ARTICULATORY CHARACTERISTICS OF SINGLE AND BLENDED LINGUAL GESTURES

Dani Byrd†
UCLA Department of Linguistics
†*now at Haskins Laboratories, 270 Crown Street, New Haven, CT 06511-6695 USA*

ABSTRACT

This study uses electropalatography to investigate the temporal and spatial organization of lingual consonants in English consonant clusters. Reduction differences between onsets and codas and between stops and fricatives are observed. Gestural overlap explains contact patterns in juncture geminates.

INTRODUCTION AND METHOD

The sequences considered are (1) juncture geminates—[d#d], [s#s], & [g#g]—which are realized with a single raising and lowering of the tongue, and (2) sequences in which one lingual consonant occurs with a labial consonant —[d#b], [b#d], [s#b], [b#s], [g#b], & [b#g]. The sequences were read in the phrase *"Type baC Cab again"* and recorded using electropalatography. Seven tokens of each sequence from each of five speakers are analyzed. In all the sequences, only a single consonant articulation is made against the palate, and no other consonantal constriction interferes with it. Based on EPG contact profiles, metrics were calculated indicating the spatial and temporal extent of the lingua-palatal contact. Effects of syllable position, place, and manner are tested. For a more detailed description of the method see [1], [2].

RESULTS

The contact profiles for the front region for [d#d] (geminated), [d#b] (coda), and [b#d] (onset) are shown for one of the five speakers in Figure 1. The y-axis represents the percent of the pseudopalate region (front or back) registering lingual contact at a particular point in time; the x-axis represents time in frames of .01 seconds. The null hypothesis, clearly not supported, is that the three contact profiles for a consonant—juncture geminate, coda, and onset—are the same.

Comparison of Means

First let's consider differences in the amount of contact in the front region for [d]. This is indexed by the maximum contact expressed as a percentage of the total possible contact in the front region. Repeated measures ANOVA determines there to be a significant effect of sequence on the maximum front contact for [d] ($F(2,8)= 5.75$, $p=.0283$) such that the coda [d]'s have less maximum contact than [d]'s in the other two sequences. There is also a significant interaction with speaker, with Speaker B having the reverse pattern. The other speakers have a group mean of 58% contact for the onset [d]'s and 42% for codas. The combined mean maximum contact for [d#d] across speakers is

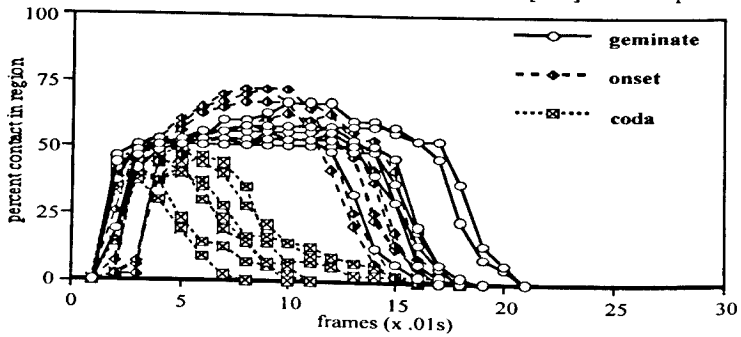

Figure 1. Contact profiles in the front region for [d#d], [d#b] & [b#d], Speaker K.

56%. This parallels results reported elsewhere on reduction of final tongue tip gestures [3], [4].

The duration of linguapalatal contact for [d] is longer in [d#d] than for the other sequences ($F(2,8)=12.55$, $p=.0034$). For three Speakers, A, K, and M, codas were shorter than onsets as well. Next, consider the shape of the profile, or temporal distribution of contact. One measure of this is skewness. Roughly speaking, a greater (positive) skew indicates a shorter closure formation in the contact profile than closure release. For these same three speakers, codas had a greater positive skew than onsets. There was a significant interaction of sequence and speaker in affecting skew ($F(8,90)= 19.460$, $p=.0001$), with Speaker K showing the strongest effect. The time taken in forming the contact was shorter than that needed for the release (*i.e.* positive skew) for both coda and onset [d]'s with the asymmetry being greater in coda position. Another measure of shape is the FLATNESS of the contact profile, indexed here by the mean contact divided by the maximum contact. There was a significant interaction of speaker and sequence on FLATNESS ($F(8,90)= 6.464$, $p=.0001$). All speakers had flatter profiles for [d#d] than for the other sequences. Three speakers, K, A, and B, also had flatter onsets than codas.

The next sequences considered are [s#s], [s#b], and [b#s]. The contact profiles for these are shown for Speaker K in Figure 2. First consider the degree of contact. ANOVA shows there to be no difference among the sequences [s#s], [s#b], and [b#s], in maximum contact in the front region. Next, duration of contact is of interest. There are significant differences in duration ($F(2,8)= 18.35$, $p=.001$). The juncture geminates have the longest durations of contact, and, excepting Speaker S, onsets are longer than codas. For all speakers, contact profiles for codas are less flat and have a more positive skew than either the geminated or onset consonants, as determined by the main effect of sequence on FLATNESS ($F(2,8)= 8.125$, $p=.0118$) and SKEW ($F(2,8)=16$, $p=.0016$). In fact, the coda [s] was the only one of the three [s]'s to have a positive skew for all subjects; only two subjects had a positive skew for the onset [s]. This parallels the findings for [d], suggesting that while coda [s]'s may not undergo spatial lenition, they, like coda [d]'s, are shorter and have faster constriction formation in coda position than in onset position.

The dorsal stop consonant [g] was examined in the sequences [g#g], [g#b], and [b#g]. Here the relevant articulatory region is the back one. The contact profiles are shown for Speaker K in Figure 3. ANOVA determines there to be a significant effect of sequence on maximum displacement in the back region ($F(2,8)=5.476$, $p=.0318$). For all speakers, except Speaker B, displacements decrease from onset to geminated to coda [g]'s. For Speaker B, onsets rather than codas have the lowest maximum contact; codas are still less displaced than geminated [g]'s. There is also a significant difference between the duration of [g] in the three sequences ($F(2,8)=9.51$, $p=.0077$). All speakers'

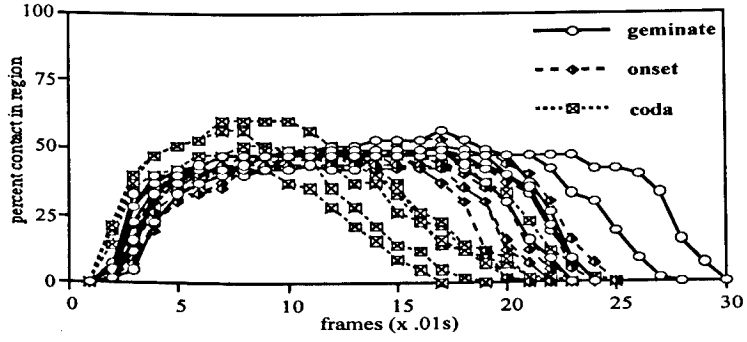

Figure 2. Contact profiles in the front region for [s#s], [s#b] & [b#s], Speaker K.

geminated sequences are longest, and all, except Speaker B, have longer onset [g]'s than coda [g]'s. There is also a significant effect on FLATNESS ($F(2,8)=5.788$, $p=.0279$). Contact profiles for four speakers are flatter for codas than onsets. There is no main effect on SKEW for the velar consonant, although there is a significant interaction of speaker and sequence ($F(8,90)=8.511$, $p=.0001$) with Speakers K, A, and S having onsets more skewed to the right than codas, although most speakers' skews for all three sequences are negative.

Summary

Graphical comparisons illustrating differences in reduction and shortening are shown in Figure 4. (However, recall that Speaker B's data often pattern opposite to those of the other speakers, making an examination of the group means less representative of the general behavior.) In summary, for the stop consonants, onsets are generally more displaced (*i.e.* have greater maximum lingua-palatal contact) than codas. For most speakers, the stops in onset are also longer than in coda. For [s], contact in onset position is longer than in coda position, but there is no difference in spatial extent. Contact profiles for front consonants are generally flatter and less (positively) skewed in onset position than in coda position. This difference is probably due to the need for the jaw to lower for the immediately following vowel in the onset sequences but the possibility of a slower release due to a longer high jaw position for the following bilabial consonant in the coda sequences. (Changes in jaw height would have a much smaller influence on [g] skewness due to the posterior hinge location of the jaw.) For the back stop consonant, contact profiles are flatter in coda position than in onset position. Finally, for all three consonants, the juncture geminates are longer and flatter than both onset and coda consonants.

JUNCTURE GEMINATES

Munhall and Löfqvist [5] examined the blending of two laryngeal gestures separated by a word boundary. This situation is analogous to our geminated sequences where two lingual gestures are canonically present. They observed that a single smooth movement occurred as the gestures overlapped at fast speaking rates. Lingua-palatal contact profiles for our juncture geminate sequences also show a single smooth movement. Both studies find the coproduced movement for juncture geminates to be longer than the non-coproduced movement for a single gesture. Additionally, Munhall and Löfqvist [5] found no consistent tendency for the combined single movement to be larger than an individual (non-coproduced) movement, although a simulated summation of the gestures predicts such a difference. At medium speech rates one of their speakers showed larger geminated movements but this behavior reversed at fast rates. Their other speaker showed no consistent difference. Our data above also show no consistent increase in maximum contact for the geminated consonants, suggesting that a summation process is not at work. (In fact, data here and in [6] suggest some

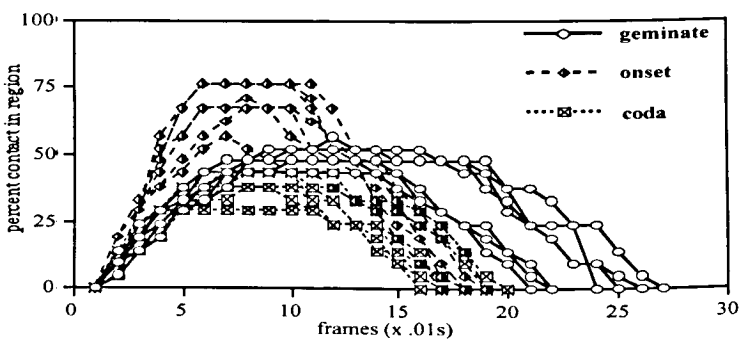

Figure 3. Contact profiles in the back region for [g#g], [g#b] & [b#g], Speaker K.

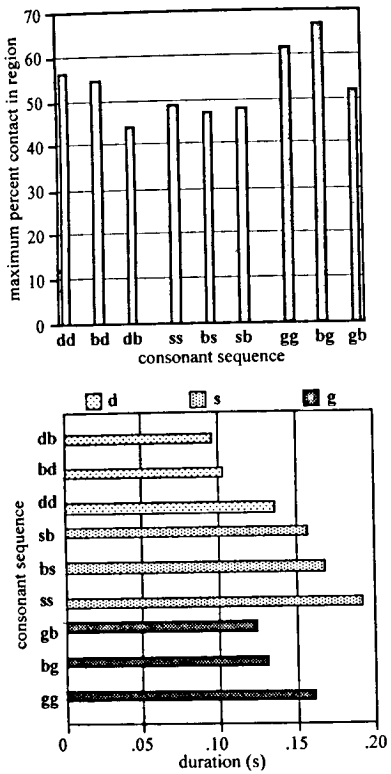

Figure 4. (top) Mean maximum percent contact in region. (bottom) Mean duration of contact in region.

tendency for the onset to be larger than the geminate.) Similarly, Kelso and Tuller [7] (cited in prepublication form in [8]) report that a larger gesture would typically have both increased amplitude and steeper onset and offset slopes. Partly on this basis, Browman and Goldstein [8] argue for the presence of two overlapping bilabial gestures in Chaga [mp] sequences because of the similarity in slope and amplitude to single bilabial closure gestures. The result of the overlap is simply a longer movement. Likewise, we observe a pattern of similar slopes and amplitudes with longer durations for our [C#C] sequences as compared to the single consonants, arguing against gestural summation in these sequences. Furthermore, by virtue of Occam's Razor alone, the overlap account is preferable to the supposition of a new mechansim [8] or to the modification of a gestural score by the substitution of a single 'macro' gesture for the abutting lingual gestures (cf. [9]).

ACKNOWLEDGEMENTS

This work was supported by an NSF graduate fellowship & NSF grant DBS9213604 to the author & Pat Keating. Some of the above work can be found in [2]. Many thanks to Pat Keating, Peter Ladefoged, and Louis Goldstein.

REFERENCES

[1] Byrd, D., Flemming, E., Mueller, C.A., and Tan, C. C. (in press), "Using regions and indices in EPG data reduction", *JSHR*.

[2] Byrd, D. (1994), *Articulatory Timing in English Consonant Sequences*, UCLA Ph.D. diss.

[3] Barry, M. (1992), "Palatalisation, assimilation and gestural weakening in connected speech", *Sp. Comm.*, 11, pp. 393-400.

[4] Browman, C. & Goldstein, L. (1995), "Gestural syllable position effects in American English", in F. Bell-Berti and L. Raphael, eds., *Producing Speech: Contemporary Issues for Katherine Safford Harris*.

[5] Munhall, K. G. & Löfqvist, A. (1992), "Gestural aggregation in speech: Laryngeal gestures", *J. Phon.*, 20, pp. 93-110.

[6] Dunn, M. H. (1993), *The phonetics and phonology of geminate consonants: A production study*, Yale Univ. Ph.D. diss.

[7] Kelso, J. A. S. & Tuller, B. (1987), "Intrinsic time in speech production: Theory methodology, and preliminary observations", in Keller & Gopnik, eds., *Sensory and Motor Processes in Language*. Hillsdale, NJ: Erlbaum, pp. 203-222.

[8] Browman, C. & Goldstein, L. (1986), "Toward an articulatory phonology", *Phonology Yearbook*, 3, pp. 219-252.

[9] Recasens, D., Fondevila, J., Pallarès & Solanas, A. (1993), "An electropalatographic study of consonant clusters", *Sp. Comm*, 12, pp. 335-356.