approximant and other continuant rhotics, and, in trills, in the formant structure of the brief intervals between the closures of the trill, as well as in the transitions to and from the consonant in any adjoining vowel.

A lowered third formant is a well-justified specification for the various articulations of American English ɹ, including that in figure 7.17. Some of the approximant rhotics in other languages also share this property. All four speakers of Izon examined by Lindau showed a considerably lowered third formant very similar to that of American English and many of the Italian speakers we have examined also show a relatively low third formant. The third formant lowers in all six of the Toda trills shown in figure 7.5. But other rhotics have high third formants. For example, the Hausa retroflex approximant in figure 7.21 has a third formant at the same level as that in the surrounding a vowels, and the Czech fricative rhotic in figure 7.11 has a third formant near 3000 Hz. Uvular r-sounds in figure 7.10 from Swedish, in figure 7.14 from French and in figure 7.16 from German all show a third spectral peak over 2500 Hz, although otherwise they are somewhat different from each other. The Arrernte retroflex approximant shown in figure 7.23 also has a high third formant.

These differences in the location of formants in the approximant r-sounds are important cues to the constriction location. Uvular r-sounds have a high third formant, sometimes close to the fourth formant. Dental r-sounds also have a relatively high third formant, as illustrated in the Spanish spectrograms in figure 7.12, though not as high as the uvulars (Fant 1968). A lowered third formant signals a particular set of articulatory configurations. It is thus not a good candidate for a property that unifies the rhotic class.

But if the phonetic correlate is not the proposed lowered third formant, is there any property that makes us recognize all these different sounds as rhotics? Lindau suggests that "there is no physical property that constitutes the essence of all rhotics. Instead, the relations between members of the class of rhotics are more of a family resemblance." She argues for a series of step-by-step connections. Thus the uvular trill used in Southern Swedish and the American English approximant do not seem to have much in common. However, there are striking similarities between trills at different places. The similar pulsing patterns in apical and uvular trills could explain the changes from

and Schaltz 1977).

There is also acoustic similarity between trills and taps and flaps. From an acoustic point of view, a trill is not unlike a series of taps. Particularly in intervocalic position, trills may be reduced to a single period (sometimes referred to in the literature as a 'one-tap trill'). In a number of cases we have observed that frication and trilling may co-occur. This may result in fricative-approximant variants as noted in French, Edo and other languages. Several of the trills illustrated in section 7.2 were produced with one or more closures followed by an open phase that is prolonged into an approximant instead of further alternations of shorter openings with closures. This instability in the production of trills, leading to trills with a prolonged open phase, could explain why trilled r-sounds vary with, or change into, approximants.

In this way, according to Lindau, each member of the rhotic class resembles some other member with respect to some property, but it is not the same property that constitutes the resemblance for all members of the class. Trills and taps are alike in having short closure duration, the open phase of a trill resembles an approximant in the presence of formants, and tongue-tip trills and uvular trills resemble each other in their pattern of rapid pulses. Rhotics produced with the same constriction location(s) are alike in the distribution of spectral energy.

Such family resemblances explain well several *of* the synchronic alternations and diachronic changes that connect different types of rhotics to each other, but equally close resemblances also extend to many sounds that are not traditionally considered members of the rhotic class. Sounds with similar constriction locations are likely to have similar spectral properties whether or not they are 'rhotic'. Taps, flaps and trills all have similarities to stops because they all involve closure, and, indeed, often alternate with them. Fricative rhotics have obvious similarities to other fricatives. And so on. Although there are several well-defined subsets of sounds (trills, flaps, etc) that are included in the rhotic class, the overall unity of the group seems to rest mostly on the historical connections between these subgroups, and on the choice of the letter Y to represent them all.

Clicks

Clicks are stops in which the essential component is the rarefaction of air enclosed between two articulatory closures formed in the oral cavity, so that a loud transient is produced when the more forward closure is released. The means of moving the air in the production of clicks is called the velaric airstream mechanism. It is always ingressive, and cannot be used for sounds other than stops and affricates.

Clicks are a regular part of the consonant systems of many of the languages spoken in Southern Africa. They are most common in the Khoisan languages such as !X66, !Xu and Nama, in which they are very frequent. Over 70 percent of the words in a 1X66 dictionary (Traill 1994) begin with a click. They also occur, with a far lower frequency, in a number of Bantu languages of Southern Africa, such as Zulu, Xhosa, RuGciriku and Yei, and in three East African languages, Dahalo, a Cushitic language of Kenya, and Sandawe and Hadza, two languages spoken in Tanzania. In all these languages the proportion of words with clicks is much smaller. In a vocabulary of Sandawe containing approximately 1200 entries (Kagaya 1993) only about 25 percent of the words contain clicks, and the entire set of Dahalo words containing clicks amounts to only about 40 (Maddieson, Spajic, Sands, and Ladefoged 1993). Clicks do not occur in any ordinary languages outside Africa, although they are familiar as extralinguistic signals in many societies. They were also reported in Damin, the auxiliary language formerly used by Lardil speakers in Australia, which is constructed somewhat on the lines of a language game (Hale and Nash, unpublished).

The sequence of events in the production of a simple alveolar click is illustrated in figure 8.1, which is based on x-ray tracings of a !X6o speaker published in Traill (1985). For simplicity, we describe it in terms of four phases: (1) A body of air is enclosed by raising the tip of the tongue to form a closure in the

the cavity just before the release of the anterior closure. The dashed lines show the lowered tongue positions corresponding to steps 3 and 4.

front of the mouth, and by also raising the back of the tongue to make a velar closure on the soft palate. (2) The air in the cavity between the two closures is rarefied by the downward movement of the center of the tongue, while both the back and the tip of the tongue maintain contact with the roof of the mouth. (3) The tip and blade or side of the tongue move down, releasing the forward closure so that air rushes into the mouth to equalize the air pressure, producing a sharp transient. (4) The closure formed by the back of the tongue is released.

The presence of a posterior closure is an essential component of a click, and every click has both a tip or blade (or lip) action determining the type of click, and also an accompanying velar or uvular articulation. Beach (1938) coined a pair of terms for these two aspects of the articulation of a click. He calls the first, the location and release of the front closure, the click *influx*. From our point of view the click influx determines what we call the click type. The velar or uvular articulation and other accompanying properties were in Beach's terminology the click *efflux*. We will not use this term, but will instead use the expression click accompaniment to describe properties of the back oral articulation together with any pulmonic activity, laryngeal setting, or nasal airflow that accompanies the click.

8.1 Articulatory Properties of Click Types

Because no language is known to use more than five click types we will regard any click as belonging to one or other of only five types: bilabial, dental, alveolar, palatal and lateral. We symbolize these five click types as 0, | !, =5 | |,

Doke (1926)	Zulu	dental	palato-alveolar		post-alveolar lateral
Doke (1937)	^Khomani	dental with friction	palato-alveolar instantaneous	alveolar instantaneous	lateral with friction
Kohler (1981)	Kxoe	dental	palatal retroflex	alveolar	lateral
Maddieson (1984a)	Nama	dental affricated	alveolar	palato-alveolar	alveolar lateral affricated
Maddieson (1984a)	Zulu	alveolar affricated	palato-alveolar		alveolar lateral affricated
Sagey (1986)	Khoisan	+ coronal + anterior + distributed - lateral	+ coronal - anterior - distributed - lateral	+ coronal + anterior + distributed - lateral	+ coronal - anterior - distributed + lateral
Snyman (1975)	Zhu|'hoasi	denti-alveolar	palatal	alveolar	lateral
Taljaard and Snyman (1990)	Zulu	apico-lamino-dental	apico-palatal		lateral apico-alveo-palatal

respectively. Although the click types are given labels that refer primarily to place of articulation, these terms cover several aspects of the front articulation. Each should be considered a shorthand description for a range of articulatory and acoustic characteristics that tend to occur together and which jointly define a family of clicks that are considered to belong to the same type. We will note the differences in the articulation of these types, both between languages and between speakers within languages in the following discussion. Compare-

such that we and writers such as Snyman (1975) give precisely the opposite names for ! (our alveolar, their palatal), and £ (our palatal, their alveolar); other authors offer yet other names for these two sounds. Similarly, what we call dental, Maddieson (1984a: 297) calls alveolar in Zulu, and our alveolars are his palato-alveolars. There are several reasons for this variation in naming. The maximum occlusion during a click is more extensive than the occlusion that exists just before the release; judgments on the place of articulation will vary according to whether place is based on the maximum occlusion or a later timepoint. Also, auditorily similar click types can be produced by different speakers using somewhat different articulations. Finally, different authors stress different aspects of the articulations, for example, adding comments on the abrupt or fricated nature of the release.

The articulatory positions for the five types of clicks in !X6o are illustrated in figure 8.2, which is based on cine-radiology data from Traill (1985). In the original data the lips are visible only in the case of the bilabial click. Outlines of the lips have been added to each of the other clicks, with their positions based on those of the lower teeth, which are visible on the records of all the clicks. In each case the left-hand diagram shows the maximal occlusion, when the cavity enclosed by the tongue is at its smallest, while the right-hand diagram indicates the position just before the anterior closure was released.

We will consider the moments of maximal closure (the left-hand diagrams) first. There are smaller differences among the click types at this time than there are just before the release. The left-hand diagrams are rather similar, except for the bilabial click. In all of the four lingual click types, the tongue contacts much of the upper surface of the oral cavity. The most significant difference among them at this time is that the anterior margin of the enclosed body of air is somewhat further from the front of the mouth for the alveolar and palatal clicks than for the dental and lateral types.

The diagrams on the right of the figure show that the differences in articulatory positions among the click types are greater just before the release. The differences between the two columns reflect the considerable tongue movements required to produce the rarefaction of the air in the cavity, which forms the basis of the velaric airstream. A more retracted location of the anterior

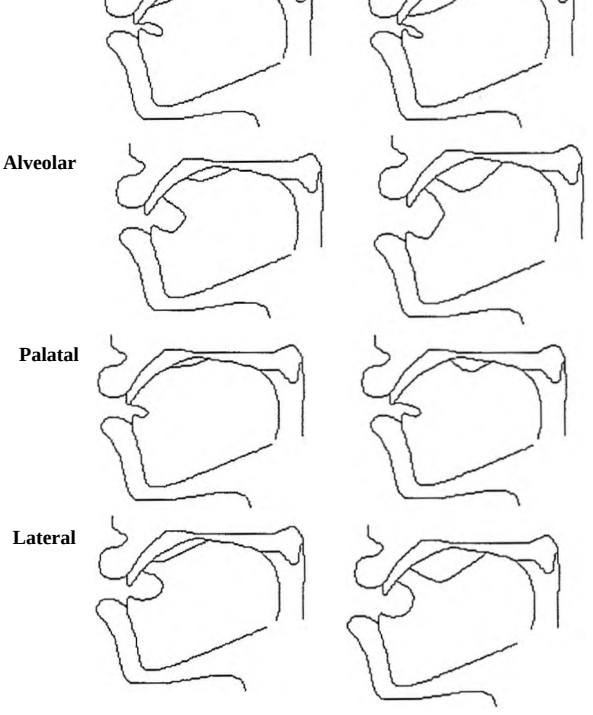

Figure S.2 The positions of the vocal organs at the onset of the click closure (left column), and just before the release of the click closure (right column) in the five click types of 1X66, based on cine-radiology data published in Traill (1985).

margin of the cavity continues to distinguish alveolar and palatal clicks from the dental and lateral types. A different grouping emerges from examining the lowest point of the center of the tongue just before release. This is lower for the alveolar and lateral click types than for the dental and palatal types.

The distinctive acoustic characteristics of any click type are determined by the location of the closure at the moment of release, not the location of the

languages. They are illustrated in the top row of figure 8.2. In most forms of this click the lips are together, but not rounded or protruded unless there is labialization. The regular gesture is one of lip compression rather than the puckering of the lips normally associated with a kiss. In some productions the lower lip may articulate against the upper teeth as the click is released, thus increasing the turbulent airflow associated with the release of the click.

The dental click type (illustrated in the second row of figure 8.2) occurs in more languages than any other type. In the particular token illustrated in the figure, the release involves only the tip of the tongue. We do not know what part of the tongue was involved in the frame of the film immediately prior to this, but usually both the tip and blade of the tongue are used to make the front closure, so we would classify this click type as typically having a laminal articulation. Louw (1977) suggests that speakers of Nama and Zulu as well as most speakers of Xhosa use an articulation "with the tip of the tongue being sucked away from the upper front teeth." He may be considering the term 'tip of the tongue' to encompass what we would term the blade. The linguogram of a Zulu speaker in Doke (1926) certainly shows a relatively broad laminal contact on the tongue for |. However, Louw notes one group of Xhosa speakers who "press the tip of the tongue against the lower teeth and suck the front part of the tongue... away from the upper teeth." These speakers clearly use a laminal articulation and, in comparison with them, the other speakers Louw is describing might be said to have a more apical articulation. Doke (1925) suggests that the dental click type may be produced with an interdental articulation in !Xu ; and we have ourselves observed some speakers of Sandawe and Hadza who protrude the tip of the tongue between the teeth. Thus, as with dental sounds of other classes, the specific articulation used for a dental click may vary in place of contact and tongue shape.

When the clicks of this type are formed, the front closure may extend as far back as the post-alveolar region, so that it might seem preferable to call these denti-alveolar or even denti-palatal clicks. But, as we noted earlier, the crucial point in the description of a click type is the position at the moment of release. In the clicks that are being classified as dental, the closure at the time of the

conventionally called 'palatal', but we have chosen to call them alveolar as the contact just before release is usually confined to a location well in front of the palatal region, although it may certainly be post-alveolar. Traill (1985) prefers the term postdental on the grounds that most of the considerable number of speakers of Khoisan languages that he has examined have smoothly sloping palates without an alveolar ridge, making it difficult to separate articulatory regions behind the teeth. An alternative would be to call these sounds simply apical clicks on the grounds that by far the majority of clicks of the ! type are made with the tip of the tongue contacting the roof of the mouth at the moment of release of the closure. But this is not true for all speakers; our linguograms show that some speakers of Hadza and Sandawe have a laminal articulation in which the tip of the tongue does not touch the roof of the mouth.

Clicks of the ! type are often post-alveolar in place of articulation; hence the occurrence of terms such as retroflex and cerebral in the 1 column of table 8.1. (In fact, the symbol 1 derives from adding the dot diacritic used to indicate retroflex by scholars of Indian languages to the slash used to represent dental clicks.) Both apical post-alveolar and sub-apical post-alveolar varieties occur, but we do not know of any contrasts between click types with these different articulatory positions. Rather, these seem to be variants within the same language, as in the palatograms in figure 8.3 (re-drawn from Traill 1985:103). These show single articulations of words containing initial ! produced by five different speakers of !X66. Note the inverted curve for the first two speakers (marked by the arrow). The contact in the center of the mouth is further back than at the sides. This kind of contact area is produced by the tip of the tongue curling back as it touches the roof of the mouth, in a sub-apical articulation. Similar contact areas have been found in studies of the retroflex consonants in Malayalam (Dart 1991). As for the other three speakers' articulations, 3 and 4 might be best described as alveolar, while speaker 5's pronunciation is post-alveolar but lacks any indication of sub-apical articulation. These five palatograms thus illustrate three articulatory strategies for producing the same click type. Similar variations are apparent in production of the ! click type in Zulu and Xhosa. Doke (1927: 127) and Beach (1938: 82) both publish palatograms of a single speaker using both laminal postalveolar and sub-apical variants of !.

Doke (1925: 148) described a sub-apical retroflex click in !Xu and implies

that this retroflex click type contrasts with the alveolar type. Jan Snyman, the most experienced investigator working on this language (Snyman 1970, 1975, 1978, 1980) does not note any such contrast, but consistently transcribes the words that Doke writes with a retroflex click as simply containing clicks of the ! type. No linguists working on other Khoisan languages report a contrast between alveolar and retroflex places for clicks. It seems most likely that some of Doke's speakers used a retroflex click, but no contrast existed then or exists now between this sound and a non-retroflex form of the ! click. It is certainly possible that retroflex clicks may be the favored form of pronunciation of ! in some languages, but we do not believe that it is a contrastive possibility.

We have studied the production of the ! click type in Sandawe and Hadza. These languages also demonstrate substantial variability in the production of these sounds. In both languages, clicks of the ! type were especially noted to vary a great deal in terms of how forcefully they were produced by speakers. In some instances, the amplitude of the release was very low, as if the click were produced with very little suction (for more details, see Sands, Maddieson and Ladefoged 1993). A notable allophonic variation of the click type occured for a number of speakers. In these instances, the tongue tip makes contact with the bottom of the mouth after the release of the front click closure. The release of the front closure and the contact with the bottom of the mouth is one continuous, ballistic movement, with the underside of the tip of the tongue making a percussive sound as it strikes the floor of the mouth. This version of the ! click is thus similar to the sound sometimes made by speakers of non-click languages trying to imitate the sound of a trotting horse and is the articulation which Tucker, Bryan and Woodbum (1977) characterized as a flapped palato-alveolar click. The only parallel variant reported from any Southern African languages with clicks concerns an individual 'Xu speaker who used what Doke called a palato-alveolar flapped click. The tongue-front is "flapped smartly to the floor of the mouth, the under-side making a resounding 'smack' behind the lower front teeth and on the floor of the mouth" (Doke 1925:163).

Palatograms, linguograms and inferred sagittal sections of the front articulation of the 1 clicks for two speakers of Hadza are shown in figure 8.4. In