveolar	1225	1425
laminal dental	1350	1750
apical post-alveolar	1300	1800
laminal post-alveolar	1800	2250

In Melpa and Mid-Waghi the lowest F2 is again found in the apical alveolars, but F2 is lower in the velar laterals than in the laminal dental type, contrary to expectation. This may be seen for Mid-Waghi in figure 6.8. However, note that F2 is much higher in these velar laterals than it is in velarized alveolars (i.e. those in which the back of the tongue is partially raised toward the velum) as in Albanian, Bulgarian and Russian, for which values are given in table 6.5. Although one must be cautious in comparing data across different subjects, it does seem that F2 is lowest in apical laterals with an additional narrowing at the back. F2 will be lower the narrower this constriction becomes, as for the production of high back vowels.

Table 6.5. F2 in laterals differing in velarization.

	Russian	Bulgarian	Albanian
velarized / ɫ /	c 900	1000	950
contrasting lateral	c 2200	1800	1550

6.2. Other types of laterals

In addition to the common type of voiced lateral approximants, the following types of laterals are known to occur: voiceless lateral approximants and lateral approximants with a laryngealized or breathy voice quality, voiced lateral taps and flaps, voiced and voiceless lateral fricatives and affricates, and lateral clicks. Lateral clicks, like all clicks, may occur with a large number of different phonatory and articulatory acompaniments, and their production is discussed in chapter 8 together with clicks of other types. In the present chapter we will only give evidence of their contrast with other laterals. Lateral affricates and fricatives may be produced as ejectives. As with non-lateral fricated sounds, ejective affricates are encountered more frequently than ejective fricatives. Words exemplifying six contrasting types of laterals in Zulu, including voiced and voiceless lateral clicks, are given in table 6.6. Additional comments on these sounds and their transcription will be made below (except for the clicks).

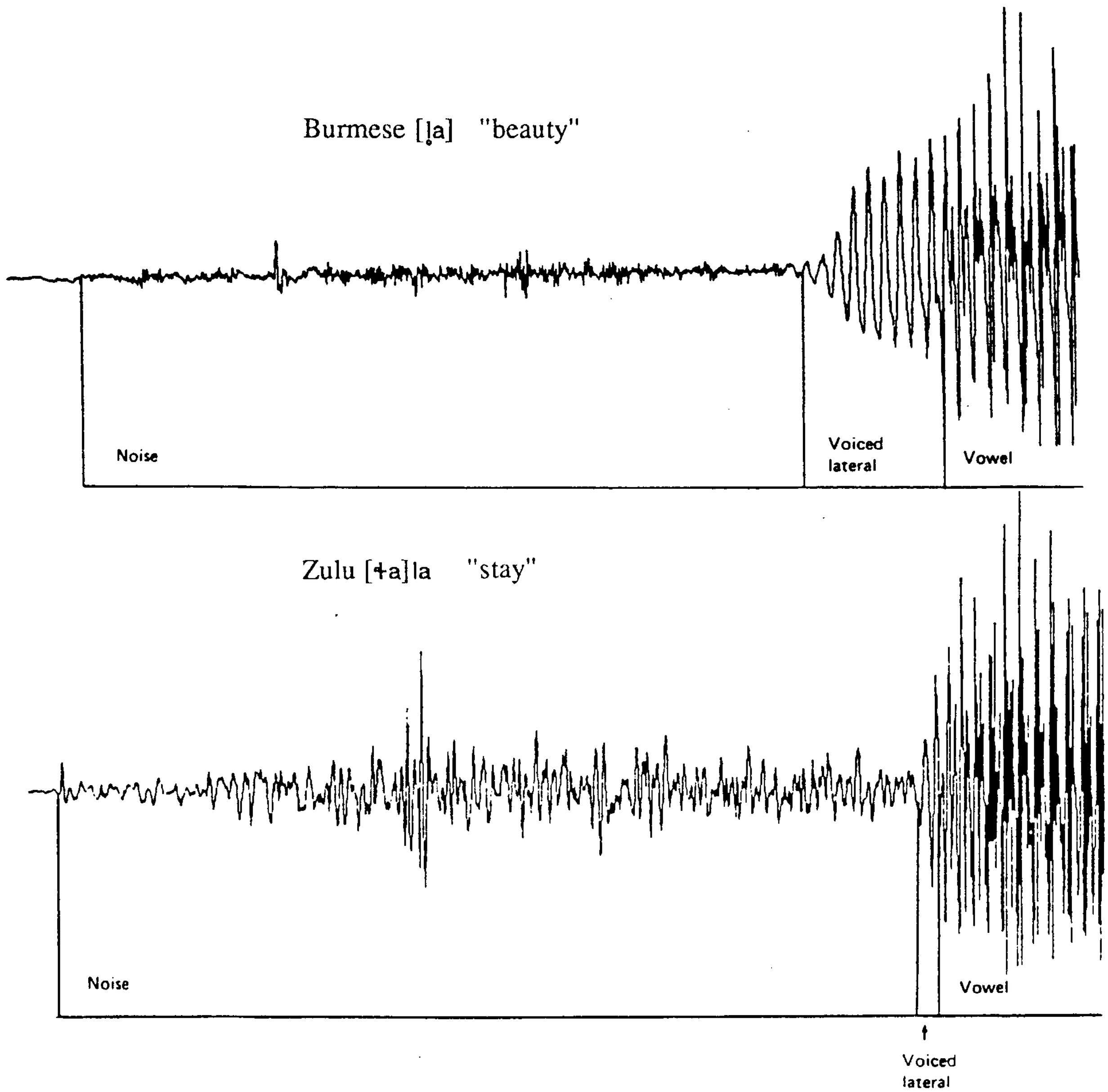


Figure 6.9. Waveforms illustrating the difference between (a) voiceless approximant lateral and (b) voiceless fricative lateral. Tokens of [l̥a] from Burmese and [ɬa], the first syllable of [ɬala], from Zulu showing noisy voiceless portion, voiced lateral transitional portion and the onset of the vowel.

Table 6.6 Lateral consonant types in Zulu

voiced alveolar lateral approximant	lálà	'lie down'
voiceless alveolar lateral fricative	ɬàɬá	'cut off'
voiced alveolar lateral fricative	ɮálà	'play'
voiceless alveolar lateral affricate	ínt͡ɬànt͡ɬà	'good fortune'
voiceless velar lateral ejective affricate	kʟ̥'èlá	'stand in line'
voiceless alveolar lateral click	ǁóǁà	'narrate'
voiced alveolar lateral click	ɡǁálà	'stride'

It is rare for laterals of the less usual types to be other than apical alveolar in their articulation, but, apart from flaps, which must be apical, this pattern of occurrence may be an accidental result of the relatively rarity of any of these segment types rather than because of any constraints on combining place and manner in laterals.

As we noted earlier, most lateral approximant segments are voiced, but they are also found with other phonation types. Voiceless lateral approximants occur as contrastive segments in languages such as Burmese, Tibetan, Klamath, Iaai, Kuy and some dialects of Irish. In some instances, linguists have chosen to regard such sounds as phonemically composed of either / l /+ / h /, as in Purnell's (1965) analysis of Mien (Yao), or of / h / + / l /, as Smith (1968) does for Sedang, but we believe these segments are in no way distinct from other voiceless lateral approximants. In the case of a substantial number of other languages the available descriptions do not specify if the voiceless laterals occurring in them are approximant or fricative in nature. Perhaps this is because there is a widespread tradition of regarding all voiceless laterals as fricatives, with turbulence necessarily resulting from the air passing through the lateral aperture (cf. Pike 1943). However, laterals can be articulated with a wide enough passage to permit non-turbulent airflow. And voiceless lateral approximants are distinguishable acoustically from voiceless lateral fricatives in a number of different ways (Maddieson and Emmorey 1984). The voiceless approximants typically have a lower amplitude of noise, a greater tendency to anticipate the voicing of a following vowel, and a concentration of energy lower in the spectrum than voiceless fricative laterals do. Waveforms of tokens from Burmese and Zulu illustrating some of these differences are given in figure 6.9. We do not know of a language with a minimal contrast between these segments but both types may appear in the same language. Hupa (Golla 1960) has the allophone [l̥] after / h / in the word /tʃ'ahl / 'frog' as well the fricative / ɬ /, e.g. in / mɯɬ / 'when'. It is not unusual for lateral approximants to become substantially devoiced in clusters with voiceless segments, or in final position. All three lateral segments in Melpa and Mid-Waghi devoice in final position, as noted in the Melpa examples given in table 6.7, but in these languages the results of this devoicing process are best described as lateral fricatives.

Table 6.7 Devoicing (and frication) of final laterals in Melpa.

	laminal dental		apical alveolar		velar	
medial	kial̪tɨm	'fingernail'	lola	'speak improperly'	paʟa	'fence'
final	waɬ̪	'knitted bag'	baɬ	'apron'	raɬ	'two'

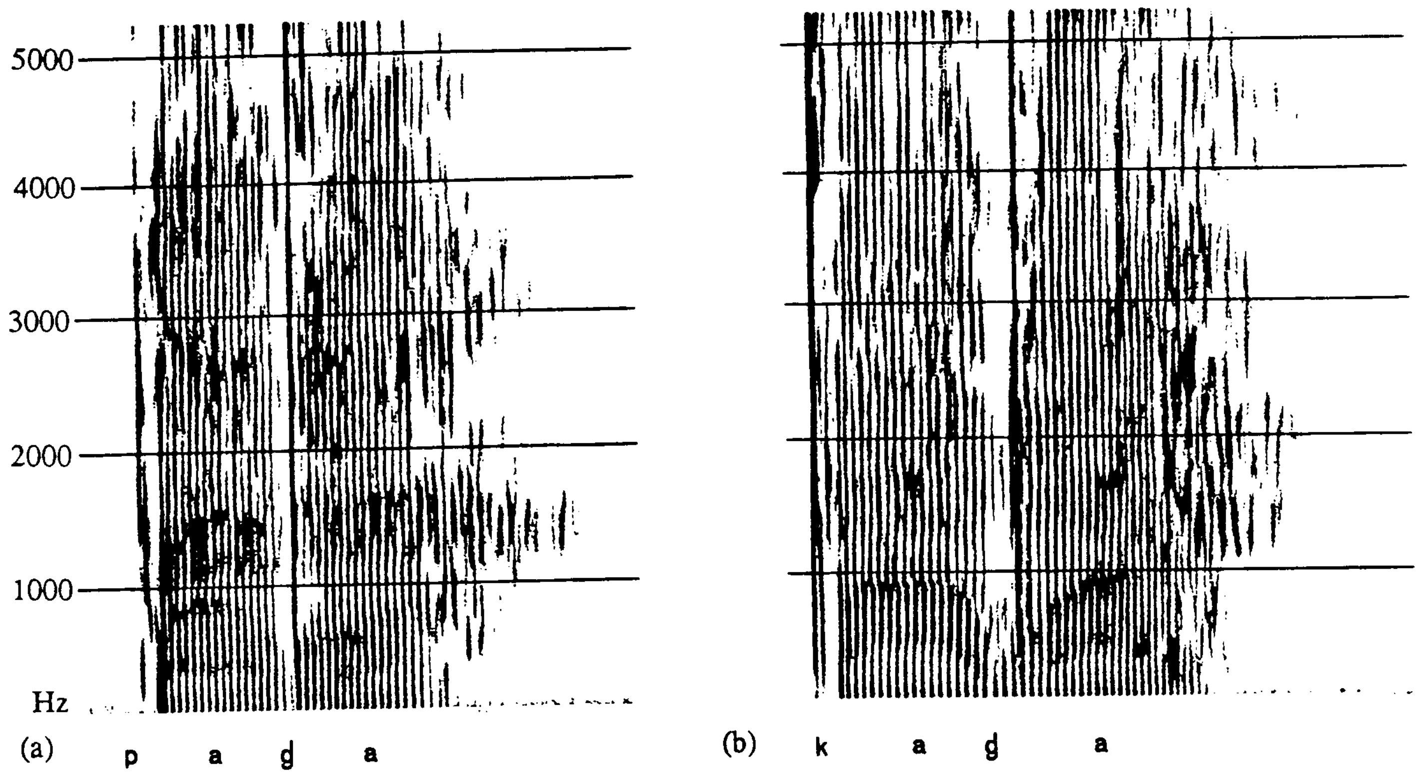
We know of few languages in which voiceless lateral approximants occur at other than alveolar place. However, according to Ozanne-Rivierre (1976), a voiceless apical postalveolar (retroflex) lateral occurs in Iaai, contrasting with its voiced counterpart. As seems to be the usual pattern for languages with voiceless lateral approximants, there are also voiceless nasals in Iaai.

Laryngealized lateral continuants occur in several languages, such as Tiddim Chin, Nez Perce, Chemehuevi, Haida, Sedang and Klamath. These last two languages thus have a three-way contrast of voice quality in laterals, having voiced, voiceless and laryngealized lateral approximants. A laryngealized lateral from Columbian Salish was illustrated in figure 4.2. Hindi is often considered to have a phonemic contrast of plain and breathy voiced lateral approximants, though Ohala (1983) suggests that [l̤] should be regarded as a sequence / l h / principally because breathy voiced liquids and nasals are limited to medial position. Dixit (1975) showed that although vocal cord vibration continues throughout this segment, there is also a glottal opening gesture. This gesture starts after the oral closure for the lateral is formed, and peaks some 40 msec after the release. In broad terms, this relative timing pattern is similar to that seen for breathy voiced consonants of other types in intervocalic position, hence we consider [l̤] a genuine lexical segment of Hindi. Although they have not been studied in such detail in any other language, breathy voiced laterals occur in several other Indo-Aryan languages and in several languages in the Wu and Yue groups of Chinese dialects, for example in Rongxian (Tsuji 1980).

Manner contrasts in laterals include the occurrence of flaps and taps. These are two types of segments in which the articulators make only brief contact. Ladefoged (1971) suggests that there are only flaps, not taps, among laterals. Although flaps, generally with a post-alveolar contact, are probably more frequent, there seems no reason to doubt that segments which should be called lateral taps do occur. As Ladefoged (1971) notes

> "a flap is an articulation which usually involves curling the tip of the tongue up and back and then allowing it to hit the roof of the mouth as it returns to a position behind the lower teeth. A flap is therefore distinguished from a tap by having one articulator strike against another in passing while on its way back to its rest position, as opposed to striking immediately after leaving its rest position." (p. 50-51).

The velar laterals in Kanite and Melpa, samples of which are illustrated in the spectrograms in figure



"fence" "dog"

Figure 6.10. Spectrograms illustrating velar lateral taps in (a) Melpa and (b) Kanite.

6.10, are very brief and they can only be described as taps (since flaps cannot be produced by the back of the tongue). We have used the same symbol for these as for velar approximant laterals. Elugbe (1978) suggests that alveolar lateral taps occur in Ghotuo and Abua (as well as a number of other Nigerian languages for which he has only secondary data). In these languages there is a contrast between an alveolar lateral approximant of normal duration, and an alveolar lateral of brief duration that forms part of a series of lenis consonants in the phonological structure of these languages. Elugbe states that the formant frequencies of both the laterals are the same; however, in the one published pair of spectrograms this does not seem to be the case. In particular, F2 seems lower in the brief lateral than it is in the longer one. We are therefore not sure if the description of these as taps, rather than flaps is correct.

The lateral segments of brief duration which occur in other languages are most commonly reported as flaps, but we are rarely sure that the authors of these reports have in mind the same distinction between flap and tap that we are using. We have encountered lateral flaps first hand in several languages. For example, one occurs in Chaga in contrast with what seem to be only one other lateral phoneme, albeit one which has rather varied allophones. Chaga (at least the KiVunjo dialect represented in our data) has a lateral approximant which is most typically laminal dental. In most vowel contexts this has a rather low F2 suggesting possibly some velarization, but before / i / it becomes a palato-alveolar or palatal lateral with a considerably higher F2. Before [j] a laminal alveolar lateral with some palatalization occurs. This lateral approximant is in contrast with an apical alveolar lateral flap [ɺ]. This segment varies acoustically depending on segmental context less than / l / does. The three major allophones of / l / and the flap / ɺ / are shown in the spectrograms in figure 6.11. We also have seen and heard production of an apical post-alveolar lateral flap in Pima and Papago. Balasubramanian (1972) demonstrates that the non-geminate sublaminal lateral in Tamil is usually produced as a flap. Lateral flaps thus probably occur at all the places which have apical or sublaminal articulations.

Lateral fricatives also occur at a variety of places and with different phonation types, although they are most frequently voiceless. We have illustrated a waveform of a voiceless alveolar lateral fricative from Zulu in figure 6.9. When voiced lateral fricatives occur in a language they are usually in contrast with voiceless lateral fricatives. Zulu again serves as an example, as the data in table 6.6 show. Bura is unusual in having not only a voiced apical alveolar lateral fricative but also a contrast between voiceless lateral fricatives at two places of articulation, apical alveolar and palatal. We suggest the symbol [ʎ̥] for the palatal lateral fricative. There is also an alveolar lateral of the more usual voiced approximant type. Spectrograms of these four sounds are given in figure 6.12. According to Ladefoged (1968) there is also a voiced palatal lateral approximant, making Bura a language with 5 lateral segments. However, this segment was not found to occur during a more recent study of the language by Schuh and Maddieson. Of the voiceless lateral fricatives, the palatal has a higher frequency center to the main noise concentration than the alveolar. A similar distinction is found between the apical alveolar and laminal post-alveolar voiceless lateral fricatives of Diegueno.

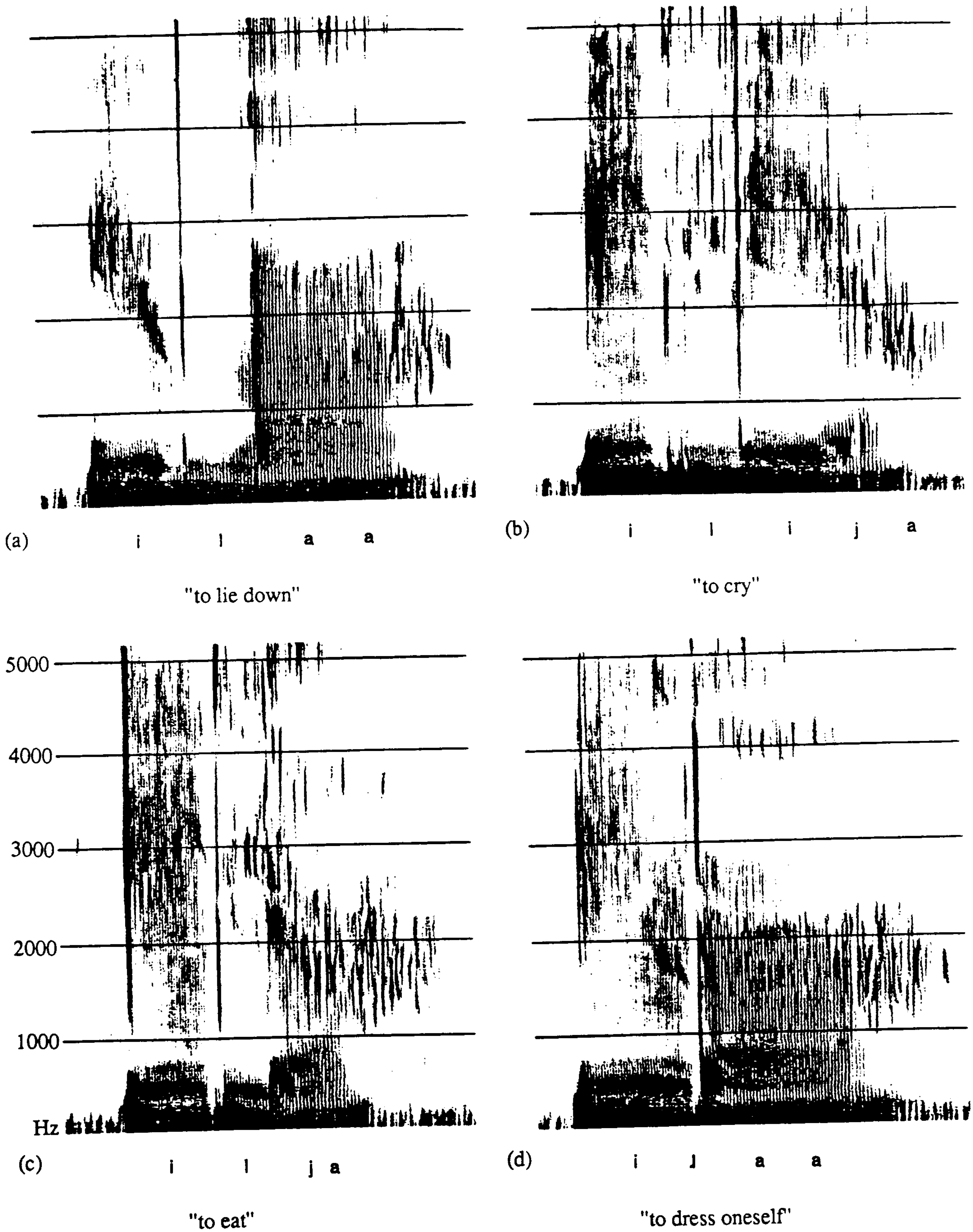


Figure 6.11. Spectrograms illustrating allophones of /l/ in KiVunjo Chaga before (a) /a/, (b) /i/, (c) /j/, and (d) the alveolar lateral flap /ɺ/.

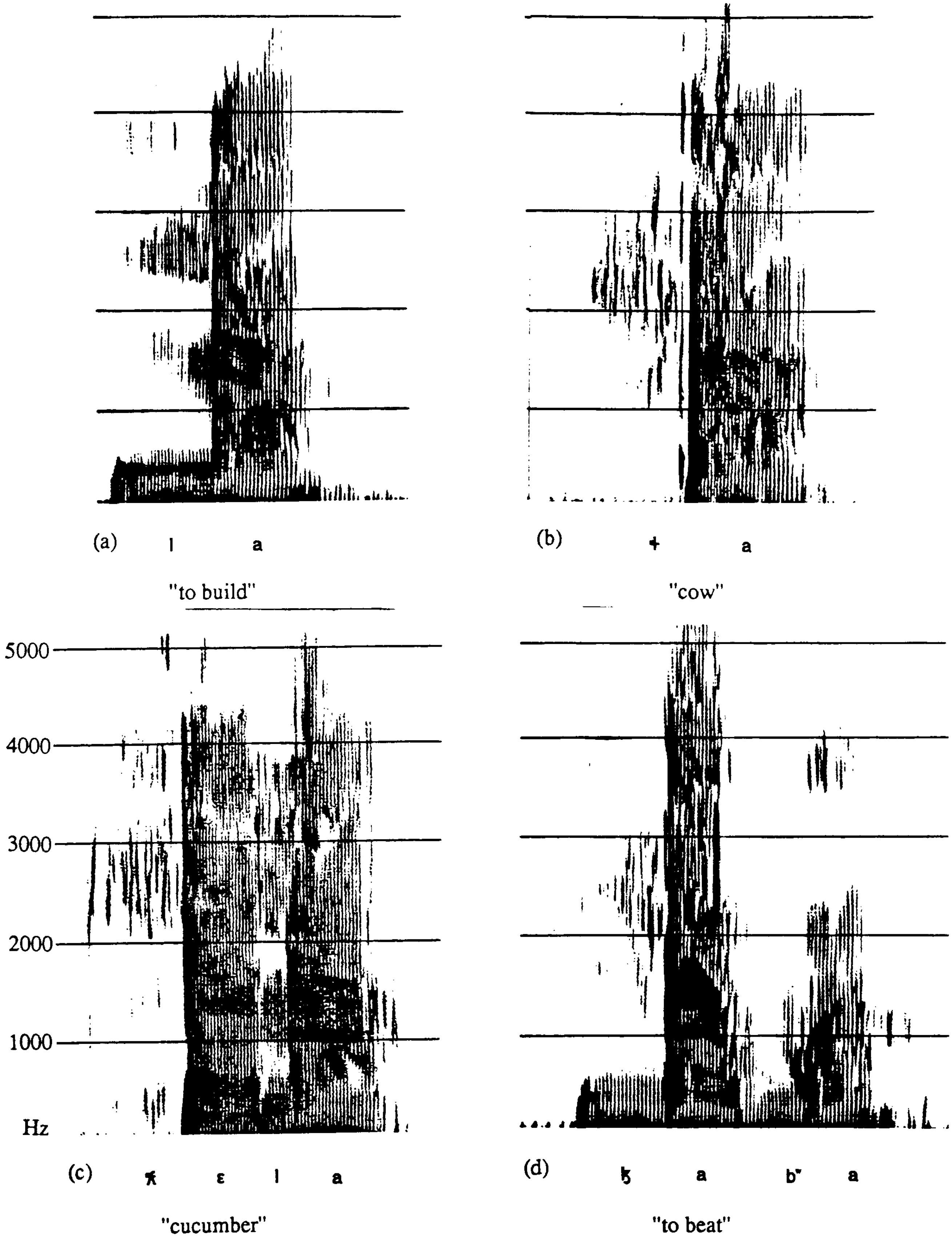


Figure 6.12. Spectrograms illustrating lateral segments in Bura; (a) voiced apical alveolar lateral approximant, (b) voiceless apical alveolar lateral fricative, (c) voiceless laminal palatal lateral fricative, (d) voiced apical alveolar lateral fricative.

A voiced lateral segment described by Shafeev (1964) as a "prepalatal fricative" occurs in Pashto. This would appear to be the voiced counterpart of the Diegueno segment. The Taishan dialect of Chinese has a voiceless apical dental lateral fricative, which for many speakers can vary with a central dental fricative, [θ]. Gowda (1972) describes a voiced apical post-alveolar lateral fricative in Ao (Naga). We have not heard this sound but the description seems quite clear. We therefore know so far of dental, alveolar, post-alveolar (apical and laminal) and palatal places of articulation for lateral fricatives.

Lateral fricatives may combine with stops to form lateral affricates. The reasons for regarding affricates as a separate type of segment, rather than as simply a combination of a stop and a fricative are given in chapter 3 and will not be repeated here. In lateral affricates, of course, the stopped portion of the segment is not itself lateral (it could not be a stop otherwise), but the stop is released by lowering some portion of the sides of the tongue, rather than the center. Such affricates are more commonly voiceless than voiced, and are frequently ejective. Ik, Iraqw, Hupa and Lushootseed (Puget Sound Salish) are among languages that have an ejective lateral affricate without having the corresponding non-ejective affricate. Ejective lateral fricatives occur in a number of languages but they are not as frequent as pulmonic lateral fricatives or ejective lateral affricates. In some languages, such as Zulu -- for which details are given below -- there are allophonic relationships between two of these three types of laterals, or all three. But contrasts between voiceless pulmonic and ejective lateral fricatives do occur, especially in languages of North America, for example in Tlingit. This language is unusual in that it has laterals of five distinct types but none of them is a voiced lateral approximant of the usual type. The examples of verb stems in table 6.8 from Story and Naish (1973) illustrate the contrasts between laterals in Tlingit. Place of articulation is not clearly indicated in the sources we have seen but is fairly certainly alveolar.

Table 6.8 Contrasts between laterals in Tlingit

voiceless fricative	ɬaa	'melt'
ejective fricative	ɬ'aa	'suck'
voiceless affricate	tɬaa	'be big'
voiced affricate	dɮaa	'settle (of sediment)'
ejective affricate	tɬ'aak'	'be wet'

Standard descriptions of Navaho (Sapir & Hoijer 1967) suggest that there are also five different types of laterals in contrast in this language. Four of them are reported to be the same as those in Tlingit, but Navaho has no ejective fricative. It does have a voiced lateral approximant. Figure 6.13 shows spectrograms of the five different types of alveolar lateral (or partly lateral) onsets in Navaho. The figure includes data from two speakers; 6.13 (a), (b), (d) and (f) are from a female speaker, (c) and

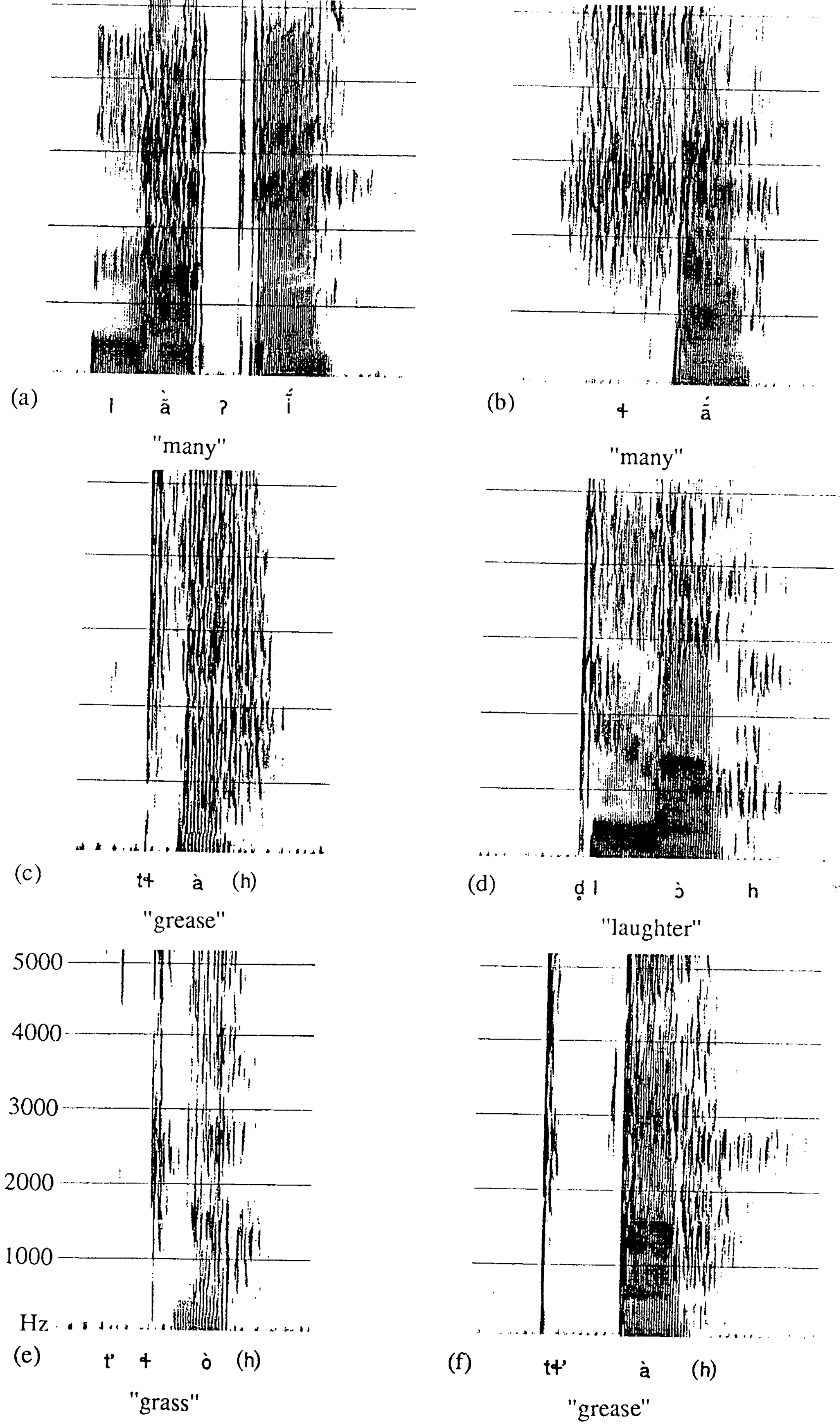


Figure 6.13. Spectrograms illustrating the five contrasting alveolar laterals of Navaho; (a) voiced lateral approximant, (b) voiceless lateral fricative, (c) voiceless lateral affricate, (d) 'voiced lateral affricate' produced as [d̥l], (e) and (f) voiceless lateral ejective affricates. Two different speakers are represented, (a), (b), (d) and (f) are from a female speaker; (c) and (e) from a male speaker.

(e) are from a male speaker. The voiced lateral approximant and voiceless lateral fricative are shown in 6.13 (a) and (b). The speakers we have heard do not agree on which lexical items are pronounced with the ejective lateral affricate and which with the pulmonic voiceless affricate. Figure 6.13 (c) shows the word meaning 'grease' as pronounced by one of the speakers, using a pulmonic lateral affricate in accord with the dictionary of Young and Morgan (1972). Note that the release burst is followed immediately by a relatively short lateral fricative component. In contrast, the 'voiced affricate' in 6.13 (d) is not in fact an affricate. Instead of a component [ɮ] of brief duration after the stop release, there is a long approximant lateral, similar to that seen in 6.13 (a).

Figure 6.13 (e) and (f) show two different ways of producing a lateral ejective affricate. In (e) it seems as if the alveolar closure is released some time before the onset of lateral frication, and the friction directly precedes the vowel. From the acoustic pattern we deduce that the glottal closure is held without the larynx being raised, and the friction is produced with pulmonic air after the glottal closure is released. The word meaning 'grease', pronounced by the female speaker with an ejective lateral affricate, is shown in 6.13 (f). In this production, the alveolar closure is released with lateral frication while the glottal closure is maintained. Later the glottal closure is released directly into the vowel. From the intensity of the noise of the fricated release in this case, we infer that it involves a truly glottalic airstream with the larynx raised before the alveolar release. We have notated the phonetic difference between these ejectives by placing the apostrophe before the lateral fricative symbol in the first case, and after it in the second. If our interpretation of these spectrographic records is correct, only the second of these types is strictly an affricate, since the closure is not released into a fricative component in the first. However, we believe that the two types are linguistically equivalent and the difference is a matter of personal idiosyncracy.

The place of articulation of lateral affricates is most frequently alveolar but a velar lateral affricate, which is usually ejective in its production, occurs in Zulu. In Ladefoged (1971) this segment was described as a palatal lateral ejective affricate (on the grounds that velar laterals were not believed to be possible speech sounds). However, there seems no reason to doubt that both components of this affricate are really velar in place of articulation, and we have described it this way in table 6.6 above. As Doke (1926) observed, when a homorganic nasal precedes this element that nasal is / ŋ /. We add that when a vowel precedes, the auditory impression is clearly of a velar closure. The fricative component of this affricate is auditorily reminiscent of the velar fricative [x] but is lateral. Doke developed the symbol [✢] for a voiceless velar lateral fricative and we will adopt his suggestion for its transcription, transcribing the affricate as [k✢']. Spectrograms of two speakers' pronunciation of this segment are shown in figure 6.14. Note that these speakers differ in the way they produce this lateral ejective affricate in a similar way to that noted in Navaho. The female speaker in 6.14 (a) apparently releases the velar closure well before the initiation of lateral friction, whereas the male speaker shown in (b) releases the velar closure directly into the lateral component and only releases the glottal closure at the onset of the vowel. We are not sure of the timing of the glottal release in 6.14 (a), but believe it precedes the lateral.

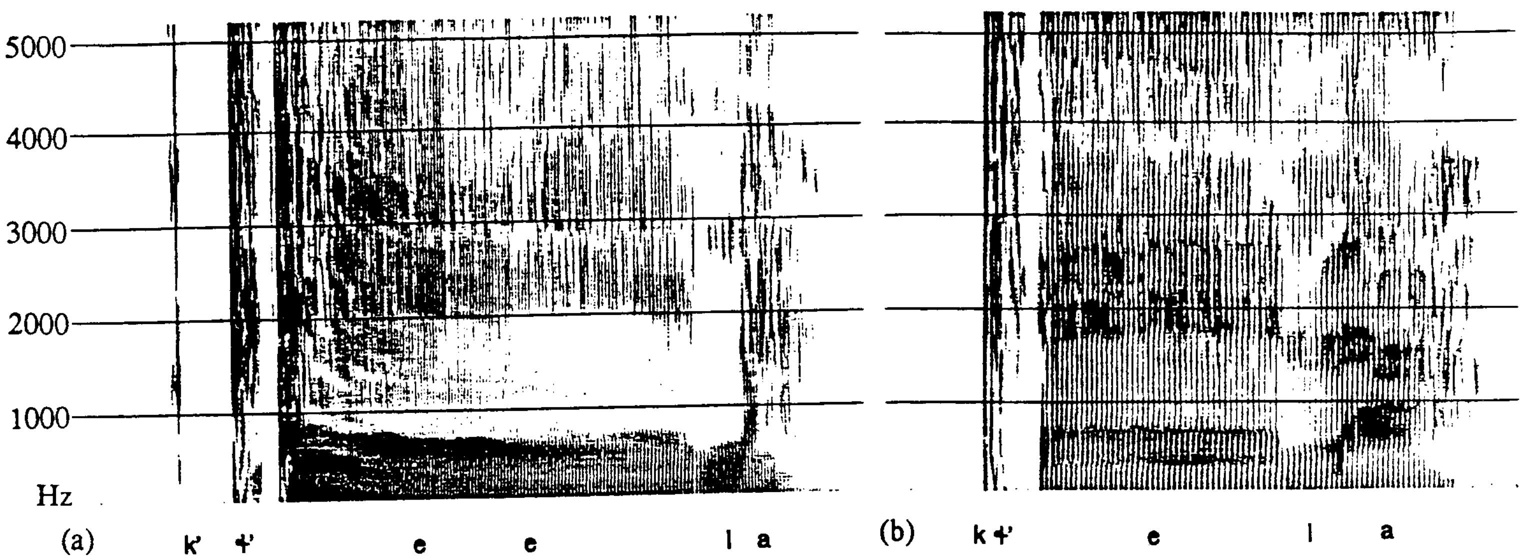


Figure 6.14. Spectrograms illustrating the voiceless velar lateral ejective affricate [k͡ɬ'] in the Zulu word *klela* 'stand in line' spoken by two different speakers; (a) is female, (b) is male.

In addition to a velar lateral affricate, Zulu also has an alveolar lateral affricate. This segment only occurs as an allophone of the voiceless lateral fricative / ɬ / after a nasal. Spectrograms illustrating the four lateral sounds [ɬ, tɬ, ɮ, l] spoken by the previously exemplified male speaker of Zulu are given in figure 6.15. For some speakers the alveolar affricate may be produced as an ejective, but the token we show is pulmonic. For this speaker the spectrum of [ɬ] appears to have a greater amount of energy in the region below 2000Hz than [ɬ]. The voiced fricative [ɮ] has a noise spectrum similar to that of its voiceless counterpart; it has a considerably lower amplitude of voicing than the voiced approximant [l] and lacks any strong low frequency resonance that might be labeled the first formant. Thus, the large number of laterals in Zulu are clearly differentiated from each other.

A non-ejective velar lateral affricate may occur in Axluxlay (Stell 1972) but the description is somewhat unclear. In Zulu and perhaps Axluxlay a voiceless velar lateral fricative occurs as a component of an affricate. A set of several velar, or more precisely prevelar, laterals of different types are reported to occur in Archi. These are all fricatives or affricates. We have not heard these sounds, but Kodzasov (1977) gives the following description:

> "In the production of lateral fricated sounds the tip of the tongue is passively lowered to the lower teeth while the body of the tongue is raised to the palate, forming an extended obstruction covering both the velar and palatal regions. ..... In their articulation and auditory quality the Archi laterals are similar to palatalized velars (Archi speakers perceive Russian soft / x / as a lateral fricative)" (pp. 225-6, our translation.)

If we classify all these Archi laterals as velar, then this language provides examples of voiced and voiceless velar lateral fricatives and voiceless pulmonic and ejective lateral affricates.

Clusters consisting of homorganic approximant laterals and stops in either order occur widely in the world's languages. Because the articulatory adjustment required to pass from a lateral to a stop or vice-versa is a minimal one, these sequences can be closely bound together at the level of articulatory organization. We are not aware of any languages for which it has been proposed that a lateral + stop (or fricative) sequence should be analyzed as a single segment, parallel to the 'prenasalized stops' discussed in chapter 4. However, in a small number of languages prestopped laterals have been so analyzed. In Arabana and Wannganuru (Hercus 1972) [d̪l̪, dl] occur as allophones of the (laminal?) dental and apical alveolar lateral approximants. These variants occur in word-medial positions after the initial stressed syllable in words which begin with a consonant. Although the distributional pattern of these elements may justify their treatment as single units from the phonological point of view, there is no evidence that they are phonetically distinct from stop+lateral clusters. We have noted above that the length of the approximant lateral segment in [d̥l] pronunciations of the voiced lateral 'affricate' in Navaho is similar to that of the lateral segment [l]

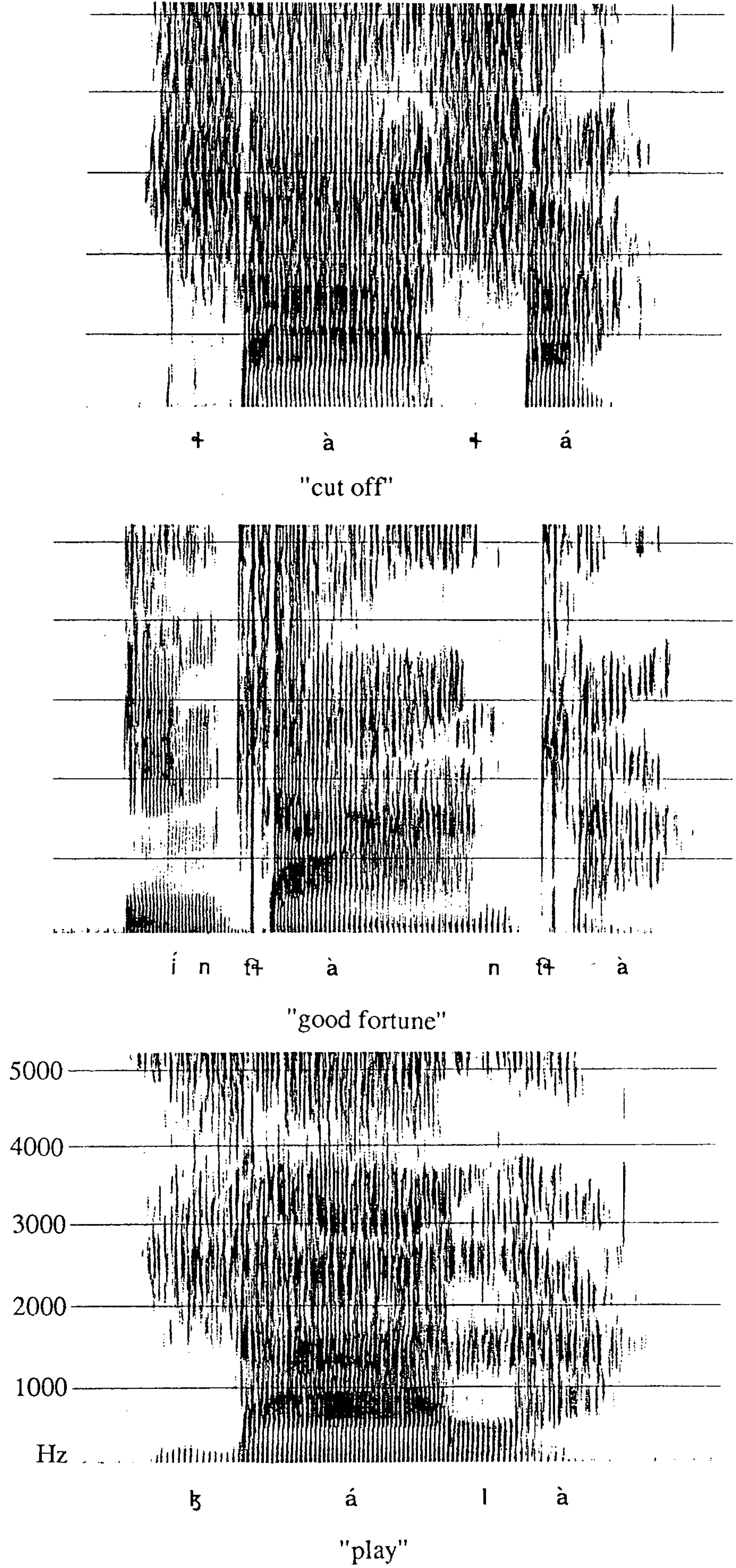


Figure 6.15. Spectrograms illustrating the lateral sounds [ɬ, tɬ, ɮ, l] in Zulu.

occurring alone.

Table 6.9 expands on table 6.3 by providing names of languages which exemplify some of the manner and place combinations in laterals. The table does not include all of the types of laterals that we have discussed, omitting particularly differences of phonation apart from the simple contrast of voicing. But it does include most of those which differ in manner of primary articulation, especially those that we know to occur at more than one place of articulation. All of the languages mentioned in this table have been discussed earlier in this chapter except for the Kabardian dialect of Adyghe. We infer from descriptions provided by Kuipers (1960) that the laterals in this language are laminal dentals. The possible types of lateral flaps are limited. But apart from this restriction, the majority of the gaps in this table are accidental. A linguistic phonetic framework should not rule out the occurrence of lateral segments of the types that happen to be missing from this chart.

Table 6.9. Languages exemplifying contrasting types of lateral segments.

	dental		alveolar		post-alveolar		palatal		velar
	apical	laminal	apical	laminal	apical	laminal	sublaminal	laminal	
	1	2	3	4	5	6	7	8	9
voiced approximant	Albanian	Kaititj	Albanian	Russian	Panjabi	Bulgarian	Malayalam	Italian	Mid-Waghi
voiceless approximant			Burmese		Iaai				
voiced flap			Chaga		Pima		Tamil		
voiceless fricative	Taishan	Kabardian	Zulu			Diegueno		Bura	Archi
voiced fricative		Kabardian	Zulu		Ao	Pashto			Archi
voiceless affricate			Navaho						Archi
voiced affricate			Tlingit						
ejective affricate		Kabardian	Navaho						Archi
ejective fricative			Tlingit						

6.3 The feature description of laterals

Phonetic feature inventories traditionally include a feature [lateral]. At first glance it seems as if this feature is one which unambiguously has only binary values. An articulation is either lateral or not. However, the situation with laterals is not the same as that with nasals, where we argued that a single binary feature gave an appropriate phonetic classification for the position of the velum. Whereas we know of no linguistic contrast based on varying degrees of width of the velic opening, there are important differences between laterals based on the size of the lateral escape aperture. Laterals can be either approximant or fricative. Although this distinction often correlates with voicing -- approximants being voiced and fricatives being voiceless -- it cannot be predicted from it, since both voiced fricative laterals and voiceless approximant laterals occur in contrast with the more common types. Hence manner of articulation -- approximant or fricative -- must be specified with respect to the lateral aperture. The location of this aperture, except perhaps for velar laterals, is at a different position on the upper surface of the vocal tract from that for the maximal constriction, which is traditionally recognized as the place of articulation for the lateral. The manner specification describing the lateral aperture thus does not apply to the articulation which is defining the place of the lateral segment.

Moreover, as we noted above, it is not necessarily true that laterals are produced with a central contact. Hence, to describe phonetic detail, including important allophonic variation in some languages, the degree of central stricture also needs to be specified. In a sense, then, we are arguing that laterals are segments with two articulations. One governs the location and degree of stricture of the central articulation and the other governs the location and size of the lateral aperture. Admittedly, there are probably few instances where advantage is taken of the degrees of freedom implied by recognizing two articulations. Lateral fricatives (and the fricative phase of lateral affricates) will normally be produced with a central closure since this will facilitate narrowing of the lateral escape aperture. Most research indicates that lateral approximants also usually have a central closure. Nonetheless we need to be able to provide a description of (at least) lateral approximants with and without central closure and laterals with a central closure with and without a fricative escape. We will postpone further discussion of this issue until chapter 12 where it will be taken up again in the context of other consonants with multiple articulations.

Finally we note that since lateral segments certainly occur at places of articulation that are Lingual or Dorsal in terms of the scheme proposed in chapter 2, it is inappropriate to attach the feature [lateral] to any single node in a place hierarchy. Laterals are not necessarily coronal.

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