tion 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 0 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 v. 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 w, which also appears in the language in certain predictable environments. His analysis of the patterns of nasalization in UMbundu leads him to posit v as one of a set of four underlying nasalized consonants, namely v, 1, h, j. 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 v 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).

4.5 Conclusion

The aerodynamic and acoustic consequences of a lowered velum depend very much on whether or not there is a concurrent oral or glottal occlusion. In accord with this, we follow traditional phonetics and make a strict distinction 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 v and j 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, there is no need for more than the indication of the presence or absence of nasality. 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 [stop] value of the feature Stricture; 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 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 and Vergnaud 1980) in a multi-tiered representation, or to a separate node in a feature tree (Sagey 1990, Ladefoged 1988, 1992). 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 was 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), Vaissiere (1983) and Cohn (1990) 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.

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 chapter 6. Secondary articulations will be discussed in the chapter on multiple articulations. 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 chapter on vowels.

The gesture forming 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 it is held against another. It usually 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 millimeters 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 the nasal n (Bladon and Nolan 1977, Subtelny and Oya 1972, Lindblad 1980, Byrd 1994).

		ALVEOLAR (RETROFLEX)	(PALATO-ALVEOLAR) PALATAL)	(ALVEOLO-	(HISSING- HUSHING)	(RETROFLEX)
PLAIN	0 3 0 3	4.				
SIBILANT	S z s z S z		J 3	c z S z		5 <

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 call the latter type sibilants, a term which has been used for a few centuries (e.g. by Holder 1669, and many phoneticians after him). More recent terms for these sounds include strident (Jakobson, Fant and Halle 1952, Chomsky and Halle 1968) and obstacle fricatives (Shadle 1985, Shadle, Badin and Moulinier 1991). In other fricatives, such as 0, 3, 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 these terms and symbols are used in slightly unconventional ways. 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 4 for a post-alveolar retroflex fricative. Following Catford (1983) and the practice of phoneticians in the former Soviet Union we have used s, z for what we will describe as closed post-alveolar sibilants. We have also included within the table the IPA symbols c, z, which are traditionally called alveolo-palatal fricatives, but which we will regard as palatalized post-alveolar sibilants. The terms for the places of articulation in table 5.1 are not exactly the same as those listed in chapter 2. At the end of the chapter we will discuss how the data suggest a more elaborate descriptive framework.

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 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 (1980) 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.

5.1 Non-sibilant Anterior Fricatives

We noted the difficulty of finding examples, of a contrast between bilabial and labio-dental stops and nasals in the discussion of places of articulation in chapter 2. It is a lot clearer that these places contrast among 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. As we also noted in chapter 2, labiodental fricatives are more common than bilabial ones, and the latter in many cases are allophones of bilabial stops. This allophonic variation produces intervocalic distinctions between voiced bilabial and labiodental fricatives in many Bantu languages. In some of these languages further changes have led to a situation in which unconditional contrasts between the two can be found. Examples from Tsonga were given in table 2.2 above.

Bilabial fricatives, like bilabial stops, are made with a gesture that involves a lowering of the upper lip in addition to the larger and more significant

Table 5.2 Words and phrases illustrating Ewe bilabial and labiodental fricatives

e <j>a	'he polished'	e fa	'he was cold'
epe	'the Ewe language'	eve	'two'
e 4>le	'he bought'	e fid	'he split off'
epi6	'mushroom'	e vlo	'he is evil'

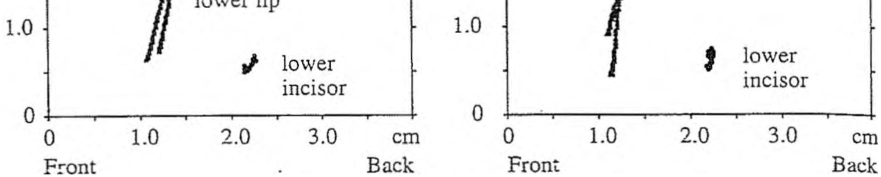

Figure 5.1 Movement trajectories of the upper and lower lips and the lower incisors during production of the Ewe words e0e 'people' and eve 'two'. Each panel represents the mean of ten repetitions (see Maddieson 1993 for further details).

movement of the lower lip. In labiodentals ordinarily only the lower lip moves. Movement patterns for the lips in the two words on the second line of table 5.2 spoken by a speaker of the Agio dialect of Ewe from Kpando are shown in the two panels of figure 5.1. This figure shows the trajectory taken by receivers placed on the outer surface of the upper and lower lips and on the lower incisors. For p, in the left panel, the upper lip moves down and back and the lower lip moves up and back. (Note that the receivers do not meet due to the need to mount them where they will not interfere with natural speech.) The release of the constriction lies in a plane a little behind that of the movement towards constriction. For v, in the right panel, the lower lip makes a larger excursion, reaching a higher and more retracted position than is reached in p. The upper lip remains stationary and takes no part in the articulation. It is in a slightly higher position throughout the articulation of the word eve than it is during any part of the word epe. For this speaker, the upper lip height in eve is similar to that seen in eke 'sand', suggesting that there is some coarticulatory lowering of the upper lip during the vowels surrounding the p in epe. The lower incisor trace shows that in neither case is there much raising of the jaw, although there is some retraction.

Sequences of frames from side-view cine-films of speakers of several European languages published by Bolla and his co-workers at the Institute of Phonetics in Budapest indicate that broadly similar movement patterns are found in the labiodental fricatives of the speakers of Finnish, German, Russian, Polish and English. The upper lip remains in a static position while the lower lip is recent fieldwork (Maddieson 1995) has shown that this is not the case. Another language, Isoko, which contrasts a labiodental fricative v with a labiodental approximant v also has a higher upper lip position for the fricative v than for the approximant *v*, as shown in figure 9.33, again presumably not because the upper lip is actively raised, but because it is lowered for the approximant. We will discuss this articulation when we consider semivowels in chapter 9.

The contrast between bilabial and labiodental fricatives also occurs in a number of Southern Bantu languages. In these languages there is sometimes a slight lip protrusion when making the bilabials fy, p. We investigated contrasts as produced by three speakers of Kwangali, and three speakers of RuGciriku, two Bantu languages in the Kovango group, spoken in Namibia and Southern Angola. Both these languages contrast voiced bilabial and labiodental fricatives, but do not have voiceless sounds of this kind. Both voiced and voiceless bilabial and labiodental fricatives also occur in Venda; we recorded a single speaker of this language. In all these languages the contrast was made by drawing the lower lip back over the lower teeth for the labiodental, and (for some speakers) bringing the corners of the lips forward to make a more slightly rounded version for the bilabial (the latter gesture was present in only three of our seven speakers). Ladefoged (1990b) discusses some of the implications of this use of different techniques for making the contrast between bilabials and labiodentals, but, as we noted, he was wrong in believing that the majority of speakers of West African languages such as Ewe and Siya have an active upward movement of the upper lip in the labiodentals.

Labiodentals may also be produced with less retraction of the lower lip than the articulations we have been discussing. From our own observations of speakers of English we know that the lower lip may be positioned so that the narrowest constriction is between a part of the inner surface of the lip and the front surface of the incisors.

Figure 5.2 shows spectrograms of the Ewe words in the second line of table 5.2. The speaker was conscious of the reason for recording these words, and consequently the fricatives are somewhat longer than usual. The second formant transition has an earlier onset and moves to a lower frequency for the bilabial fricative. There are differences in the spectra of the two fricatives,

e p £ eve

6 100 200 300 400 500 6 100 200 300 400 500 ms

Figure 52 Spectrograms of Ewe bilabial and labiodental voiced fricatives in epe 'people' and eve 'two'.

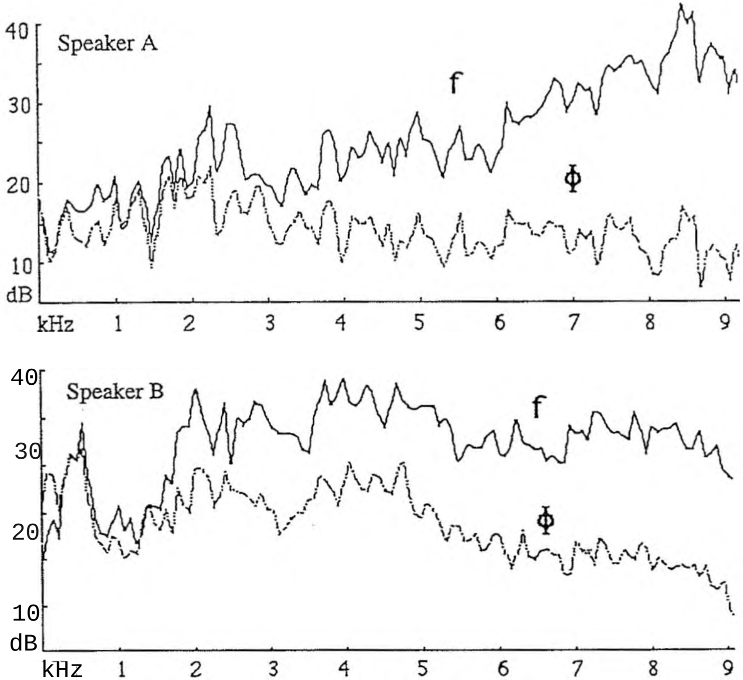

Figure 5.3 Means of 30 FFT spectra made at 5 ms intervals throughout the Ewe fricatives <f> and f as produced by two speakers during the words in the first row of Table 5.2. The mean noise on the part of the recording immediately adjacent to each word has been subtracted from each spectrum.

Tomas (1968), who describes (and diagrams) Spanish 0 as in Olrjko *cinco* 'five' as being interdental with the tongue "beneath the edges of the teeth", and Balasubramanian (1972), who provides palatographic data showing that Tamil 0 as in p^ha:6r 'half' is dental.

There is evidence that dialects of English differ in this respect. Textbooks teaching the pronunciation of the RP dialect of British English (e.g. Jones 1956, Gimson 1970, Roach 1983) diagram 0, 5 as being typically made with the tip of the tongue behind the upper front teeth, in a gesture which we will call dental, whereas those teaching American English from a Western US perspective (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 percent of the Californian speakers produced 0 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 percent of the British speakers made this sound in this way; 90 percent of them used an articulation with the tip of the tongue behind the upper front teeth.

Interdental fricatives are, of necessity, laminal; the constriction is between

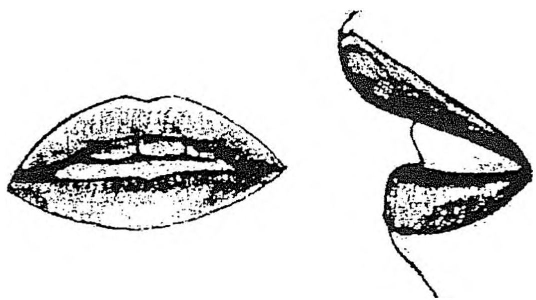

Figure 5.4 The tip of the tongue protruded between the teeth in 0 as in *thief* as pronounced by a speaker of Californian English.