GESTURAL OVERLAP AND GESTURAL WEAKENING IN CONNECTED SPEECH

Martin C. Barry
Department of Linguistics, University of Manchester, UK

ABSTRACT
This paper reports an investigation into the temporal characteristics—duration and relative timing— of coronal and dorsal lingual gestures in [nk], [tk] and similar clusters in English and Russian. Electropalatographic evidence is considered in relation to the question whether the 'assimilations' described in this context for a number of languages may be viewed as instances of gestural overlap, gestural reduction, or of genuine assimilation (change of one entity into another). Electropalatographic evidence suggests that the general case involves, initially, increased overlap between coronal and dorsal gestures, accompanied by a reduction in the magnitude of the coronal gesture once this is masked by the dorsal; there may additionally be some compensatory lengthening of the dorsal gesture. The paper therefore gives qualified support to the account proposed in the theory of Articulatory Phonology, while contributing to well-motivated explanation of the phenomenon.

1. 'ASSIMILATION' IN [nk] CLUSTERS

The phenomenon attested in many of the world's languages, whereby a sequence of consonants consisting of a dental or alveolar consonant followed by a velar may exhibit a process generally (but loosely) termed 'assimilation', yielding what has generally been identified as a geminate or partial geminate sequence [kk] or [ŋk], has been widely reported. A number of studies (cf. [1]) have sought to investigate whether 'assimilation' *stricto sensu* might not be an appropriate label for the process, since implicit in the use of the term is the assertion that one entity changes into another at some level of description (e.g. the underlying /t/ phoneme becomes a /k/; or the consonantal occlusion is formed entirely, and for geminate duration, at the velar place of articulation.) One approach which has sought to contradict the conventional view is that of Articulatory Phonology [2], according to which the phenomenon under consideration, like all phonetic and phonological phenomena, is attributable not to an assimilatory change of identity of a phonetic or phonological object, but rather to a change in the relation between these objects. The relationship in question— "phase" in the terminology of the theory— is that governing the relative timing of two independent articulatory gestures, which are themselves the primitives of the representation. It follows from this that the theory proposes a simple and economical account of the so-called 'assimilation' phenomena, from which any notion of an arbitrary change in the nature of the representation is eliminated.

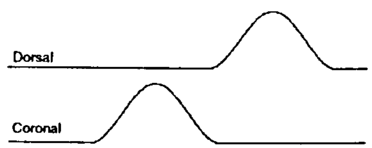

Figure 1. Schematic gestural trajectories for coronal and dorsal gestures in [nk] sequence.

The durational aspects of the data in question are crucial in evaluating the relative merits of the competing accounts. While the conventional 'assimilation' treatment predicts a significant durational difference between, e.g. the velar closure in a surface [tk] cluster (i.e. one in which the assimilation has not taken place) and a [kk] cluster resulting from such an assimilation, the Articulatory Phonology version of events predicts no such distinction, since the [tk] has been reduced to [k] by a shortening of the interval between the coronal and dorsal gestures, with the original [t] finally masked from the listener by the now-simultaneous velar closure. Under these conditions, the masked [t] is then subject to deletion, since both the onset and the offset of the closure phase of the consonant cannot, by virtue of the overlapping velar closure, be audible to the listener.

2. EXPERIMENTAL METHOD

The study reported here involved the acquisition of electropalatographic data from speakers of both English and Russian (5 English speakers, 3 Russian speakers), uttering carrier sentences involving target sequences of coronal plus velar consonants at controlled speaking rates, giving a range between slow, careful and rapid colloquial speech. EPG data was recorded at sample rates varying from 100 Hz to 220 Hz (the experimental was conducted in various laboratories in the UK, determined by availability subjects, particularly Russian speakers). From the raw EPG signal time varying plots corresponding broadly to gestural trajectories were calculated by summing contacts over regions of the palate corresponding to target contact regions for consonants in the denti-alveolar and velar regions.

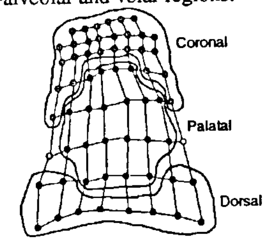

Figure 2. Sub-regions of the EPG palatal surface used for calculating coronal and dorsal (and, redundantly here, palatal) gestural trajectories.

This, I have argued, yields gestural plots of comparable quality to those derived from X-ray microbeam tracking data; the same might be argued for the comparison between EPG data and data from electromagnetic articulography. Figure 2 shows the delimited sub-regions of the artificial palate which were used for calculating coronal and dorsal gestures.

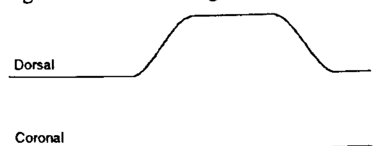

Figure 3. Schematic trajectories for coronal and dorsal gestures in underlying [nk] sequence pronounced as [ŋk]

The plots derived in this way were smoothed by the fitting of ninth-order polynomials over the data range, such that the coefficient r for the correlation between the data points and the smoothed curve was consistently greater than 0.97. The curve fitting served the dual purposes of smooth interpolation between the data points and the simple determination of onsets and maxima in the gestural trajectories; these tasks were performed by computer software written specially for the purpose, which permitted the results from a relatively large body of data to be accumulated. 60 tokens were considered from each of the eight speakers.

3. HYPOTHESES

The data collected was used to evaluate a number of competing hypotheses as to the patterns which might be discerned in the gestural trajectories for coronal-dorsal sequences.

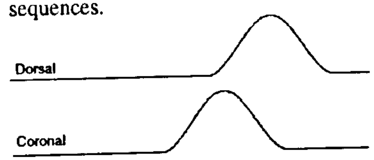

Figure 4. Schematic gestural trajectories for coronal and dorsal gestures in [nk] sequence with increased gestural overlap.

Hypothesis 1:
At increased rates of speech the coronal gesture is replaced by a prolonged dorsal gesture, with a closure duration for the stop comparable to that of a geminate sequence (Figure 3). This is the phonetic realisation predicted by the 'assimilation' analysis, and, if observed, would therefore support the view that at some cognitive level the speaker substitutes a velar for the original coronal consonant.

Hypothesis 2:
At increased rates of speech the coronal and dorsal gestures both remain intact, but the interval governing their relative timing is reduced (Figure 4). This is the pronunciation which the Articulatory Phonology account appears to propose. Under this view the perceived 'assimilation' is simply a consequence of the overlap in time of the two gestures.

Hypothesis 3:

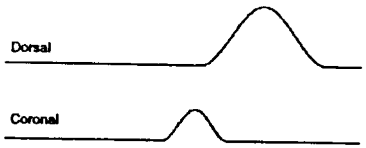

Figure 5. Schematic trajectories for coronal and dorsal gestures in [nk] sequence with coronal weakening.

At increased rates of speech the coronal gesture simply diminishes in magnitude (Figure 5). This has been proposed [3] as an alternative explanatory mechanism for the loss via apparent assimilation of syllable-final coronals. This view carries with it the prediction that the coronals will be subject to assimilation or loss in contexts other than before a heterorganic non-continuant consonant. This prediction, though, beyond the scope of the investigation reported here, does not appear to be born out by the general descriptive literature.

4. RESULTS

4.1 Sample of detailed results for a single speaker

The results obtained may best be illustrated by consideration of the patterns discernible in the articulatory activity of a single speaker. Figures 6–8 show the mean measured gestural trajectories over

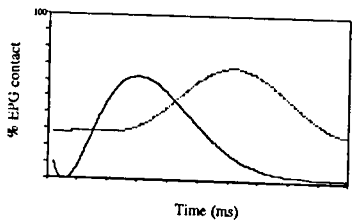

Figure 6. Mean gestural trajectories for [nk] clusters in slow utterances (Speaker DM)

twenty tokens for [nk] clusters uttered by one of the English speakers at the three self-selected speaking rates slowly, normal conversational rate and quickly.

It is evident from these figures that the data are consistent with none of the three hypotheses outlined above considered in

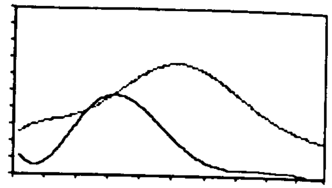

Figure 7. Mean gestural trajectories for [nk] clusters in normal conversational-rate utterances (Speaker DM)

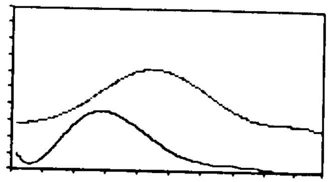

Figure 8. Mean gestural trajectories for [nk] clusters in fast utterances (Speaker DM)

isolation, but they appear to show tendencies reflecting both hypotheses 2 and 3: gestural overlap increases, and at the same time the magnitude of the coronal gesture reduces. Hypothesis 1, on the other hand, appears to receive less support from the data: in the general case, the duration of the dorsal gesture does not vary significantly across speaking rates, and there is no tendency exhibited for the velar gesture to lengthen in compensation as the supposed 'assimilation' takes effect. This last tendency is subject to certain exceptions, discussed below in 4.3.

4.2 General trends in the results

The tendency in the data for the speaker considered above to show compatibility with a hybrid version of hypotheses 2 and 3 (gestural overlap plus coronal reduction) was repeated for **all speakers** and for **both languages**. The question proposes itself: are there genuinely two independent forces at work in connected speech, inducing increased gestural overlap simultaneously with but independently from coronal reduction? This would, naturally, be an uncomfortable result, since (for the eight speakers and two languages considered here) the two phenomena appear to be closely linked, since we do not encounter either effect in the absence of the other.

A clearer picture may be obtained by observing the detailed pair-wise correlation between the two dimensions being measured. Figure 9 shows a plot of measurements from all the tokens recorded in the study. The horizontal axis shows the interval between the peak value (corresponding to the mid-point in time) of the coronal gesture and the peak value for the dorsal gesture; thus the nearer to the left of the diagram, the shorter the phase-interval between coronal and dorsal gestures. The vertical axis shows the magnitude of the coronal gesture (as % of the maximum degree of lingual-(denti)alveolar contact for a fully-articulated stop closure). A point on the graph therefore shows the degree of coronal reduction for a given inter-gestural phase interval.

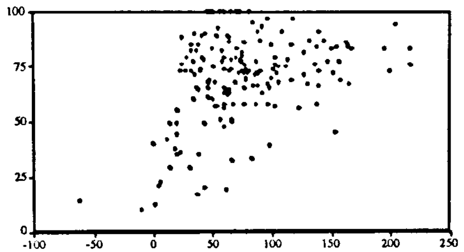

Figure 9. Plot of inter-gestural phase interval (in ms; horizontal axis) against magnitude of coronal gesture (in % of notional maximum; vertical axis) for all speakers.

The pattern of distribution observed here is once again broadly consistent across all speakers and both languages, and suggests that significant coronal weakening is encountered (predominantly, though not exclusively) in tokens where the interval between mid-points of the coronal and dorsal gestures is less than around 60–70 ms, in other words, in tokens in which the release of the anterior *closure* (and perhaps in some cases also its onset) is masked by the *closure at the velum*. This relationship perhaps allows one to argue that the motive force here is gestural overlap, in line with the Articulatory Phonology account; whereas coronal weakening is a subsidiary effect dependent on the overlapping of consonantal closures.

4.3 Exceptions in English

In the English data, though not the Russian, a significant subset of tokens did not follow the general pattern outlined above, but rather showed total or near-total reduction of the coronal gesture at the same time as *significant lengthening* of the dorsal gesture. These tokens, then, do indeed display compensatory lengthening in a process which is perhaps most aptly considered 'assimilation'. What appears to be the case is that English 'phonologises' the general phonetic effect (sc. of gestural overlap sometimes leading to loss of the coronal) observable in the English and Russian data, by making available to speakers a categorical phonological rule allowing the substitution of a geminate (or partial-geminate) velar for the original alveolar consonant—thereby forestalling the implementation of increased gestural overlap which would have led to a similar result, namely the percept of a velar-only consonantal sequence.

5. CONCLUSIONS

The data considered here give support to the principle embodied in the theory of Articulatory Phonology, that changes in inter-gestural phase relationships may be taken to be a motive force in the derivation of phonetic and phonological patterns. At the same time, it would appear that coronal weakening is licensed by the masking of one stop closure by another, again as a consequence of shifting phase relationships. English, at least, also allows the articulatory effects generated by these forces to play a role in the phonological system.

REFERENCES

[1] Nolan, F.J. (1992), "The descriptive role of segments: Evidence from assimilation", in Docherty & Ladd, *Papers in Laboratory Phonology II*, pp. 261–280. (Cambridge: CUP)

[2] Browman, C.P. & Goldstein, L. (1992), "Articulatory Phonology: An Overview", *Phonetica*, 49:155–180.

[3] Hayes, B. (1992), "Comments on the paper by Nolan", in Docherty & Ladd (*op. cit.*)