Velar Activity in Voicing Distinctions: A Simultaneous Fiberoptic and Electromyographic Study*

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PURPOSE

The present study was undertaken in order to determine the relationship between increases in electromyographic potential and articulator movements, the articulator in this case being the soft palate. Our immediate aim was to provide simultaneous measures of velar height and EMG potential which would strengthen our belief that different levels of EMG activity in minimal contrasts may be used as an indicator of differences in articulator position. A year ago (Berti and Hirose, 1971) we reported differences in the magnitude of EMG signals recorded from the muscles of the velopharyngeal region for the production of voiced and voiceless stop consonants. We interpreted these differences as indicating differences in the magnitude of articulator displacement. Greater EMG activity in the levator palatini for voiced stops was taken to mean an increased velar height, hence, increased pharyngeal volumes for voiced stops than for their voiceless cognates. We assumed that the levator palatini is the muscle essentially responsible for palatal elevation, and that we were then dealing with a simple one muscle—one parameter system (although we know that contraction of the levator palatini results in movements of the soft palate in more than just the vertical dimensions—that is, it also moves the palate posteriorly).

METHODS

A subset of our original stimulus inventory was used. We compared voiced and voiceless labial stop consonants in nasal-oral (fimbip) and oral-nasal (fimbip) contrasts within the vowel environments /i/ and /a/. Hooked-wire electrodes were inserted perorally into the dimple of the soft palate. The EMG potentials were recorded into magnetic tape. To assist


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with identification of palatal movement, a grid made of a thin plastic film was placed along the floor of the nasal cavity. A fiberoptic endoscope was inserted to the subject's right nostril and positioned to provide a view of the velum as it was raised and lowered. A random list of our eight utterance types was repeated ten times. Motion pictures were taken through the fiberscope, at 60 frames/sec, of all repetitions of the utterance list. A synchronization mark was recorded on the EMG data tape. The line-up point chosen for averaging tokens was the end of /m/ when it preceded the medial stop (for example, at the end of the /m/ in /fimbip/), or the beginning of /m/ when it followed the stop (for example, the onset of /m/ in /fimbip/). This point is identified as "zero" on the abscissa. The EMG potentials were rectified, integrated, and computer-averaged for eight to ten tokens of each utterance type. Frame-by-frame measurements of velar height were also made for each of eight to ten tokens of each utterance type. Only vertical movement of the soft palate was determined. The velar height measurements were averaged for each token of each utterance type.

RESULTS

Figure 1

Comparisons of EMG activity and velar height reveal timing differences between the two measures, as we would expect. Increases in EMG activity always precede velar elevation. The upper figure shows that peak EMG activity for an utterance in which /m/ precedes /b/ (/fimbip/) occurs 10 msec prior to the end of /m/, while peak velar height occurs approximately 100 msec after the end of /m/, a temporal separation of approximately 110 msec. The lower figure which compares EMG activity and velar height for an utterance in which /b/ follows an oral vowel (/fimbip/) demonstrates a temporal separation of the peaks of about 60 msec, with the EMG peak again preceding peak velar height. The time lag between the EMG peak and peak velar height is generally greater for a stop following a nasal (/m/), in this case about 110 msec, than for the stop following an oral vowel (/i/), in this case about 60 msec.

Figure 2

In addition to differences in the time-lag between peak EMG activity and peak velar height for stop consonants in these environments there are also differences in the magnitude of velar movements and their corresponding EMG potentials. Inspection of the EMG potentials for these utterances (the lower figure) reveals a greater increase in activity, as well as a greater peak magnitude, of the EMG potential for the /b/ which follows the /m/ (in /fimbip/) than for the /b/ which follows the /i/ (in /fimbip/). The solid line in the upper figure, representing velar height for the utterance in which /b/ follows /i/ (/fimbip/) remains above the dashed line until after the "zero" line-up point. The peak velar height associated with the /b/ articulation (at 4 frames before zero) for this utterance, in which /b/ follows /i/ (/fimbip/), is greater than the corresponding peak (at 6 frames after zero) for the utterance in which /b/ follows /m/ (/fimbip/). Although the increase in velar height is greater when /b/ follows /m/ (/fimbip/), absolute velar height may not reflect this difference.

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/fimbip/ --- Velar Height
/fimbip/ --- EMG (Levator Palatini)

Fig. 2
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<thead>
<tr>
<th></th>
<th>1</th>
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<th>3</th>
<th>4</th>
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<td>HEIGHT</td>
<td>BASELINE</td>
<td>TIME</td>
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<tr>
<td>ORAL-NASAL</td>
<td>177, $\mu$V</td>
<td>4.</td>
<td>13.5</td>
<td>95 MSEC</td>
</tr>
<tr>
<td>NASAL-ORAL</td>
<td>348, $\mu$V</td>
<td>13.5</td>
<td>1.5</td>
<td>130 MSEC</td>
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Figure 3

When increases in velar height and the EMG potentials for stop consonants in all oral-nasal contrasts (where the stop follows a vowel) are pooled and compared with all nasal-oral contrasts, three trends are revealed. Looking at Column 1, we see that there is a greater average increase in EMG activity for stop consonant articulation in nasal-oral utterances (348, $\mu$V) than in oral-nasal utterances (177, $\mu$V). The second trend is revealed in Column 2: there is a greater increase in velar height for stop consonants in nasal-oral utterances (13.5 units) than for stops in oral-nasal utterances, that is, where the stop follows a vowel (4. units), even though absolute velar height may be greater for a stop in an oral-nasal contrast as shown in Figure 2. This is possible because the starting point against which the increase in velar height was measured, which is given in Column 3, is considerably higher for oral-nasal than for nasal-oral utterances. The third distinction between stops in the two environments is that the average time-lag between peak EMG activity for a stop consonant and peak velar height for that stop is greater when the stop follows a nasal (approximately 130 msec) than when the stop follows a vowel (approximately 95 msec). This might be explained as a function of the increased work-load when the palate must be elevated from a lower position.

A Pearson product moment correlation coefficient was computed between our two parameters: that is, for the increases in velar height and the increases in EMG potential. The Pearson $r_{xy}$ is .84, which is significant at the 0.005 level. This implies that given equal starting points, the greater the EMG activity the greater the velar height.

CONCLUSION

In conclusion, although there is no obvious constant relationship between absolute velar height and the absolute magnitude of the EMG signal for that articulation, there is a strong correlation between the magnitude of the increase in EMG potential and the magnitude of the change in velar height. That is, the larger the increase in EMG potential, the greater will be the corresponding increase in velar height. This conclusion is supported by the data displayed in Figure 4 for the minimal utterance pair /fipmi/-/fibmip/. The EMG potentials for the stop consonant articulation are in the
Fig. 4
lower figure. The EMG peak is greater for /b/ (the dashed line) than /p/ (the solid line) in utterances in which both follow the same vowel. The upper figure reflects this difference in the level of EMG activity: the curve of velar height is higher for the /b/ than for the /p/ in the region of the voiced-voiceless comparison, while the velar height curves are similar for those regions in which the EMG curves are similar.

We feel, therefore, that for minimal utterance pairs increases in EMG potential should be interpreted as reflecting increases in velar height. Our earlier results, in which subjects varied in the differences they demonstrated in EMG potentials for voiced and voiceless stop consonants (in similar phonetic environments) may be interpreted as reflecting differences in velar height, and, therefore in pharyngeal cavity size.

SUMMARY

In summary, we compared simultaneous measures of velar height and EMG activity of the levator palatini for utterances contrasting voiced and voiceless consonants in various environments. We found a strong correlation between the size of the increase in the EMG signal and the size of the increase in articulator displacement. We concluded, therefore, that differences in the strength of EMG signals for contrasting phonemes in otherwise constant environments should be interpreted as differences in velar height.

REFERENCE