GESTURAL ECONOMY

Ian Maddieson
University of California, Los Angeles, USA

ABSTRACT

This paper outlines a theory of gestural economy in language structure, with illustration partly drawn from studies of Ewe sounds using electromagnetic articulography and video. It argues that languages tend to be economical both in the number and nature of the gestures used to construct their inventory of contrastive sounds. Tests of this theory are provided by complex consonants and claims of 'polarization' of contrast.

INTRODUCTION

As is well-known, languages show a tendency to construct their inventory of contrastive sounds in a way that is at least partially symmetrical. For example, a language with the stops /p, t, k/ is far more likely to also have /b, d, g/ than to have /ɖ, ɟ, ɢ/. If sounds are regarded as composed of features, this tendency can be expressed as maximum exploitation of compatible feature combinations. The number of features needed to form a given number of contrasts is thus economized.

This paper argues that a similar pattern can be seen in the articulatory organization of the sounds of a language. That is, there is an analogous tendency to be economical in the number and nature of the distinct articulatory gestures used to construct an inventory of contrastive sounds, and it is this (rather than a more abstract featural analysis) that underlies the observed system symmetry. Moreover, this tendency can be seen as an aspect of a more general principle that can be given the name 'Gestural Economy'.

There are three principal strands to the argument in support of this overall view. First, there is the well-known evidence that languages as a whole favor certain articulatory positions and movements, which are by-and-large those that are more efficient (i.e. acoustically effective) and involve less extreme movements. Second, within a language a given articulatory gesture is often exploited for several distinct segments, for example, nasals and stops usually occur at the same places of articulation and complex segments are built up out of gestures used in simple ones. Third, articulations are not generally displaced from the 'economical' positions or otherwise modified when a language includes further contrasts at nearby places. That is, evidence for systematic use of polarization strategies is lacking.

Only a very brief review of the first point will be provided. The second point is supported by a demonstration that the labial and velar gestures in simple bilabial and velar stops are largely similar to those in labial-velar stops in Ewe. The third point will be supported by showing that one of the best-known hypothesized polarization effects is spurious: labio-dental fricatives in Ewe do not ordinarily involve use of an 'enhancing' elevation of the upper lip in these segments.

What is meant by a gesture?

Before proceeding to any further discussion, it may be useful to characterize what is meant by a gesture in the present context. This term is not intended to refer to a primitive element in the organization of phonology (as in Articulatory Phonology [1]), nor to an articulatory invariant. Here, it simply refers to a typical movement trajectory for a given articulatory subsystem in realizing a given phonetic contrast, bearing in mind the initial conditions for the start of the gesture, anticipation of the following context, and any competing demands of other simultaneously specified aspects of the phonetic element of which the gesture is a component. It is thus a recasting of the traditional phonetic notion 'place of articulation' in dynamic terms and with the focus on the properties of the movements of active articulators as much as on the sites at which constrictions are formed.

INVENTORY STRUCTURE

Cross-linguistic studies of segment inventories show that languages tend to include many of the same segments [2]. The stops /p, t, k, b, d, g/, the fricatives /f, s, ʃ/, and the nasals /m, n, ɲ, ŋ/ are more common than other segments of their respective classes. Moreover, languages show a strong tendency to have small 'families' of sounds that share common articulatory positions. This already emerges from the listing of common sounds above, where the sets /p, b, m/, /t, d, n/ and /k, g, ŋ/ share - in traditional phonetic terms - the same place of articulation.

These commonalities are part of the motivation for the proposal of gestural economy. There is good reason to believe that the commonly found articulatory gestures are more frequent since they are in themselves efficient and economical, but further 'economy' is achieved by re-using the same gesture in a variety of segments (even if the gesture is an inherently less economical one), and by resisting uneconomical modifications that might be made in the interests of generating larger acoustic distinctions between competing sounds. The remainder of the paper will illustrate these two points using simple and complex stops as an example of re-use of common gestural patterns, and labio-dental fricatives as an example of the absence of modification.

SIMPLE AND COMPLEX STOPS

Ewe, a language spoken in Ghana and Togo, is among those with the labial-velar stops /k͡p, g͡b/. The component gestures of these labial-velar stops are very similar to those in simple bilabial and velar stops, as discussed in some detail in [3]. In that paper, evidence for the similarity of the gestures in doubly- and singly-articulated stops was illustrated with data from one speaker in an experiment using electromagnetic articulography [4]. Data from a second speaker is presented in Figures 1-3.

Figure 1 shows the time course of the vertical movement of the lower lip in the word /apaa/ *'job'*. In this figure and the next two, the movement data have been converted to standard scores so that they can be plotted on the same scale and with the same origin. Release of the consonant closure, determined from the acoustic record of the utterances, is at 300 ms. This point is used as the line-up point for aligning repetitions. Each of the figures represents the mean of ten repetitions.

Figure 2 shows the vertical movement of a point on the back of the tongue during the plain velar stop in the word /aka/ *'charcoal'*.

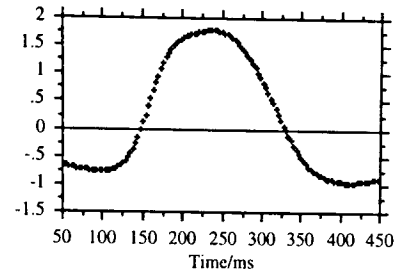

Figure 1. Normalized mean vertical movement of the lower lip in /apaa/

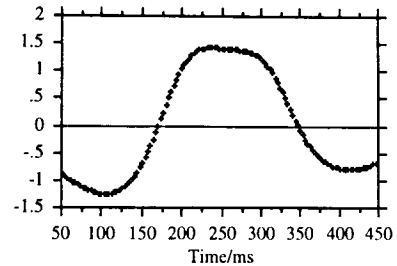

Figure 2. Normalized mean vertical movement of the tongue back in /aka/.

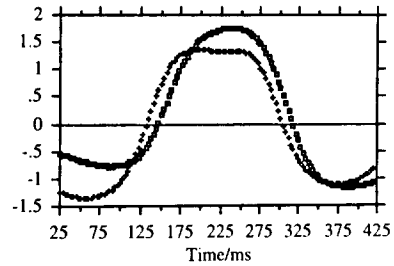

Figure 3. Normalized mean vertical movement of the lower lip and tongue back in /akpa/.

The corresponding movements of both the lower lip and the tongue back during the word /akpa/ *'too much'* are shown in Figure 3. The velar gesture, plotted with small crosses, leads the labial one (small squares) by a few milliseconds, but both gestures are in all salient particulars like those in the simple stops /p/ and /k/. The movements in the doubly-articulated stop have very comparable time courses, very similar shapes, and very similar amplitudes to the movement of the same articulator in a simple stop (amplitude

cannot be read off the normalized plots shown here, but is very comparable in the unnormalized data.) This, of course, need not be the case, and some differences, especially in time course, might have been expected.

Some differences between the oral gestures in voiced and voiceless simple stops at the same place, and between the simple stops and the components in doubly-articulated stops were indeed observed and reported in [3], but with one exception these can be accounted for as contextual effects, due to the demands of other specified aspects of these segments. The exception concerns a backward movement of the tongue body in doubly-articulated stops that is absent in simple velars. Its explanation remains undetermined, but it could be an aerodynamically-induced consequence of a double closure in the oral tract.

Apart from this detail, Ewe doubly-articulated labial-velar stops appear to be made in the simplest way possible – by combining the well-rehearsed movements that are used in simple labial and velar stops. It is not just that labial-velar stops employ two places of articulation that are used elsewhere in the language; they are constructed of the same specific gestures used elsewhere. We hypothesize that languages take maximal advantage of such opportunities for limiting the number of distinct gestures employed, as part of a general preference for gestural economy.

ABSENCE OF POLARIZATION

Ewe is also known as one of the relatively small number of languages with a contrast between [ɸ, β] and [f, v]. It has been claimed [5] that Ewe speakers (and speakers of other languages in the same area with [ɸ, β] and [f, v]) 'enhance' the bilabial/labio-dental contrast among fricatives by using an active raising gesture of the upper lip in the production of the labio-dentals. According to this view, the structure of the set of phonologically significant distinctions in the language has a direct influence on the production of a sound type – a labio-dental fricative – that is among those that are the most highly favored in the world's languages [2].

It seems likely that labio-dental fricatives are favored because this is an optimal place for creating fricatives. It requires precise positioning of only one active articulator rather than two as for a bilabial, and a relatively small movement compared to, say, a linguo-labial or interdental. Labio-dentals are also acoustically readily distinct from all fricatives produced further back – except perhaps [θ].

From a gestural economy perspective, these virtues would be expected to be retained, rather than disturbed because of a contrast with less economical sounds. The articulatory target might in such a case be more precisely defined, constraining the variability in order to protect the contrast, but that is all.

The two Ewe speakers' productions of bilabial and labio-dental fricatives were also investigated using electromagnetic articulography. These speakers showed no upward movement of the upper lip for [f, v]. The upper lip in words such as /eve/ *'two'* remained in the same position as in words like /eke/ *'sand'* [6]. The upper lip lowers quite substantially for [ɸ, β], resulting in a visibly higher lip position for the labio-dentals than for the bilabials. However, this is not due to raising the upper lip in the labio-dentals.

In order to study this question in greater depth, 17 additional Ewe speakers were videotaped saying words contrasting bilabial and labio-dental fricatives, and words containing velar stops in the same vowel environments. In addition, a videotape made earlier of another speaker was analyzed. Both frontal and lateral views of the lips were examined on a frame by frame basis.

A population of 20 Ewe speakers (all from the northern part of the Aŋlo dialect area, where the vowel /e/ is pronounced as a mid front vowel [ɐ] rather than as [ə]) was thus examined. Of these, two show some clear raising of the upper lip in labio-dentals, and two others show some smaller adjustment of the upper lip position either forward or upward. More typical articulations are illustrated in Figures 4 and 5. These figures are digitized frames from the videotape of one of the speakers and show the culminating phase of the word-medial consonants viewed from the side. Both figures show the lip position in /afa/ *'half'* on the left of the figure. For this sound the upper teeth are not completely covered by the upper lip but the lip is not lifted out of the way

to any degree. Figure 4 compares this lip position with that in /aɸa/ *'shout'*. For [ɸ] the upper lip is lowered and drawn inwards to meet the lower lip; it entirely covers the upper teeth. Figure 5 shows that in [f] the upper lip is in a position almost identical to that in the velar stop of /aka/ *'charcoal'* on the right of the figure. The angle of the lip profile below the nose is the same for these two sounds. (Note that a small distortion is introduced just below the superimposed time-coding on the video-tape. This must be ignored in making the comparison.)

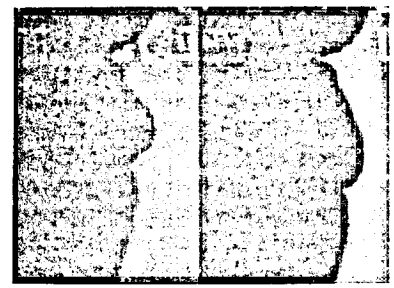

Figure 4. Position of the lips at the center of the consonants in /afa/ 'half' (left) and in /aɸa/ 'shout' (right).

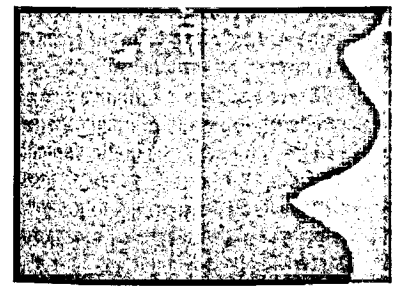

Figure 5. Position of the lips at the center of the consonants in /afa/ 'half' (left) and /aka/ 'charcoal' (right).

Most of the Ewe speakers do not raise the upper lip to produce labio-dentals, but a few do. To determine if this is greater than the cross-speaker variability that one might find in another language without a bilabial/labio-dental contrast, 20 speakers of Sɛle (Santrokofi) were also examined on video-tape. This language, spoken by a people who are neighbors of the Ewe, has only one labial fricative of any kind, [f]. Of this group, two showed a clear raising of the upper lip during [f], three others showed some raising or fronting. Because a more extensive wordlist was taped with the Sɛle speakers, it was also possible to note that the speakers who tended to raise the upper lip for [f] often had a rather similar gesture with certain other consonants, such as [s] and [ɲ].

These data suggest that the occurrence of a raising gesture for labio-dental fricatives is not in any way associated with the presence in the same language of a contrasting bilabial place of articulation for fricatives. Labio-dentals are typically produced in the same way – without an added upper lip gesture – regardless of inventory structure.

SUMMARY

This paper has suggested that some patterns of linguistic structure can be attributed to a principle of gestural economy. Support for this view can be demonstrated both by language-internal comparison across different segments, and cross-linguistically by comparing production of similar segments in differently structured inventories.

ACKNOWLEDGEMENTS

Work supported in part by the National Science Foundation in the US and the US Information Agency in Ghana.

REFERENCES

[1] Browman, C. P. & L. Goldstein (1992), "Articulatory Phonology: an overview", *Phonetica*, 49: 155-80.

[2] Maddieson, I (1984), *Patterns of Sounds*, Cambridge: C. U. P.

[3] Maddieson, I. (1993), "Investigating Ewe articulations with electromagnetic articulography", *Forschungsberichte des Instituts für Phonetik und Kommunikation der Universität München* 31: 181-214. (Also see *UCLA Working Papers in Phonetics* 85, 22-53.)

[4] Perkell, J. S., M. Cohen, M. Svirsky, M. Matthies, I. Garabieta & M. Jackson (1992), "Electromagnetic Midsagittal Articulometer (EMMA) systems for transducing speech articulatory movements", *JASA*, 92: 3078-96.

[5] Ladefoged, P. (1993), *A Course in Phonetics* (3rd Edition), New York: Harcourt Brace Jovanovich.

[6] Ladefoged, P. & I. Maddieson, (1995), *Sounds of the World's Languages*, Oxford: Blackwells.