MASSETER, TEMPORALIS, AND MEDIAL PTERYGOID ACTIVITY WITH THE MANDIBLE FREE AND FIXED

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Experiment One

Introduction

In general each of the speech articulators is acted on by a number of anatomically different muscles. The muscles which act on a given articulator may either 1) have activity levels which are functionally interchangeable or 2) each muscle may have a separate function which is seldom (if ever) accomplished by substitution of activity in other muscles. The Russian physiologist, Nicholas Bernstein (1967), has stressed the extent to which the first possibility; i.e., the functional interchangeability of activity level in different muscles, operates in normal human movements. In relation to speech, MacNeilage (1970) presents a perspective which (in this one respect) is related to Bernstein's ideas. MacNeilage believes there is a ubiquity of variability in muscle activity for attainment of vocal tract targets.

Textbooks of speech anatomy (Palmer, 1973; Zemlin, 1968) imply that masseter, temporalis, and medial pterygoid act in a similar manner to raise the mandible during speech. If this is the case, these muscles might typically operate interchangeably in many combinations for similar speech movements. However, the jaw closing muscles have been studied extensively in the dental literature (e.g., Kawamura, 1974) and the anthropological literature (e.g., Hylander, 1975). These studies have illustrated important differences in function and activity patterns between jaw-closing muscles. On the basis of these studies one might expect that each jaw-closing muscle has a specific functional role during speech and its activity is not typically interchanged with activity in other muscles.

There is not room to discuss the electromyographic (EMG) studies of the jaw-closing muscles during speech. However, the research to date does not provide much data concerning the above issue. Therefore, the purpose of the present study is to examine EMG activity and make comparisons between and within jaw-closing muscles during speech.

Method

Hooked-wire electrodes were used to record EMG from masseter, temporalis, and medial pterygoid in four normal adults. Jaw movement was transduced with a strain gauge technique. Each subject produced three to six repetitions of 11 isolated syllables, seven syllables in a carrier phrase, trains of syllables at various rates, and the rainbow passage. The limitations on the length of this paper preclude adequate description of experimental methods; however, a full report of this research will be ready for publication soon.

Results and Discussion

Figure 1 shows a typical example of EMG activity during the first sentence of the rainbow passage. Medial pterygoid was the most active muscle, not only in this example, but for all four subjects in almost all speech tasks. This example is typical as medial pterygoid tends to be: 1) moderately active throughout the utterance, 2) most active in relation to jaw closing, and 3) reduced during jaw opening. In Figure 1 masseter and temporalis were slightly active, but in many instances they were quiet throughout the speech sample. When masseter and temporalis were active, it tended to be during jaw-closing movements of large displacement or velocity.

Even though one might hope medial pterygoid activity would increase when the jaw moves further or faster, this is not necessarily the case due to the nonlinear relations between EMG and muscle force (Bigland and Lippold, 1954), and the difficulty in relating jaw-closing forces to parameters of jaw movement. As illustrated for isolated VCs by one subject in Figure 2, medial pterygoid EMG did not increase as a function of displacement. In fact, for the four subjects half the correlations between peak medial pterygoid EMG and displacement (0.15, -0.25, -0.37, and -0.17) and peak velocity (0.53, 0.23, -0.32, and 0.14) were negative. If one assumes that more muscle force is required to increase jaw-closing displacement or velocity, then either this is not reflected in our EMG measurements or is produced by muscles other than medial pterygoid. Figure 2 also shows that for isolated VCs temporalis became more active for larger displacements ($r = 0.66$). Three of the four subjects tended to increase

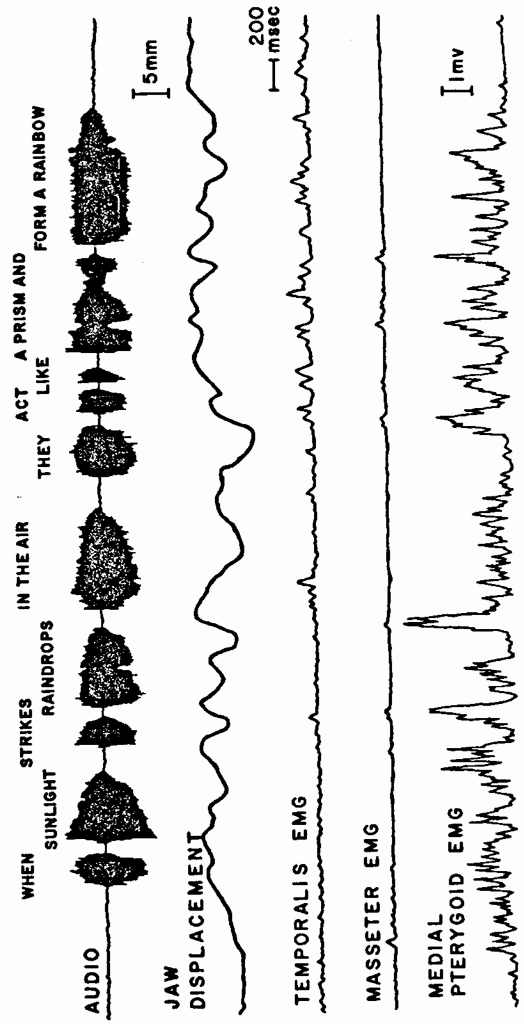

Figure 1. Rectified and smoothed (20 msec TC) EMG during reading for subject 3.

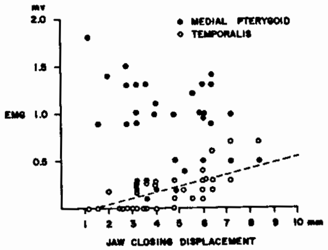

Figure 2. Scatterplot of peak EMG and jaw-closing displacement for isolated VCs by subject 4. The dashed line is a linear regression through the temporalis points. Masseter was zero for all syllables.

temporalis activity for larger (or faster) jaw-closing movements. The other subject tended to use masseter rather than temporalis.

A notable aspect of Figure 2 is the spread in EMG values for movements with similar displacements. Variability is especially evident in repeated syllables with matched displacement and velocity. For example, the subject in Figure 2 repeated [pæ] 24 times in rapid succession. Closing displacement was consistent as one standard deviation was only 16% of the average displacement. One standard deviation of peak velocity was only 14% of average. Mean medial pterygoid activity was 1.05 mv; however, it showed a standard deviation of 43%. Masseter averaged 2.15 mv with a standard deviation of 81%. This is surprising as masseter was quiet throughout the isolated syllables for this subject even though the repeated syllables were well within the range of displacements and velocities for isolated syllables. Variability was evident for most situations, but occasionally subjects were consistent. For example, on the left of Figure 3 one standard deviation of peak medial pterygoid EMG is only 10% of the mean.

In summary, medial pterygoid is consistently more active than masseter and temporalis. However, within this general distinction there appears to be a large amount of utterance-to-utterance variability in the way these muscles are employed.

Experiment Two

Introduction

A number of papers have illustrated the abilities of the speech motor control system to compensate for mechanical modifications in movement of the jaw (Folkins and Abbs, 1975; Lindblom, Lubker, and Gay, in press). Both Lindblom et al. and Perkell (1979) suggest that speech motor systems produce appropriate gestures in spite of perturbing factors by employing central stimulation strategies. For example, when one speaks with a bite block, a central movement plan adjusts the roles of many articulators for the lack of jaw movement. As the jaw is fixed with the bite block one might also expect the central movement plan to eliminate "unnecessary" jaw-closing muscle activity. The purpose of this experiment was to record EMG from the jaw-closing muscles with a bite block in place and see if there is a reorganization of muscle activity.

Method

This experiment was carried out in the same experimental sessions, with the same electrode placements as experiment one. After producing the speech sample with the jaw free to move, the sample was repeated with the jaw fixed with a bite block. Bite blocks providing both 5 mm and 15 mm of interincisor distance were employed.

Results and Discussion

With both sizes of bite blocks there were consistent bursts of EMG activity which related closely to the temporal patterns of EMG found in each muscle during the jaw free condition. This is illustrated in Figure 3 for medial pterygoid as [pæ] was repeated at a fast rate.

As the mandible is not moving, it is not clear why the phasic jaw muscle activity persists with the bite block. A complete central reorganization would be expected to remove unnecessary muscle activity. As an alternative, it may be that the phasic jaw muscle activity is involved in the organization of other articulatory movements occurring with the bite blocks. That is, peripheral motor control mechanisms (including brainstem reflexes; McClean, Folkins, and Larson, in press) may be important

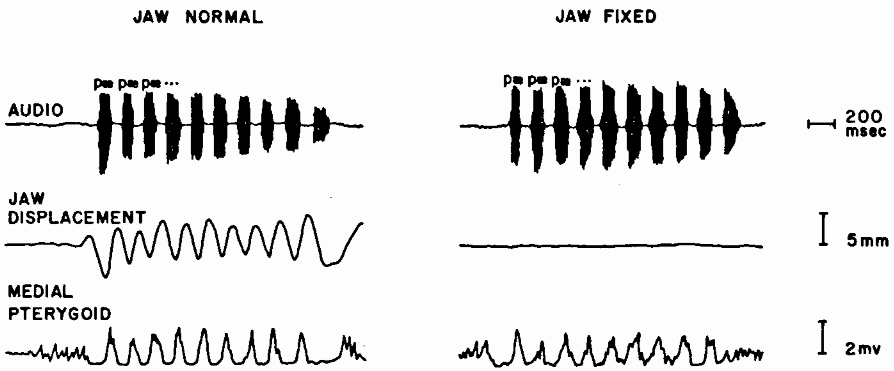

Figure 3. Rectified and smoothed (20 msec TC) EMG for [pæ] repeated at a fast rate by subject 1.

components in the processes which accomplish appropriate speech movements with and without mechanical interferences.

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