Velar Movement and Its Motor Command*

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In order to investigate the relationship between movement of the velum and its motor command during speech, electromyographic (EMG) recordings of the levator palatini muscle and direct viewing of the velum were performed separately on one Japanese subject. The same utterance types were used in both experiments.

Electromyographic signals were computer-processed and will be shown in the form of an averaged and smoothed pattern for each utterance type (Kewley-Port, 1973). Velar movement was filmed at the rate of 50 frames per second through a fiberscope inserted in the nasal cavity (Ushijima and Sawashima, 1972).

In this report we would like to point out four important findings obtained in this study.

The lower part of Figure 1 shows the time course of velar height for the utterance /seesee/ followed by a carrier word /desu/. Note the difference in height between the consonants and the vowels. Similarly, the level of EMG activity associated with the interconsonantal vowel /e/ is much lower than for /s/ in the upper figure (thick line). This difference is quite consistent for all the samples. This implies that for this particular subject the different levels of EMG activity between /s/ and /e/ seem to be realized in the form of small differences in velar height. In other words, there seem to be quantitatively different neural commands for the movements of the velum for consonant and vowel production, although both segments are generally regarded as [-] nasality. It seems reasonable to say that the velum is not controlled by a simple binary on-off mechanism.

The next point is related to the differences among four nonnasal consonants. Figure 2 shows comparisons of peak EMG amplitude for the consonants /t/, /s/, /d/, and /z/ in each utterance type. They are classified and pooled into seven groups according to their phonetic environment. It should be


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1In this figure """, "#", and "N" represent, respectively, a syllable boundary, a word boundary, and a syllable-final nasal.

[HASKINS LABORATORIES: Status Report on Speech Research SR-41 (1975)]
Figure 1
remarked here that there is variation in the peak values for the utterances in each group. There is no clear systematic segmental difference between voiced and voiceless consonants or between stop and fricative consonants. Instead, it is notable that the activity is greatest for the consonants after a syllable-final nasal /N/ (Groups 6 and 7), and least for the consonants in intervocalic position (Groups 4 and 5). It seems, then, that the activity level of the muscle for a given nonnasal phoneme varies according to its phonetic environment.

The same comparisons may also be obtained for velar height (Figure 3). The environment of the consonant seems to be the most dominant factor in determining velar height. The discrepancy between EMG measures and velar height measures for consonants following nasals is due to the fact that EMG activity is related to the distance the palate must move, rather than the absolute height it reaches. At any rate, our data seem to show that the activity level of the muscle and velar height for a given nonnasal phoneme vary according to its phonetic environment.

The third point concerns differences between syllable-initial and syllable-final nasals. In Japanese, there are two syllable-initial nasals, one labial, one alveolar. However, a syllable-final nasal (the uppercase /N/) has some special features. Its inherent phonetic values, nasality and voicing, are prerequisite, but the specification of its place of articulation varies as a function of the following phoneme (Fujimura, 1972). For example, labial, alveolar, and velar articulations are possible.

The upper part of Figure 4 shows the EMG curves, while the lower part shows velar height curves for the contrastive pair. Our earlier data, obtained from velar movement analysis using other subjects, implied an inherent difference between the two nasals with greater velar suppression for the syllable-final nasal (Ushijima and Sawashima, 1972). We also reported some EMG evidence supporting that result, and commented that the duration of nasal segments and speaking rate may be important factors for determining velar height (Ushijima and Hirose, 1974).

In Figure 5 we have plotted velar height and the duration of the acoustic segment for each nasal occurrence in the fiberoptic run in this study. The

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2 In this figure the voiced consonants fail to show a constantly higher elevation of the velum than their voiceless counterparts. One reason for this result seems related to the fact that the levator activity, or velar height, is not the only indication of pharyngeal cavity enlargement. The strategy for pharyngeal enlargement to maintain voicing probably differs subject by subject as Bell-Berti and Hirose (1972) first reported. This particular subject seems to use strategies other than the velar height change for voicing.

3 Labial closure occurs for a /N/ if it is followed by a labial consonant. Dental or alveolar closure occurs before /t/ or /d/. More posterior place of closure is seen if the phoneme is followed by /s/, /z/, /k/, or /g/. There is less vocal-tract stricture if the phoneme precedes a vowel. In such a case the syllable-final nasal becomes phonetically equivalent to a nasalized vowel.
Figure 4
Figure 5
upper part of the figure was made from samples of meaningful words, spoken at conversational rate. The lower part of the figure shows the effect of speaking rate on velar height and duration, since both the initial and final nasals were repeated in a string of nonsense syllables at both fast and slow speeds. It is interesting to note that velar height for the final nasal /N/ (filled circles and squares) tends to vary with both duration and speaking rate, while the initial nasal /n/ (open circles or squares) seems to be more independent of these two factors.

A possible explanation for this might be the following: articulatory accuracy is required for the production of the initial nasal /n/, that is, complete contact of the tongue tip to the alveolar ridge with simultaneous lowering of the velum. On the other hand, for the production of the final nasal /N/, the place of articulation tends to be less constant as the duration becomes short, which might cause less lowering of the velum. Of course, such a hypothesis should be clarified by further studies using other methods such as spectrography, cineradiography, or palatography.

The final point we would like to make is about nasal coarticulation of the velum. The analysis of velar movement in this study provides us with results that support our previous EMG data (Ushijima and Hirose, 1974).

In Figure 6 we compare three utterance types. The thin line represents an entirely oral sequence /see'ee/. The thick line represents a sequence /see'en/ with a syllable-final nasal in final position in the test word. The dashed line represents a sequence with a syllable-final nasal in medial position, /seN'ee/. The dashed line in the upper figure shows that immediately after the peak for /s/ there is suppression of EMG activity for the vowel and following nasal. In contrast, in the utterance with the sequence-final nasal (the thick line), activity for the vowel after /s/ has the same level as the vowel in the utterance without the nasal (the thin line). Looking at the thick line, we see that the activity begins to fall about 100 msec after the lineup. The lower figure also indicates the clearly delayed onset of the velar lowering for the sequence-final nasal /N/ (the thick line) compared with the sequence-medial nasal /N/ (the dashed line). This phenomenon might be interpreted as indicating that there is a restriction on anticipatory lowering of the velum. Moll and Danilo (1971) proposed a hypothesis of "unspecified" velar position for English vowels. According to them, velar lowering for a terminal nasal should start at the beginning of a preceding vowel string.

In this sense, our data do not appear to support their hypothesis. It seems reasonable to consider that anticipatory coarticulation may not always extend beyond a syllable boundary.

If we again examine the dashed line in the upper half of Figure 6, we see that EMG activity for the vowel after a syllable-final nasal /N/ does not reveal any carry-over suppression from the preceding nasal. Rather, it shows an increase over the EMG level necessary for the vowel sounds of the completely oral sequence (the thin line). At the level of the neural command to the velum, then, there is no carry-over effect in the vowel segment after the syllable-final nasal /N/. In this case, then, the carry-over effect does not seem to extend beyond the syllable boundary of the test word. This tendency is also visible in the lower figure showing velar height. One possible explanation for
this phenomenon is that the elongation of the vowel segments after a syllable-
final nasal /N/ may have to be oralized to prevent listener confusion. 4 On the
other hand, we observed a clear carry-over effect for the vowel segment follow-
ing a syllable-initial nasal /n/, which is not shown in Figure 6.

Our observations have been based entirely on Japanese materials, but we
assume some of the results of this study can be generalized to other languages.

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4One example of possible listener confusion:

/KaN'oo/ (to enjoy seeing the cherry blossoms)
vs.

/KaNnoo/ (full payment of a tax).