Effect of Speaking Rate on Stop Consonant-Vowel Articulation*

T. Gay† and T. Ushijima++
Haskins Laboratories, New Haven, Conn.

ABSTRACT

The purpose of this experiment was to study the effect of speaking rate on the articulation of the stop consonants /p, t/ in combination with the vowels /i, a, u/. Two speakers of American English read lists of nonsense syllables containing /p, t/ in all possible vowel-consonant-vowel (VCV) combinations with /i, a, u/ at both normal and fast speaking rates. Electromyographic (EMG) records were obtained from the orbicularis oris, superior longitudinal, and genioglossus muscles. The EMG data were analyzed using the Haskins Laboratories' data system. For both labial consonant and lingual consonant production, the effect of an increase in speaking rate was an increase in the activity level of the muscle (orbicularis oris and superior longitudinal). However, for vowel production, the effect of an increase in speaking rate was a decrease in the activity level of the genioglossus muscle. These results are discussed in relation to a general account of speaking rate control.

INTRODUCTION

In some recent experiments on the production of labial CV sequences, we showed that an increase in speaking rate involves more than a simple reordering of the timing of commands to the muscles (Gay and Hirose, 1973; Gay, Ushijima, Hirose, and Cooper, 1974). Rather, the production of both the consonant and the vowel segments of a syllable during fast speech was shown to be characterized by changes in motor organization as well as changes in motor timing. For labial consonants, the effect of an increase in speaking rate is an increase in the activity levels of the muscles that control lip closure; however, for vowels, the opposite effect occurs, i.e., an increase in speaking rate is accompanied by a decrease in the activity level of the muscle (genioglossus).


† Also University of Connecticut Health Center, Farmington.

++ Visiting from University of Tokyo, Japan.

The purpose of the experiment reported here was to obtain additional labial consonant data from both of our previous subjects and to extend our observations of VCV articulations to lingual CV sequences.

METHOD

Subjects were two adult males, both native speakers of American English. The speech material consisted of the consonants /p, t/ and the vowels /i, a, u/ in a trisyllable nonsense word of the form /k V₁ C V₂ pə/, where V₁ and V₂ were all possible combinations of /i, a, u/, and C was either /p/ or /t/. The utterances were randomly ordered into a master list. Each utterance (preceded by the carrier phrase, "It's a....") was read at two speaking rates: normal and fast. Each rate was based on the subjects' own appraisal of comfortable slow and fast rates. On the average, the fast speech was two-thirds to three-fourths the duration of the normal speech.

For both subjects, conventional hooked-wire electrodes were implanted in the orbicularis oris, superior longitudinal, and genioglossus muscles. The orbicularis oris muscle is largely responsible for closure of the lips, the superior longitudinal is active for tongue-tip elevation (for the production of /t/), and the genioglossus is a prime mover (protruding and bunching) of the tongue. EMG data from these muscles were recorded on magnetic tape and subsequently averaged using the Haskins Laboratories' EMG data system. The basic procedure was to collect EMG data for a number of tokens of a given utterance (in this experiment, between 10 and 15 repetitions), and to average the integrated EMG signals at each electrode position.

RESULTS

The effect of speaking rate on the production of the labial CV syllables is illustrated in Figure 1. This figure shows the averaged EMG curves of the orbicularis oris and genioglossus muscles for Subject FSC during the production of the utterance /pip/ at both normal and fast speaking rates. The orbicularis oris curves, as shown here, are associated with lip closure for the consonants, while the genioglossus curves are associated with tongue movements for the vowels. "0" on the time axis represents the time of offset of voicing of the first vowel.

This figure shows that for fast speech, orbicularis oris activity increases, while genioglossus muscle activity decreases. These changes, which coincide with our earlier findings, are consistent and occur for each subject and all utterances.

Although the existence of these effects is consistent, the magnitude of the differences varies considerably, and the data do not show any clear preconsonantal or postconsonantal vowel effects. We suspect that these inconsistencies are caused, at least in part, by trade-offs between lip closing and jaw closing.

The decrease in genioglossus muscle activity for vowel production also occurs for each subject and for all utterances. These decreases imply that the undershoot observed for vowels during faster speech is programmed into the gesture and is not the result of a too fast succession of motor commands.
Our data also show that the lip rounding component of /u/ is likewise produced with greater levels of muscle activity during faster speech. This is illustrated in Figure 2, which shows orbicularis oris activity for the utterance /utap/ for Subject FSC.

Figure 3 illustrates the effect of speaking rate on the production of the lingual CV syllables. This figure shows the averaged EMG curves for the superior longitudinal and genioglossus muscles for the utterance /itip/, this time for Subject TG. These data show the same changes in muscle activity levels as the labial consonant data: an increase in speaking rate is accompanied by an increase in activity level for the consonant (superior longitudinal) and a decrease in activity level for the vowel (genioglossus). Again the same results occur for both subjects and all utterances, and the data do not show any consistent vowel effects. The different effects of an increase in speaking rate are especially interesting in this set of data because they demonstrate that different motor reorganization strategies can be used for different muscles of the same articulator.

The results of this experiment can be summarized as follows. For lip movement associated with either labial consonant production or rounding for a vowel, and for tongue-tip movement associated with lingual consonant production, an increase in speaking rate is accompanied by an increase in the activity level of the muscle. For tongue movement during vowel production, in increase in speaking rate has the opposite effect: a decrease in the activity level of the muscle. The first finding implies an increase in articulatory effort and an increase in the speed of articulatory movement, while the second finding implies a decrease in articulatory effort, combined with a decrease in the speed of articulatory movement and/or a decrease in articulatory displacement.

DISCUSSION

The results for both the orbicularis oris and the superior longitudinal muscles can be explained quite readily: the production of both /p/ and /t/
requires a complete occlusion of the vocal tract; thus, under the constraints of an increase in speaking rate, the articulators move faster and with greater effort to produce that occlusion.

The data for the tongue, however, cannot be explained so straightforwardly. Obviously, the reduction in EMG activity for the vowel during faster speech is not compatible with an "extra effort" or even a "timing only" (equal-effort) control mechanism. Rather, the decrease in articulatory displacement usually associated with fast speech is built into the planning of the gesture.

Our findings for vowel production also argue against the notion that a vowel target is internalized as a set of invariant spatial coordinates. If a vowel is organized in terms of an articulatory coordinate system, the system must be a multiple coordinate one, or one characterized by an articulatory field. Another view, however, and one that might better explain our data, would be that a vowel is internalized as a set of acoustic targets, and that the speech production mechanism uses any of a number of strategies to produce the required acoustic result. This view would also explain the differences in the tongue and lip data for /u/ during faster speech, i.e., a greater degree of lip rounding serves to compensate for the decrease in articulatory displacement of the tongue.

REFERENCES
