More on the Motor Organization of Speech Gestures*

Fredericka Bell-Berti† and Katherine S. Harris‡‡
Haskins Laboratories, New Haven, Conn.

We have reported before observations of a reorganization of motor commands to muscles whose increased contraction will further narrow some portion of the upper vocal tract (Bell-Berti and Harris, 1973). This reorganization manifests itself as the merging of electromyographic (EMG) activity for two contiguous speech gestures when the second gesture requires a more closed vocal tract than the first (for example, a vowel-consonant syllable), and as the maintenance of separate activity peaks when the second gesture requires a more open vocal tract than the first (for example, a consonant-vowel syllable).

Another statement of this hypothesis might be: when a muscle must be shorter for the second element in a sequence than for the first, the motor commands for the two gestures will merge into one; when a muscle must be lengthened for the second element of a sequence, activity will be suppressed between commands for the two gestures, and the two commands will not merge. In this paper we will extend our statement about muscles that are vocal tract closers.

Anticipatory coarticulation is a phenomenon that has been described in several situations: the lip-rounding of a vowel anticipated in a preceding string of consonants, or consonant nasality anticipated in preceding vowels, for example. Henke's (1966) "look-ahead" model of anticipatory coarticulation predicts that a feature will be anticipated as soon as it is not contradicted in the intervening speech string. We have been looking for instances of anticipatory coarticulation at the motor command level. Admittedly, this is a very different level than that at which most of the work on anticipatory coarticulation has been done.

We will begin by reexamining some data from Bell-Berti and Harris (1973) and considering how it might be interpreted in light of the Henke model.

Figure 1 shows examples of EMG activity from the genioglossus muscles of three speakers of American English repeating utterances having /-ik-/ and /-ki-/ sequences embedded in them. The genioglossus muscle raises and bunches the tongue for /i/ and /k/ segments, thus narrowing the vocal tract.


†Also Montclair State College, Upper Montclair, N. J.
‡‡Also the Graduate School and University Center of the City University of New York.

GENIOGLOSSUS

LJR
µν800

-600 0 +600 msec

⁄əpi'kæpə/
⁄əp'kɪpə/

KSH
µν500

-500 0 +500 msec

⁄ə'pi:kæpə/
⁄ə'p'kɪpə/

FBB
µν700

-500 0 +500 msec

⁄ə'pi:kæpə/
⁄ə'p'kɪpə/

FIGURE 1
Whenever the sequence involves moving from a more open to a less open vocal tract (i.e., /-ik-/), only one peak of activity is present. On the other hand, when the sequence involves moving from a less open to a more open vocal tract (i.e., /-ki-/) two separate peaks of activity are present. One explanation for this might be that the /k/ gesture is anticipated during the /i/ in the /-ik-/ sequence and the motor commands for the two gestures merge into one—that is, the further closing required for /k/ during /i/ is anticipated. The converse is not true: the /i/ gesture during the /k/ in the /-ki-/ sequence is not anticipated, since the /i/ articulation is contradictory to the more closed vocal tract of /k/. Both cases would seem to fit Henke's model, as it has been extended to the motor command level.

Some other data were also inspected in this light (see Figure 2). These data were again EMG recordings from the genioglossus muscle. They were recorded as the subject repeated a series of four-syllable nonsense words beginning and ending with schwa. The two medial vowels were /i/, and the stress was systematically varied between the first and second /i/. Bilabial consonants were used since the production of a bilabial consonant is not expected to interfere with the preservation of the lingual articulation for /i/. The first and second consonants were /p/ and the final consonant was systematically varied between /p/ and /b/, producing four utterance types that were then repeated at slow and fast rates. (Some of the design detail here is to allow analysis of these data for other purposes.) The data presented are from one speaker of American English, and roughly parallel data have been obtained from two other speakers.

The EMG recordings were inspected to determine whether the two sequences of vowels (the first: stressed-to-unstressed; the second: unstressed-to-stressed) that are separated by an intervening bilabial articulation were like the /-ki-/ and /-ik-/ sequences examined earlier. Although the intervening /p/ is presumably not contradictory to the maintenance of the /i/ vowel articulation, we see that there are two separate peaks of activity in every condition (Figure 2).

We examined the two stress conditions to see if the hypothesis advanced earlier, that EMG activity will merge for sequences moving to a more closed vocal tract, is supported. The vocal tract might be expected to be more closed for a stressed /i/ than for an unstressed /i/. Thus, we might expect to find less separation of the two peaks of EMG activity in the condition where the second vowel is stressed. In fact, the lowest valleys between vowel peaks occur for the unstressed-to-stressed sequences. The most obvious explanation for this difference is that the duration of the /p/ closure is longer before a stressed vowel than before an unstressed vowel and so the EMG signal falls to a lower level before the second vowel begins.

Our conclusion, then, is twofold: first, the /-ik-/ and /-ki-/ sequences are not part of the same subset of data as the /i/ utterances; second, Henke's model does not hold at the EMG level in an example where we might have expected it—for two vowels separated by a nonantagonistic consonant gesture. Features are not anticipated as soon as they are no longer contradictory to intervening segments.

In summary, Henke's look-ahead model of anticipatory coarticulation predicts that an articulatory feature will be anticipated as soon as it is no longer contradicted in the intervening speech string. Examination of two sets of EMG data has revealed support for the model at the motor command level, in one instance,
and a contradiction of the model in the other instance. In the former case, the interacting gestures were contiguous, while in the latter case, they were separated by a presumably noncontradictory consonant articulation.

REFERENCES
