

Clusters typically have from one and a half to two times the duration of single segments of comparable type (Haggard 1973, Hardcastle and Roach 1977, Catford 1977a), even when their articulations partially overlap in time, as would usually be the case for stop sequences in English in words such as *actor* or *aptly*. Thus, doubly-articulated stops are shorter than segment sequences. Very few languages include both complex labial-velar stops and sequences of juxtaposed labial and velar stops, but one which does is Eggon (Maddieson 1981, Sibomana 1985). This language even includes sequences combining a labial-velar with a labial or velar stop, as the examples in table 10.5 show.

Unlike in English, in Eggon the first member of a stop cluster is clearly released; hence the clusters are easily distinguished from simple stops. In cases where labials, velars and labial-velars are involved the second member of the cluster is frequently lenited in more relaxed speech. Note that lenition does not occur in clusters containing alveolars (e.g. in the words atku 'calabash', odga 'leg'), suggesting that this may be a further strategy for marking the potentially ambiguous clusters. These features may be seen in the words illustrated in the spectrograms in figure 10.3 which include examples of both doubly-articulated consonants and clusters. Whereas only a single stop release is seen in the words okpu and agbu, the separate release of the stops in a sequence can be clearly seen in the remaining words. When the sequence is voiced, the release between them may have the character of a short vowel-like segment, but there is no contrast of quality in this segment.

Their briefer duration disambiguates labial-velars from sequences but, of course, does not distinguish them from single articulations. However, in a great majority of cases the complex nature of labial-velar articulation is clearly detectable by auditory/acoustic means. In the majority of intervocalic labial-velar stops we have heard, the dominant auditory impression of the transition from preceding vowel to stop is of a velar closure, while the dominant auditory impression of the transition from stop to following vowel is of a labial release. (We do not think that it is an accident that these sounds are normally transcribed as kp, gb rather than pk, bg.) The impression is that the velar articulation leads the labial one by a brief time, and is released shortly before the labial one too, so that labial characteristics dominate the release. Note that if the duration of one articulation was contained within the duration of the other,

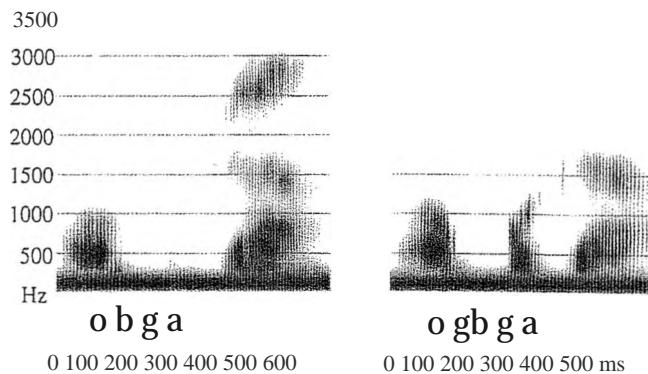
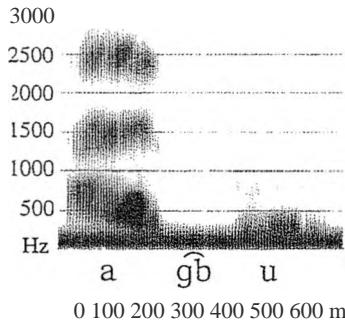
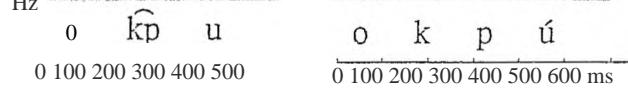


Figure 10.3 Spectrograms of words containing kp, gb, kp, bg and gbg in Eggon.

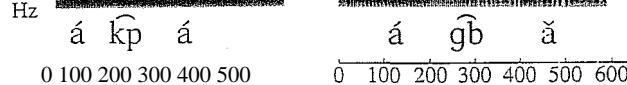


Figure 10.4 Spectrograms of kp in Efik akpa 'river' and gb in Logbara agba 'hit'.

the shorter articulation would have minimal acoustic consequences (assuming a simple pulmonic egressive airstream is used). Examination of data from a number of languages confirms the acoustic basis of our auditory impressions. As can be seen in the spectrograms of Efik and Logbara in figure 10.4, the labial-velar closure does have a similarity to a velar one while its release has similarity to a labial one. A similar point is made concerning Ibibio by Connell (1987). This feature is typical not just of the well-known West African languages with labial-velars, but is found in the New Guinea languages as well. Examples from Dedua contrasting p, k and kp are given in figure 10.5. This figure also includes spectra of a window centered on the release burst, enabling the acoustic similarity of the kp release to the p release to be seen even more persuasively.

That this auditory effect is the result of an actual difference in the articulatory timing of the closures can be seen from cineradiography of an Idoma speaker studied by Ladefoged in 1962 and in the data on an Ewe speaker obtained using electromagnetic articulography by Maddieson (1993). The temporal asymmetry of the two articulations in the Ewe data is illustrated in figures 10.6 and 10.7. These figures show the vertical displacements over time of the tongue back and the lower lip for akpa and agba respectively. The vertical scale is normalized so that comparisons can be made more easily between the two movements. The time scale is relative to the release of the labial closure, as determined from the simultaneously recorded acoustic waveforms. For both akpa and agba the raising of the tongue back occurs faster and peaks earlier than the raising of the lower lip. As the first movement upward of both articulators coincides closely, asymmetry of the closures appears to be achieved by making the upward movement of the lip slower than its downward movement.

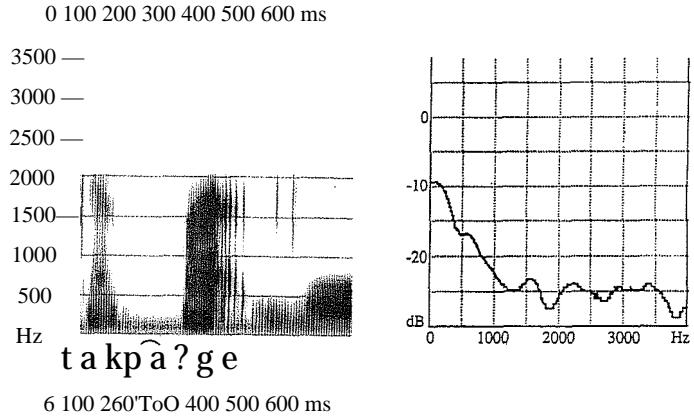
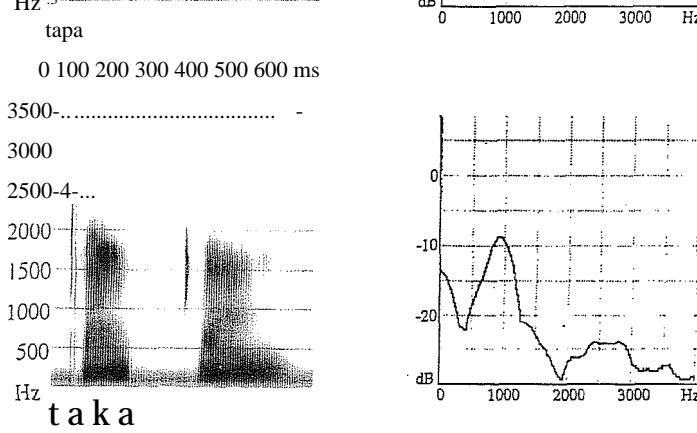


Figure 10.5 Spectrograms and stop burst spectra of Dedua words contrasting p, k and kp̪.

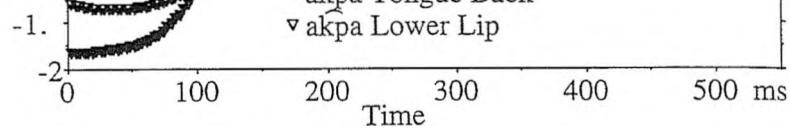


figure 10.6 Coordination of lower lip and tongue back movements in the Ewe word akpa (vertical displacement, normalized scale expressed in standard deviations, mean of ten tokens aligned at release).

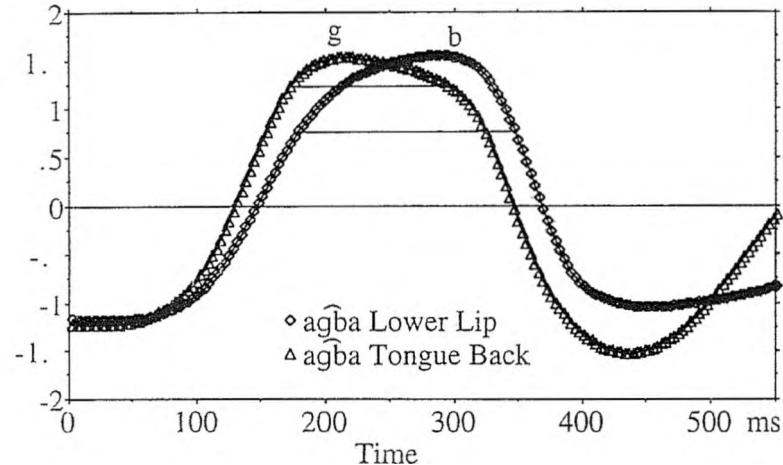


figure 10.7 Coordination of lower lip and tongue back movements in the Ewe word agba (vertical displacement, normalized scale expressed in standard deviations, mean of ten tokens aligned at release).

In both figures 10.6 and 10.7, the consonant release is at 350 ms. Two horizontal lines have been drawn on these figures. One connects the lower lip height at the time of release on the labial movement trajectory to the preceding point at the same height on the closing phase of the lip movement. A similar line connects the tongue back height at the mean time of onset of closure (from table 10.4) to the following point with the same height on the downward trajectory of the tongue back. These lines visualize the likely durations of contact.

More precise estimates of the closure durations of the velar and labial components of the labial-velar stops are given in table 10.6. These were obtained in the following way. For the labial closure durations, the time point with the nearest articulator height to the height at labial release on the upward lower lip movement was subtracted from the release time. For the velar closure the mean time at closure was subtracted from the time point with the nearest height to the height at closure on the downward movement of the tongue back.

These estimates have a number of sources of error, including the basic assumption that closure and release occur at similar heights of the articulators. The plausibility of this assumption is supported by comparison between the height at closure onset and at release of simple bilabial and velar stops, where the time of both onset and release of closure are known from the acoustic records. For each of the four comparisons between onset and release height in the set apaa, abaa, aka and aga there is less than 1 mm difference; the difference between one sample point and the next in these phases of the movement tracks is typically over 0.5 mm. (The movement data is sampled about every 3 ms.) Comparison of the data in tables 10.5 and 10.6 shows that three of the four estimated closure durations for the component articulations in labial-velars are very similar to the durations of Ewe simple bilabial and velar stops of the same voicing category. The differences are 6 ms or less. The exception is the considerably longer duration of the estimated labial closure in gb compared with the measured duration of b (174 vs 150 ms). This extends the offset between the velar and labial releases in gb.

Connell's multi-speaker study of Ibibio suggests that the mean total duration for kp of about 160 ms can be interpreted as a standard closure duration plus the slight asynchrony of the velar and labial articulations. That is, kp duration is the sum of the duration of p, measured as about 138 ms, plus the amount of time by which the velar articulation leads the labial one, which he estimates at 20 ms.

These timing features would seem to be sufficient to distinguish labial-velars from labial + velar sequences on the one hand and from simple labial or velar stops on the other. However, as Ladefoged (1968) showed, there are frequently

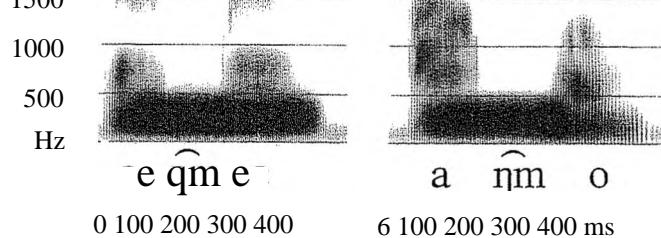


Figure 10.8 Pressure records and spectrograms of Idoma words containing labial-velar nasals with oral pressure reduction.

also aerodynamic features which distinguish labial-velars from singly-articulated stops or nasals. Ladefoged, using a system which measured air pressure in the oral and pharyngeal cavities, observed types of labial-velar stops during whose production the air pressure in the oral cavity is reduced. He concluded that a velaric ingressive airstream was involved. He also observed labial-velar nasals in which there is rarefaction of the air in the oral cavity while pulmonic air continues to pass through the velo-pharyngeal port behind the velar closure. Figure 10.8. shows pressure records and spectrograms of tokens from Idoma in which pressure reduction occurred. These too were described as having a velaric ingressive airstream.

We now feel that some of these descriptions might be rephrased in order to avoid the possibly misleading implication that these sounds are made in the same way as clicks. Let us first consider labial-velar nasals of the Idoma type. These have a bilabial closure and voiced pulmonic air flowing out through the nose. If they are also straightforwardly described as being produced with the velaric airstream mechanism, then they are effectively equated with nasalized bilabial clicks such as occur in !X6o. Yet they are clearly a different sound altogether, principally because they lack the salient burst of a click and are acoustically predominantly resonant in character. The spectrograms of Idoma rjm in

0 100 200 300 400 500 600 ms

Figure 10.9 Spectrogram illustrating a nasalized bilabial clickin ^Hda.

figure 10.8 can be compared with =j=H6a rjO in figure 10.9. In addition to the acoustic differences observed between these two types of sounds, differences in the aerodynamic patterns can also be noted. In Idoma rjm the air pressure in the oral cavity often rises initially. Since this is a nasal, we can be fairly certain that this is because the air volume between the velar and labial closures is being compressed as the jaw and the tongue dorsum continues to rise, reducing the size of the cavity between the closures. An oral pressure rise *could* occur as a result of pulmonic air pressure if the labial closure was formed before the velar closure, but only if the nasal passage remained closed until after the labial closure had been formed. Otherwise the pulmonic air would escape through the nose and there would be no pressure build-up in the oral cavity. Thus if the oral pressure increase was due to pulmonic air we would observe two additional features; first, there would be a simultaneous rise in pharyngeal pressure (since pulmonic air would only reach the oral cavity if the oral and pharyngeal cavities are not divided into two separate chambers by a closure at the velum); second, when the nasal escape was initiated there would be burst-like release of pressure through the nose. Neither the aerodynamic nor the acoustic records of Idoma support the view that the oral pressure increase can be due to pulmonic pressure, since these phenomena are absent.

In the nasals we are examining, following the oral pressure increase, the air pressure is then reduced as the cavity expands with the lowering of the tongue, sometimes reaching a level below atmospheric pressure, as in the two tokens in figure 10.8, but sometimes only reaching equality with atmospheric pressure, as in other tokens in the same data set. On the other hand, in rjO there is always substantial oral cavity expansion (see the discussion relating to figures 10.15 and 10.16 below, and compare chapter 8), creating greater negative pressure. The difference in timing between the two closure releases in

oral air is essential. It seems preferable to reserve the term 'velaric airstream mechanism' for the latter kind of situation, and to merely note the presence of an 'oral pressure reduction' in the other.

Since the articulatory gesture appears the same in the stops and nasals, the same rephrasing should apply to Idoma labial-velar stops, as well as many of those from Yoruba, Edo and other languages, described in Ladefoged (1968) as being produced with both the pulmonic egressive and velaric ingressive airstream mechanisms. Oral and pharyngeal pressure records of three repetitions of the words *okpa* and *ikpa* extracted from an Edo sentence are shown in figure 10.10. A striking fact is the difference between the two words in the oral pressure records. Following work by Silverman and Jun (1994) on coarticulated k + p sequences in Korean, we now have an explanation for differences of this type. They are due to interactions between the differing movements required for the vowel sequences in these words and the overlapping consonantal gestures. In *okpa* there is initially an increase in oral pressure, which then declines to a slightly or strongly negative value before the release. In the third repetition the increase in pharyngeal pressure substantially leads the increase in the oral pressure, confirming that the velar closure leads the labial one here and leading to the inference that the oral pressure rise is due to jaw and tongue movement. In *ikpa* on the other hand there is minimal or no oral pressure increase initially, suggesting that upward movement of the jaw and tongue is completed before labial closure occurs, and, at a later point, consistently strong negative oral pressure. The retraction of the tongue involved in passing from the i to a may account for a substantial part of this rarefaction. The timing of release is harder to read from these records. In *ikpa* the return to positive oral pressure before release probably indicates that the velar closure has been released before labial release, allowing the positive pharyngeal pressure to spread into the oral cavity. In this case there will of course be a burst, but one that is not click-like in nature. In other tokens the fall in pharyngeal air pressure and the rise from negative oral air pressure seem to be coextensive in time. This may be because the closures are released more or less simultaneously.

The situation is different when a labial-velar stop articulation is accompanied by downward movement of the larynx. Larynx lowering was inferred from the rarefaction of air in the pharyngeal cavity, observed consistently in

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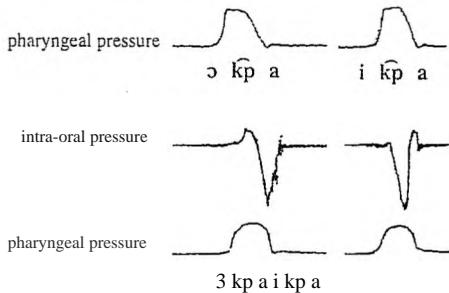


Figure 10.10 Aerodynamic records of the words okpa and ikpa extracted from three repetitions of an Edo sentence.

both kp and gb in Idoma by Ladefoged (1968). Larynx lowering might also be contributing to the decay of pharyngeal pressure build-up in some of the Edo stops shown in figure 10.10. Connell (1987) observed substantial inward airflow, accompanied by pre-voicing, in Ibibio kp. Both these features are consistent with use of a glottalic airstream. Hence, in some languages at least it seems appropriate to talk of labial-velar implosives, although these do not contrast with labial-velar plosives. (Recall that the Central Igbo labial implosives discussed in chapter 3 are derived from labial-velar plosive segments.) Other languages in which an inward airflow occurs with the labial release seem likely also to be using a glottalic ingressive airstream mechanism if the velar closure leads the labial one in the usual fashion.

Other Doubly-articulated Closures

Although Labial-Dorsal sounds are relatively common, it is much rarer to find languages combining a bilabial closure with anything other than a velar one.