VELOPHARYNGEAL FUNCTION: AN ELECTROMYOGRAPHIC STUDY

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Fine wire electrodes were inserted into the palatoglossus and palatal levator muscles of normal speakers in an attempt to obtain a description of palatal function during speech. The speech sample provided examples of voiced and voiceless 'pressure' consonants, close vowels, and open vowels produced in nasal and non-nasal environments.

This preliminary report presents measurements of integrated EMG signals from one of seven subjects.

A strong burst of palatoglossus activity typically preceeded nasal consonant production. Thus, the palatoglossus appeared to actively lower the palate for nasal consonant production. However, three of the seven subjects showed no palatoglossus activity during speech, whereas all showed very strong activity during swallowing and nasal breathing. In each case the palatoglossus was being sampled and was contracting forcefully during swallowing and nasal respiration. During speech, however, electromyographic (EMG) signals from this muscle were never as strong as during the vegetative acts, and in three subjects, were absent altogether. It is probable that during the processes of swallowing and nasal breathing the palatoglossus contracts forcefully, with virtually all motor units firing. In this case, no matter where in the muscle fine wire electrodes are located, action potentials would be detected. For speech acts, on the other hand, the muscle may not function so forcefully and only some of the motor units would fire. Thus, there is a strong possibility that the electrodes can be positioned so as to not record from those motor units that are active during speech, thereby falsely indicating a silent muscle. For example, one subject showed strong palatoglossus activity during swallowing and nasal breathing, but none during speech. The electrodes were removed and repositioned, and marked activity was noted during both speech and vegetative acts. If it can be assumed that during speech production, for at least some muscles, only a portion of the available motor units are firing, then either no activity at all or marked activity can be recorded, depending upon electrode position.

With other relevant variables controlled, more forceful contraction of the palatal levator accompanied the voiceless consonants than the voiced, more levator activity was observed during close vowel production than during the open, and virtually no activity was recorded during nasal consonants. These results agree with previous data suggesting differences in palatal levator activity between, but not within, the close and open groups of vowels. Thus, whereas levator function may involve more than a simple 'on-off' system, it may also not require a different level of neuro-muscular activity for every phoneme; i.e., palatal levator activity might be described as being grouped by certain phoneme categories. Stated somewhat differently, palatal musculature would be predicted to contract as forcefully as necessary to move the soft palate from wherever it is to wherever it must be to prevent excessive nasal coupling. In the case of phoneme 'categories', when position and context are held constant, 'where the palate must be' is largely dependent upon the velopharyngeal requirements of the category: voiceless production would require tighter velopharyngeal closure than voiced ones, since they are typically produced with greater intraoral pressure, and close vowels would require tighter closure than open ones due to the greater degree of oral tract constriction required for their production.

When position and context were not held constant, a large amount of variability in levator activity was noted within each phone type. This variability can also be explained by reference to where the palate is and where it must go. Thus, a /t/ which follows a nasal requires considerable levator contraction in order to move the palate from an open position to the tight closure required for pressure consonant production; on the other hand, when /t/ follows the vowel /i/, the palate is already elevated and only a small increase in activity is required. However, in either case, whether following /n/ or /i/, the /t/ would be produced with more activity than would the /d/ in the same position and context. The same sort of example can be made of /i/ following a non-nasal consonant; and, again, in either case /i/ would involve more activity than /a/.

Thus, a reasonable description of the process of palatal elevation during speech involves a categorization of palatal levator activity into phonetic groups. Within each group there is a large degree of variability, predictable from knowledge of the amount of activity required for production of the preceeding sound.

It is tempting to go further and explain these observations via some sort of closed-loop feedback system. Care must be exercised, however, since the wide variety of closed-loop systems which have been proposed suggest that virtually every human activity can be described by a closed-loop model, and that many such models are available from which to choose. Further, it is at least possible to explain the data presented here simply in terms of instructions applied to a dynamic system which provides variable degrees of damping and no feedback at all. Therefore, while a system which provides for some sort of proprioceptive feedback via muscle spindles is appealing, we will defer such hypotheses until more extensive data are available.

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DISCUSSION

ABRAMSON (Storrs, Conn.)

While noting more levator palatini activity during voiced consonants than voiceless ones, you said that this might be caused by the greater intraoral air pressure associated with voicelessness. Can you discuss your data in connection with the calculations of Martin Rothenberg and the findings of Yanagihara and Hyde concerning the maintaining of transglottal air flow for voicing by means of a velopharyngeal leak?

LUBKER

First, I believe that Professor Abramson intended to ask about our observations that more levator activity was noted during voiceless than during voiced consonants, rather than the reverse, as is stated in his question.

Further, we do not state that this difference is CAUSED by the greater intraoral pressure usually observed during voiceless consonants, but rather that it is in RESPONSE TO the greater intraoral pressure. That is, tighter velopharyngeal closure, and therefore increased levator activity is needed during voiceless as compared to voiced consonants in order to prevent the greater pressure from 'overcoming' the velopharyngeal seal.

Nevertheless, the decreased activity during the voiced consonants might be taken to suggest the possibility of a velopharyngeal leak to assist in the maintenance of transglottal flow for voicing. Although we have no data here to either refute or support this possibility, we believe that a velopharyngeal leak represents the least likely single mechanism to provide transglottal flow. A report by Lubker is in preparation which considers this matter in more detail. Briefly, this report suggests that the nasal airflow noted occasionally during non-nasal voiced consonants is not sufficient to provide voicing, that certain temporal inconsistencies exist among nasal airflow, intraoral pressure and voicing, and that nasal airflow is as likely to occur during voiceless as during voiced productions. It seems more probable that transglottal flow is supported by some combination of passive and active supraglottal cavity enlargement.

SCULLY (Leeds)

In connection with the first question put to Dr. Lubker I should like to add that for some subjects whose speech I have looked at aerodynamically, in some contexts at least, there is no nasal air flow during the major portion of the occlusion of either /t/ or /d/; so that in these cases transglottal air flow must be absorbed by other means.

One advantage of looking at the aerodynamic stage of speech production is that the total effect of all the muscles innervated is observed. There may perhaps be less variability in aerodynamic measurements than in those of EMG as a result.

MACNEILAGE (Austin, Tex.)

Do you think it is possible to be in the middle of a muscle that is participating in a speech gesture with an electrode of the type you used and not record any activity?

LUBKER

Yes, we feel that this is a possibility. *If* not all motor units are firing, then if the fine wire electrodes are not located near active units activity would not be recorded. Of course, it is also POSSIBLE, due to the rather small size of the palatoglossus muscle, that we were not located in the body of the muscle and therefore did not record any activity.