Table 2.11 The relationship between the major place features and individual places of articulation

LABIAL		1.	Bilabial
		2.	Labiodental
CORONAL	1. Laminal	3.	Linguo-labial
		4.	Interdental
		5.	Laminal dental
		6.	Laminal alveolar
		7.	Laminal post-alveolar (palato-alveolar)
	2. Apical	8.	Apical dental
		9.	Apical alveolar
		10.	Apical post-alveolar
	3. Sub-apical	11.	Sub-apical palatal (retroflex)
DORSAL		12.	Palatal
		13.	Velar
		14.	Uvular
RADICAL		15.	Pharyngeal
		16.	Epiglottal
LARYNGEAL		17.	Glottal

tongue protrusion, involving an articulation between the upper surface of the tip or blade of the tongue and the upper lip. In these sounds there is usually active retraction of the upper lip to meet the protruded tongue, but some native speakers of languages contrasting these sounds use very little upper lip movement. In this case the gestures are very similar to 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. There is thus some shading between linguo-labial and interdental articulations. Similarly the terms interdental, dental, al-

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.

Within the Dorsal region, articulations all involve gestures in which the body of the tongue is raised. But some languages (e.g. Yanyuwa) may have an articulation that is between what is usually called palatal and what is usually called velar, while velars in some languages are clearly produced further back (e.g. Kwakw'ala) than in others; again there is a continuous range of possible articulations within this category. Even among Radical sounds there are various phonetic possibilities exemplified among different speakers of Arabic. We have observed some so-called pharyngeal fricatives in which the constriction is in the upper part of the pharynx, although in most cases it is closer to the epiglottis.

Stevens (1972, 1989) has proposed that certain points within an articulatory range are favored in the interest of exploiting the best match between distinctive acoustic structure and the possible articulatory gestures. In this theory, which he calls the quantal theory, these favored places would be the modal places of articulation. A related concept is that some gestures are easier to make than others for physiological reasons. The notions of ease of articulation and auditory distinctiveness as influences on the phonetic structure of languages were suggested by Martinet (1964) and have been given considerable prominence by Lindblom (1990) and Lindblom and Maddieson (1988). 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 may account for the preference for use of the modal articulations listed in table 2.11, and for the preference for certain of these articulations over others.

Ladefoged (1993) has suggested considerations that may be relevant in the production of some non-modal places of articulation. His notion is that in situations where there is a contrast between two similar articulations, speakers

apart. She claims that 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 might also hypothesize that the same polarization principle occurs in the realization of some differences in places of articulation.

3

Stops

In this chapter we will consider the stops that occur in the world's languages. Stops are the only kind of consonants that occur in all languages. They may be distinguished from one another by place of articulation, as we discussed in chapter 2, and by variations in the glottal state, the airstream mechanism, and the articulatory activity during onset and offset. They may also vary in length, and possibly in strength. All these variations, which are summarized in table 3.1, will be discussed in this chapter, except for those associated with nasality and laterality (which are discussed in chapters 4 and 6, respectively). This chapter also contains an account of the different types of glottal stops that have been observed in the world's languages. We should also note that taps or flaps, which might be considered to be very short stops, are discussed in chapter 7. There is a separate discussion of clicks (in chapter 8), which are types of stops in which an oral closure plays a part in forming the airstream mechanism.

AIRSTREAM MECHANISM		pulmonic (plosive)	all languages
		(voiceless) ejective	Haida, Uduk
		voiced implosive	Igbo, Sindhi
		voiceless implosive	Igbo
ARTICULATION	during onset	pre-nasalized	Fijian, Fula
	during offset	affricated	German, Navajo
		nasally released	Yeletnye, Arrernte
		laterally released	Navajo, Mixtec
LENGTH		long	LuGanda, Pattani Malay
STRENGTH	articulatory force	fortis	Agui
	respiratory force		Korean

Table 3.2 Short definitions of terms used in this book concerning variations in the laryngeal setting

MODAL VOICE	Regular vibrations of the vocal folds at any frequency within the speaker's normal range.
VOICELESS	No vibration of the vocal folds; arytenoid cartilages usually apart (but they may be together, as for ?).
ASPIRATED	Having a greater rate of airflow than occurs in modal voice for a period before or after a stricture; arytenoid cartilages may be further apart than for voiceless sounds.
BREATHY VOICE (= MURMUR)	Vocal folds vibrating but without appreciable contact; arytenoid cartilages further apart than in modal voice; higher rate of airflow than in modal voice.
SLACK VOICE	Vocal folds vibrating but more loosely than in modal voice; slightly higher rate of airflow than in modal voice.
CREAKY VOICE (= LARYNGEAUZED)	Vocal folds vibrating anteriorly, but with the arytenoid cartilages pressed together; considerably lower rate of airflow than in modal voice.
STIFF VOICE	Vocal folds vibrating but more stiffly than in modal voice; slightly lower rate of airflow than in modal voice.

or supraglottal pressure is too high (e.g. because air is impounded in the oral cavity by an articulatory closure), even if the vocal folds are in a position that would induce vibration under other conditions. In these latter situations vocal fold vibration may be absent from some part of a spoken utterance without any alteration from a laryngeal setting appropriate for voicing having occurred. As a result there is a conflict between an acoustic and an articulatory definition of voicelessness. For some linguists, voicelessness invariably implies an open glottis, whereas for others it means the absence of vibration, whether produced by active laryngeal control or not. Since stops, by definition, are produced with a supraglottal articulatory closure (unless they are glottal stops), it it important to bear this distinction between active and passive devoicing in mind as we describe the phonatory differences that accompany their production.

We will recognize five steps in the continuum of modes of vibration of the glottis, starting from breathy voice - the most open setting of the vocal folds in which vibration will occur, passing through slack voice, modal voice, and stiff voice, and ending with creaky voice - the most constricted setting in which vibration will occur. An open voiceless state, in which the vocal folds are not vibrating because they are too far apart, may be regarded as the extension of this continuum in one direction; and glottal closure, in which the vocal folds are even more tightly together than in creaky voice, may be regarded as an extension in the other. We have chosen to name only these seven major phonetic categories, which, generally speaking, will be sufficient to enable us to describe the surface phonetic contrasts that we have observed; but we would also emphasize that there is a continuum of glottal opening, and a different number of steps might have been named.

A further term that needs to be noted is aspiration; in at least some cases voiceless aspiration involves a wider opening between the vocal folds than occurs for open voicelessness. This position can be considered as yet a further step along the continuum of vocal fold opening. However, aspiration involves matters of relative timing between laryngeal and oral articulations, and the wider opening can be viewed as an aspect of the control of this timing. We will return to this issue in the detailed discussion of aspiration below.

Note that we are not distinguishing between murmur and breathy voice, nor

closed there is no airflow.

Modal voice

We will discuss each phonation type in turn, beginning with modal voice. The physiological position for modal voice can be regarded as one in which the arytenoid cartilages are in a neutral position for speech, neither pulled apart nor pushed together (Stevens 1988). The vocal folds would be very slightly apart, if there were no air flow. We assume that the same position as occurs in ordinary voiced vowels and in voiced continuant consonants such as nasals is normally maintained in stops that are phonologically voiced. It is well known that in some languages, English being a familar example, the vocal folds may not vibrate throughout the closure for a voiced stop. Even when surrounded by other voiced sounds, such as vowels, the vocal fold vibration often ceases shortly after the closure is made and only resumes shortly after the closure is released. Most English speakers appear to leave the vocal folds in a constant position throughout such a sequence, but passive devoicing occurs as the supralaryngeal pressure builds up behind the oral closure. There are a number of maneuvers that can be made to assist the continuation of vocal fold vibration during an oral stop closure by expanding the size of the cavity behind the location of the closure; these include a relaxation of the cheeks and other soft tissues around the oropharyngeal cavity so that the pressure will passively expand the volume, as well as active gestures, such as moving the articulatory constriction forwards during the closure, moving the root of the tongue forwards, lowering the jaw, or lowering the larynx (Hudgins and Stetson 1935, Bell-Berti 1975, Ohala and Riordan 1979, Keating 1984c). Some English speakers utilize such gestures to a sufficient degree to produce vocal fold vibration during their voiced stop closures (Westbury 1983), but similar gestures are often executed by speakers producing intervocalic phonologically voiced stops without sustained vocal fold vibration (noted by Kent and Moll 1969). Flege (1982) has shown that the variation in the time at which vocal fold vibration starts near the release of utterance-initial voiced stops in English does not depend on how long before the release the vocal folds are adducted. The target

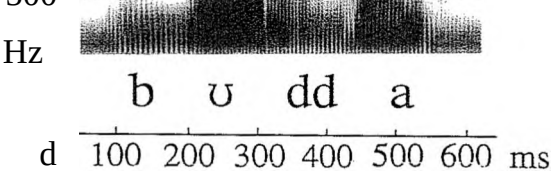

Figure 3.1 Spectrogram of the Ilwana word budda 'pelican' showing vocal fold vibration during both utterance-initial b and intervocalic geminate dd.

for voiced stops in English can therefore be said to include the maintenance of a position of the vocal folds appropriate for voicing, but not to require the employment of other strategies to sustain vocal fold vibration.

In contrast to English and several other Germanic languages, a considerable number of languages have voiced stops which require more energetic efforts to produce sustained vocal fold vibration. Such languages include well-known ones such as French and Thai, as well as more obscure ones such as Ilwana. In languages of this type, the target in the production of voiced stops must be defined as including the presence of actual vocal fold vibration through the articulatory closure period. Figure 3.1 shows the word budda 'pelican' from Ilwana. This word contains an initial voiced stop and an intervocalic geminate voiced stop which are both produced with full vocal fold vibration. This occurs despite the fact that these are both positions in which sustaining voicing requires particular additional effort, as has been shown by Westbury and Keating (1986).

In some of the languages in which sustained vocal fold vibration is part of the target for voiced stops, the downward movement of the larynx and the other cavity-enlarging movements used are sufficient to actually rarefy the air in the oropharynx. On the release of the oral closure, some inward airflow occurs. That is, there is a continuum between fully voiced stops and implosives. We will discuss this latter type of stop more fully below; here we merely want to note that implosives and fully voiced stops are not the same thing. For example, they contrast in Ilwana, as a comparison of the intervocalic stops in

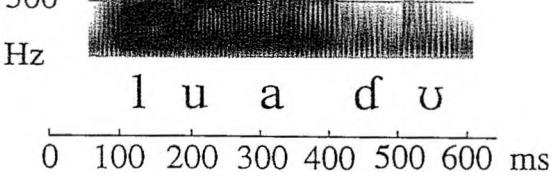

Figure 3.2 Spectrogram of the Ilwana word luarfu 'speed'.

figure 3.1 and figure 3.2 illustrates. We do want to emphasize, however, that voiced stops will have a range of acoustic patterns. But, as far as we know, no language makes use of the difference between stops with the same laryngeal setting for voice but differing solely in the presence or absence of gestures to sustain vocal fold vibration. Thus, although English and Ilwana voiced stops are different, this difference is not one that is available for meaningful contrast within a language.

Of course, a phonologically voiced stop will not necessarily maintain the same laryngeal articulation in all positions. For example, there are phonological processes that result in changing a voiced stop in a particular environment into its voiceless counterpart. Rules of this type are well known in German and Russian. Phonetic studies indicate that such processes often show some gradience. But the acoustically measured variation in the voicing of stops in languages such as English probably does not reflect variation in the actual laryngeal setting.

Voiceless

The great majority of languages of the world have a series of stops in which the vocal folds are not vibrating because they are separated by too wide an aperture. In stops of this kind in intervocalic position, it is quite common to find that the vocal folds continue to vibrate for a short time after the oral closure is formed. This is because the folds have not yet separated widely enough by the

quired, with vibration ceasing due to lack of efforts to sustain it. Acoustic measurements on intervocalic coronal stops of five speakers of Tiwi (Anderson and Maddieson 1994) showed voicing continuing for approximately 50 ms after the oral closure is formed; this is longer than usually seen, and consistent with models of passive cavity expansion. Comparisons are difficult, but closure durations may be typically longer in Polynesian than in Australian languages, and Australian stops seem to be more prone to having voiced variants.

Creaky voice (laryngealization)

Creaky voice is the term we will use for a mode of vibration of the vocal folds in which the arytenoid cartilages are much closer together than in modal voice. Creaky voice also involves a great deal of tension in the intrinsic laryngeal musculature, so that the vocal folds no longer vibrate as a whole. Sometimes the parts of the vocal folds close to the arytenoid are held too tightly together to be able to vibrate at all; on other occasions the ligamental and arytenoid parts vibrate separately, so that they are out of phase with one another. This can produce pulses with alternating high and low amplitudes. If they are almost exactly 180° out of phase with one another they may produce an apparent increase, often an approximate doubling, *of* the rate of occurrence of glottal pulses. Languages that exploit some form of creaky voice in the production of stops are areally diverse. They are reported to include Sedang and Pacoh (Austro-Asiatic); Lakkia, Sui and Lungchow (Kam-Tai); Lugbara (Nilo-Saharan); Somali (Cushitic); Hausa, Bura, and Ngizim (Chadic); Karok (Hokan); and Wapishana (Arawakan). We have not heard all these languages ourselves, so we are not sure if each of them uses what we would term creaky voice. The published descriptions suggest that there is some variation: in some of these languages the series of stops in question is described as preglottalized, while in others they are compared to implosives. There does seem to be a range of timing options for the relationship between the laryngeal constriction and the oral articulation. In some languages the laryngeal constriction occurs early in relation to the oral closure, whereas in others it is more delayed. There is also variation in degree of the glottal constriction involved.