Some Electromyographic Measures of Coarticulation in VCV Utterances*

Thomas Gay†

Abstract

The purpose of this experiment was to study the motor patterns that underlie articulator movements during the production of certain vowel-consonant-vowel (VCV) syllables. Electromyographic (EMG) data were attained from the genioglossus and orbicularis oris muscles of two subjects. The speech material contained both VCV and CVVC contrasts. The data showed surprisingly little in the way of carryover effects of the first vowel on the EMG signals of the second vowel: peak amplitudes of the same second vowel were little changed for different first vowels. For all utterances where the genioglossus muscle was active for both the first and second vowels, a trough appeared in the EMG envelope during the time of consonant production. Both findings were interpreted as supporting the existence of a neutral tongue body position during consonant production.

In a recent cinefluorographic study of vowel production (Gay, 1974), we showed, that in a vowel-consonant-vowel (VCV) utterance, vowel targets are reached efficiently and with a high degree of precision, irrespective of changes in the intervocalic consonant or in the vowel that either precedes or follows the consonant. This high degree of articulatory accuracy (evident especially for /i/ and /u/, and only slightly less so for /a/) supports a spatial target or target field specification of vowels (MacNeilage, 1970).

A basic assumption of a target-based model of speech production is that the underlying motor input to the target-directed movement is characterized by what MacNeilage (1970:184) calls, "an elegantly controlled variability of response to the demand for a relatively constant end." In other words, depending on the particular vocal-tract shape or articulator position for a preceding phone, movement toward a given target will be controlled by any of a number of different motor strategies.

*This paper was delivered at the 5th Essex Symposium on Phonetics, University of Essex, Colchester, England, 25-27 August 1975.

†Also University of Connecticut Health Center, Farmington.

Acknowledgment: This research was supported in part by a grant from the National Institute of Neurological Diseases and Stroke (NS-10424), the National Science Foundation (GSC 740 3725).

[HASKINS LABORATORIES: Status Report on Speech Research SR-44 (1975)]
In order to determine whether such different strategies do, indeed, exist for target-directed movements that originate from different contexts, we undertook a corresponding electromyographic (EMG) study of coarticulation in VCV utterances. In this experiment, we used EMG to study the motor patterns that underlie the vowel gesture in VCV sequences using the same subjects and speech material as in our original X-ray motion picture experiment. A second purpose of this experiment was to test Ohman's (1966) hypothesis that articulator movement in a VCV sequence is essentially diphthongal, with the consonant gesture superimposed on the basic vowel-to-vowel movement.

METHOD

Subjects were the same two native speakers of American English that we studied in our earlier X-ray experiment (FSC and TG). The speech material contained both VCV and CVVC contrasts. The VCVs consisted of the consonants /p, t, k/ and the vowels /i, a, u/ in a trisyllable nonsense word of the form, /kv1CV2p/, where V1 and V2 were all possible combinations of /i, a, u/ and C was either /p/, /t/, or /k/. Corresponding CVVC syllables, of the form /kv1V2p/, were included for purposes of comparing motor patterns between two vowel sequences when one set of utterances was separated by a consonant and the other was not. This contrast was used to test Ohman's (1966) vowel-to-vowel movement hypothesis. Examples of the two types of utterances are /kipapa/ - /kipapa/ and /kutupa/ - /kutupa/. Both sets of utterance types were randomized into four lists, each of which was read five times by the two speakers at normal speaking rates. The carrier phrase, "It's a ..." preceded each utterance, and syllable stress was on the second vowel.

For both subjects, EMG recordings were obtained from the genioglossus and orbicularis oris (superior) muscles. The genioglossus muscle makes up the bulk of the tongue and acts in bunching and protruding the tongue during the production of both /i/ and /u/. The orbicularis oris is active in both closing and rounding the lips. Following usual practice, conventional hooked-wire electrodes were used for the insertions, and the data were recorded on magnetic tape and later processed using the Haskins Laboratories EMG data processing system.

RESULTS

The first question we will address is whether different motor strategies are employed in the control of target-directed movements for a vowel as a function of differences in both the preceding consonant and the preceding vowel ahead of the consonant.

Figures 1 and 2 summarize the effects of the consonant on the activity level of the genioglossus muscle for the vowel /i/. These figures show the averaged EMG signals for the utterances /kupapa/, /kutupa/, and /kukupa/ for both subjects. Each plot contains three peaks. The first represents the muscle activity for the initial /k/, the second for the first vowel (which is merged with the peak for the intervocalic /k/ in /kikupa/), and the third for the second vowel. Levels for the initial /k/ vary somewhat as do those for the first vowel. We attribute this variability to the fact that the first vowel was decontexted, and probably variably so, relative to the second vowel; such stress allophones have been shown to exist (Harris, 1973). Note, however, that for both subjects the EMG signals for the second vowel are surprisingly similar in peak height. The range of variability of peak height for the second vowel was,
GENIOGLOSSUS
Subject FSC

Figure 1: Averaged EMG activity showing the effect of the intervocalic consonant on the production of the vowel, Subject FSC.

GENIOGLOSSUS
Subject TG

Figure 2: Averaged EMG activity showing the effect of the intervocalic consonant on the production of the vowel, Subject TG.
except in one instance, within 25 μv. This is a particularly narrow range considering both the place differences of the three consonants and the fact that the peak signal strength approaches 300 μv for one subject and 800 μv for the other.

Carryover effects of the first vowel (ahead of the intervocalic consonant) on the muscle signals for the second vowel are similarly absent. This is illustrated in Figures 3 and 4. Here, what we interpret as stress effects again appear for the initial /k/. Likewise, the unexpected absence of any effect of different first vowels on the muscle signal for the second vowel is also evident. Again, too, the absence of carryover effects is consistent for both subjects and for all but one utterance, and peak heights occur within a range of 25 μv.

The results described above show very small or no carryover coarticulation. Somewhat greater effects have been shown for VCV utterances by Bell-Berti and Harris (1975). Their utterances contained the same vowels (/i,a,u/) as ours and, in addition, were balanced for stress. They showed almost no anticipatory coarticulation effects of the second vowel on the first vowel, but somewhat greater carryover coarticulation than in the present study. A possible explanation is that the Bell-Berti and Harris syllables were spoken at a considerably faster rate than ours; perhaps fast speech effects were reflected by greater degrees of motor variability.

The extreme interpretation of these results would be the resurrection of the notion of motor invariance in the production of a speech gesture. Our more moderate interpretation, however, is that the observed invariance in the EMG signals for the vowel reflects rather an invariant or neutral tongue body target for the consonant. In other words, the signals are the same because the pattern of movement from consonant target to vowel target are the same.

Further evidence of a tongue body target during the production of a labial or alveolar consonant appears in several forms. Referring back to Figures 1 and 2, we can see that during consonant production, a trough appears in the genioglossus curve. The presence of this trough represents a cessation of genioglossus muscle activity during the production of the consonant, and hence, what we interpret as a break in continuous movement from the first vowel to the second. Figure 5 shows the EMG data for the corresponding CVVC utterance /kulp/. Although a small dip appears in the envelope, the basic pattern is one of uninterrupted activity throughout the entire vowel-to-vowel sequence. The interruption in EMG activity in the VCV, when compared to the continuous activity in the CVVC, would seem to argue against Öhman's (1966) hypothesis that vowel-to-vowel movement in a VCV is basically diphthongal. A more convincing "trough" illustration, however, is in the VCV utterance where both first and second vowels are the same. Figures 6 and 7 illustrate these effects for the utterances /kipi:pə/ and /kitipə/ for both subjects. Here, the basic pattern is the same as before: a peak for the first vowel followed by a trough for the consonant and another peak for the second vowel. Again, our reasoning is that if the tongue body did not assume a different position for the consonant, the EMG envelope would contain one broad peak representing positional constancy for /i/, rather than two peaks separated by a distinct trough. This is consonant with the report of Bell-Berti and Harris (1974).

A trough in muscle activity during the consonant also appears in the lip-rounding component of the vowel. Figure 8 shows both the genioglossus and
Figure 3: Averaged EMG activity showing the effect of the first vowel on the production of the second vowel, Subject FSC.

Figure 4: Averaged EMG activity showing the effect of the first vowel on the production of the second vowel, Subject TG.
Figure 5: Averaged EMG activity for the CVVC sequence, /kuipə/, Subject TG.

Figure 6: Averaged EMG activity showing two separate vowel peaks for a VCV when the first and second vowels are the same, Subject FSC.
Figure 7: Averaged EMG activity showing two separate vowel peaks for a VCV when the first and second vowels are the same, Subject TG.

Figure 8: Averaged EMG activity for both the genioglossus and orbicularis oris muscles during the production of the utterance, /kutupə/. 
orbicularis oris muscle activity data for the utterance /kutup\a/ for Subject TG. Note how both curves rise for the vowel and then dip for the consonant before rising again for the vowel. The only anticipatory movement seems to be a slight time lead for orbicularis oris activity for the second vowel. The absence of anticipatory lip rounding for the second vowel during the consonant contradicts the X-ray data of Daniloff and Moll (1968), which showed that lip rounding for a vowel can begin as early as three or four phonemes ahead of the vowel. One explanation for the Daniloff and Moll result might be that those phonemes preceding the vowel in their syllables contained lip-rounding components themselves. For example, in the word "construe," it might be argued that both the /s/ and /t/ are rounded consonants. The nonlabial consonants in our utterances (i.e., /t/ and /k/) are probably not marked by such a "rounding" feature.

CONCLUSIONS

The presence of a trough in the EMC envelope for a vowel during the time of consonant production suggests that a tongue body position or target exists for the consonant. The finding that similar motor patterns underlie the production of a vowel followed by different consonants suggests that this tongue body target is a neutral one. Both findings argue against the ubiquity of anticipatory gestures occurring earlier than one segment ahead of a particular phone (Henke, 1966). This, of course, contradicts the well-known data of Daniloff and Moll (1968) that showed the onset of lip rounding for /u/ to begin as early as four or five segments ahead of the vowel. We would like to propose, however, as an alternative interpretation of the Daniloff and Moll finding, that the so-called "early" onset of lip rounding in their data was not in anticipation of a downstream vowel but rather corresponded to a possible rounding component of one or more of the immediately preceding consonants: /n/, /s/, /t/, /r/.

Although our data do not show any evidence of anticipatory movements in VCVs, we do not propose a strict phoneme-by-phoneme specification of segmental ordering. On the contrary, the evidence for an anticipatory coarticulation field is widespread; we are proposing simply a reappraisal of current views on its size.

REFERENCES


