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EFFECTS OF ACCENT AND SPEAKING RATE ON THE CONTROL OF VELAR ARTICULATION*

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1. Introduction

For the study of articulatory dynamics, EMG and endoscopic observation of the articulatory organs have proven to be useful.[1)2)] Using these methods, we reported on the dynamic control of the velum during speech in normal speakers. Specifically, it was revealed that the control of the velum was not necessarily dichotomic as nasals vs. non-nasals, Rather, intermediate degrees were found for vowels in both velopharyngeal opening and the activity of the levator palatini.[3)4)] It was also found that there was a considerable coarticulatory effect of the adjacent segments on the velar control for vowel production.[4)5)]

The present report is aimed at investigating the effects of suprasegmental features on the control of velar articulation. In particular, the effects of accent pattern and speaking rate are examined, based on the results of simultaneous recordings of EMG and fiberoptic cinematography.

2. Experimental Procedures

2-1) Fiberscopic observation

A male Japanese speaker of the Tokyo dialect served as the experimental subject. The velar view was filmed at 50 fps by means of a fiberscope inserted through the nose, three times for each utterance type listed in Table 1. The pattern of the velar movements was then obtained by plotting the measured value of the velar height on each film frame. Since the positioning of the fiberscope was very stable, it was possible to compare the velar height, or the degree of velopharyngeal opening, even across the different speech samples.

2-2) EMG

For the EMG study the levator palatini muscle was selected as the representative muscle for the control of the velopharyngeal opening. The electrical activity of the levator palatini was recorded by means of conventional hooked-wire electrodes and then computer-processed to obtain the averaged pattern indicating the degree of muscle activity as a function of time.[6)]

2-3) Test words

Table 1 shows the two different lists of test words used in the present experiment. List 1, a group of nonsense syllable sequences, consists of

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combinations of the segment /t/, /e/, /N/ (a syllable-final nasal in Japanese) and /n/ (a syllable-initial nasal). The accentuated syllable is marked with a "hook" in each word; the first and third syllables are always accentuated. The test words in List 1 were uttered without carrier sentences. List 2 contains seven meaningful disyllablic words without accent kernels. These words were uttered with a preceding carrier word "sono" (it is ---). The subject was required to read the randomized lists (1 and 2) at two different speaking rates, slow and fast.

List 1 (Nonsense syllable sequence)	List 2 (Meaningful disyllabic word)
/te⌝tete⌝te/	/teNmee/
/ne⌝nene⌝ne/	/teNnee/
/te⌝nete⌝ne/	/teNtee/
/ne⌝tene⌝te/	/teNsee/
/teN⌝teNteN⌝teN/	/teNkee/
/neN⌝neNneN⌝neN/	/teNhee/
	/teN'ee/

Table 1. Test Words

2-4) Speaking rate

The speaking rate was controlled by timing signals of 3 Hz (for the slow) and 4 Hz (for the fast) click sounds given to the subject through an earphone. The subject was able to follow the rhythm of the sounds easily, and he tried to match the rhythm with each syllable. Consequently, the rate of speech was increased approximately 1.3 times in fast-rate speech as compared to slow speech. This method proved adequate for regulating the speaking rate, and the speech sounded quite natural.

3. Results

3-1) Effect of Accent

Figure 1 shows the pattern of velar movements for /te⌝nete⌝ne/ and /ne⌝tene⌝te/. These samples are selected from List 1 to show the effect of accent on velar height for each comparable segment. It can be seen in this figure that there is no appreciable difference in velar height for the consonant /t/ regardless of the presence of an accent kernel. Likewise, there is no difference in the degree of velar lowering for the nasal consonant /n/.

Figure 2 shows the EMG patterns of the same pair of test words as examined in Figure 1 uttered in the fast rate. It also shows that there is no appreciable difference in the peak EMG activity for /t/s regardless of the presence of an accent kernel. Also, the degree of EMG suppression of the nasal sounds appears to be the same regardless of the presence or absence of an accent kernel. These findings are given in Table 2 which shows the measured values of velar height and EMG for each corresponding segment.

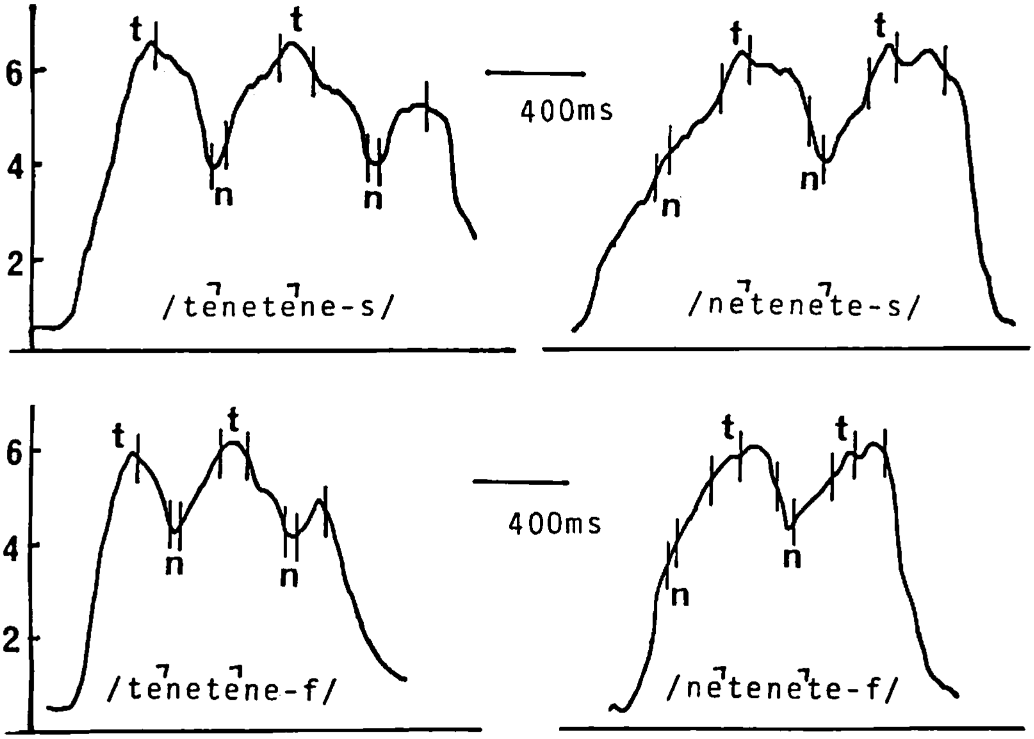

Figure 1. Velar height for /tenetene/ and /netenete/ in slow and fast-rates.

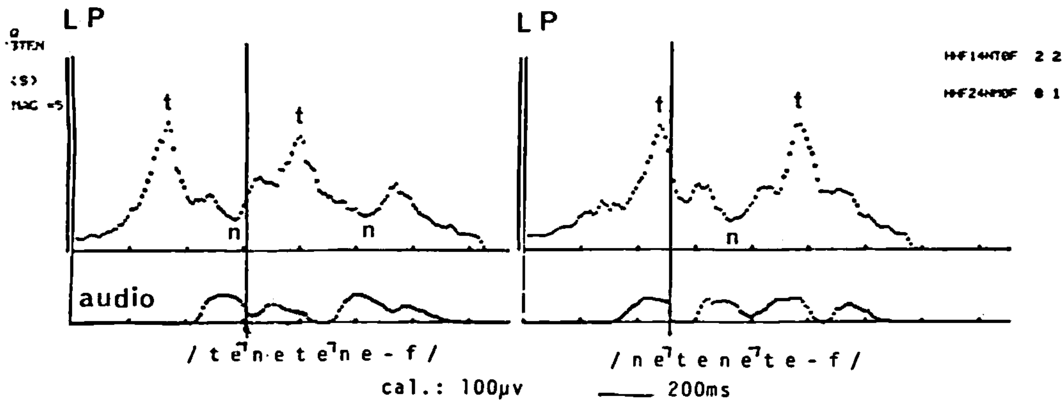

Figure 2. EMG patterns of LP for /tenetene/ and /netenete/ in fast-rate.

speaking rate	slow		fast	
type of utterance	て'ね て'ね-s $t_1 n_2 t_3 n_4$	ね'て ね'て-s $n_1 t_2 n_3 t_4$	て'ね て'ね-f $t_1 n_2 t_3 n_4$	ね'て ね'て-f $n_1 t_2 n_3 t_4$
velar height(mm)*	65 65	63 64	59 61	57 58
EMG (μv)	55 47	45 47	67 60	65 65
velar height(mm)*	39 40	X 40	42 41	X 42
EMG (μv)	13 13	X 12	15 18	X 15

Table 2. Velar height and EMG value.

*: arbitrary scale in mm measured on the screen projected through a film-analyzer

X: unmeasurable

These findings would imply that, in the production of Japanese nonsense syllables, accent pattern has little effect on the motor control of the velum. It is conceivable that the difference in accent patterns is realized more directly by other speech organs such as the larynx.[7] More detailed studies with the simultaneous observation of many speech organs as well as multi-channel EMG are needed to clarify the physiological correlates of accentuation.

3-2) Effect of speaking rate

The effect of speaking rate is well illustrated in Figure 3, which compares the patterns of EMG (lower) and velar height (upper) for the sample "sonoteNkee" uttered in slow (left) and fast (right) rates. It can be seen in this figure that the peak EMG values for the high-velum consonants /s/, /t/ and /k/ are approximately 1.3 times greater in the fast-rate than in the slow rate. As for the velar height, on the other hand, the values for these high-velum consonants appear to be slightly smaller in the fast-rate than in the slow-rate.

For nasals the degree of EMG suppression is comparable in both speaking rate conditions, reaching the resting level. On the other hand, there is a tendency for the degree of the velar lowering to be less in the fast-rate speech than in the slow-rate. This tendency appears to be more marked for /n/ than for /N/.

Similar results were obtained for other test words as shown in Table 3. In this table, the averaged velar height and EMG values are shown for each of the 13 types of segments which are classified according to their phonetic environment. For the non-nasal consonants and the vowel sequences, both the peak EMG values and the peak velar height are given, while for the nesals both the minimum EMG values and the maximum velar lowering are presented. Figure 4 illustrates these values on Table 3 in a more detailed way.

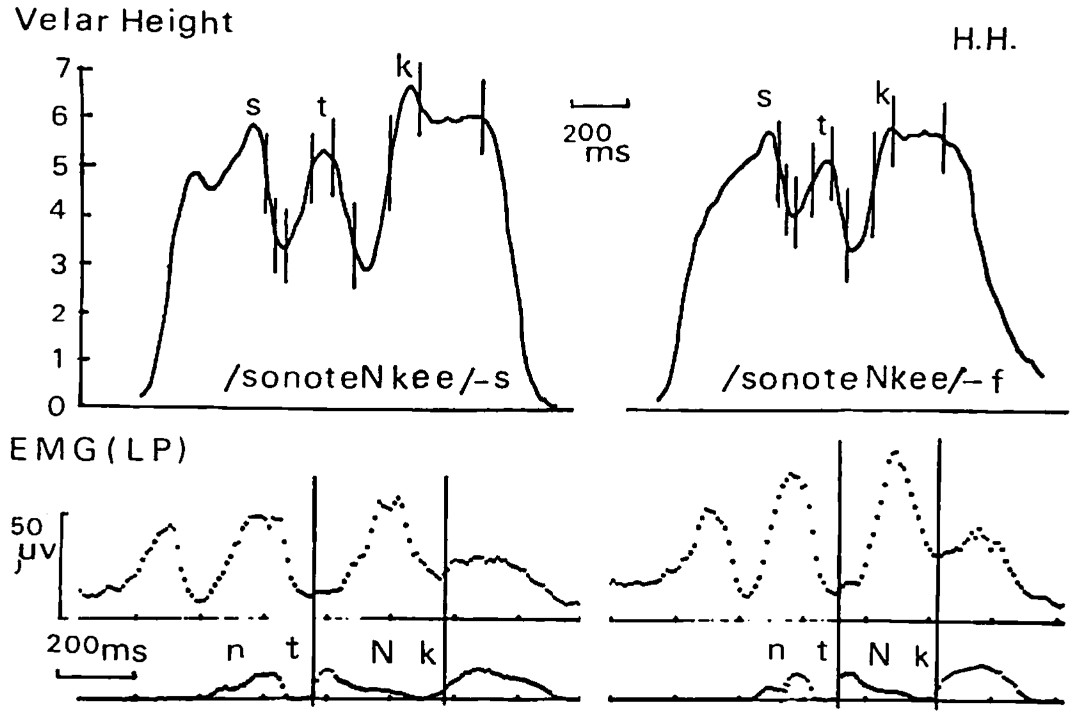

Figure 3. Velar height pattern and EMG pattern for /sonoteNkee/ in slow and fast rates.

	velar height (mm)*				EMG value (µv)			
	fast	slow	f-s	f/s	fast	slow	f-s	f/s
/t/,word initial	50	52	-2	1.0	80	55	25	1.5
/t/,following /N/	54	61	-7	0.9	90	58	32	1.6
/s/,following /N/	57	61	-4	0.9	90	60	30	1.5
/k/,following /N/	59	63	-4	0.9	82	58	24	1.4
/ee/,following /t/	57	58	-1	1.0	47	28	19	1.7
/ee/,following /s/	58	58	0	1.0	47	30	17	1.6
/ee/,following /k/	58	59	-1	1.0	45	30	15	1.5
/n/ in carrier	37	32	5	1.2	12	10	2	1.2
/Nm/	31	28	3	1.1	17	13	4	1.3
/Nn/	31	28	3	1.1	15	13	2	1.2
/N/,followed by /t/	29	28	1	1.0	13	12	1	1.1
/N/,followed by /s/	28	27	1	1.0	10	8	2	1.3
/N/,followed by /k/	31	30	1	1.0	13	10	3	1.3

Table 3. Velar height and EMG value.

*: arbitrary scale in mm measured on the screen projected through a film-analyser.

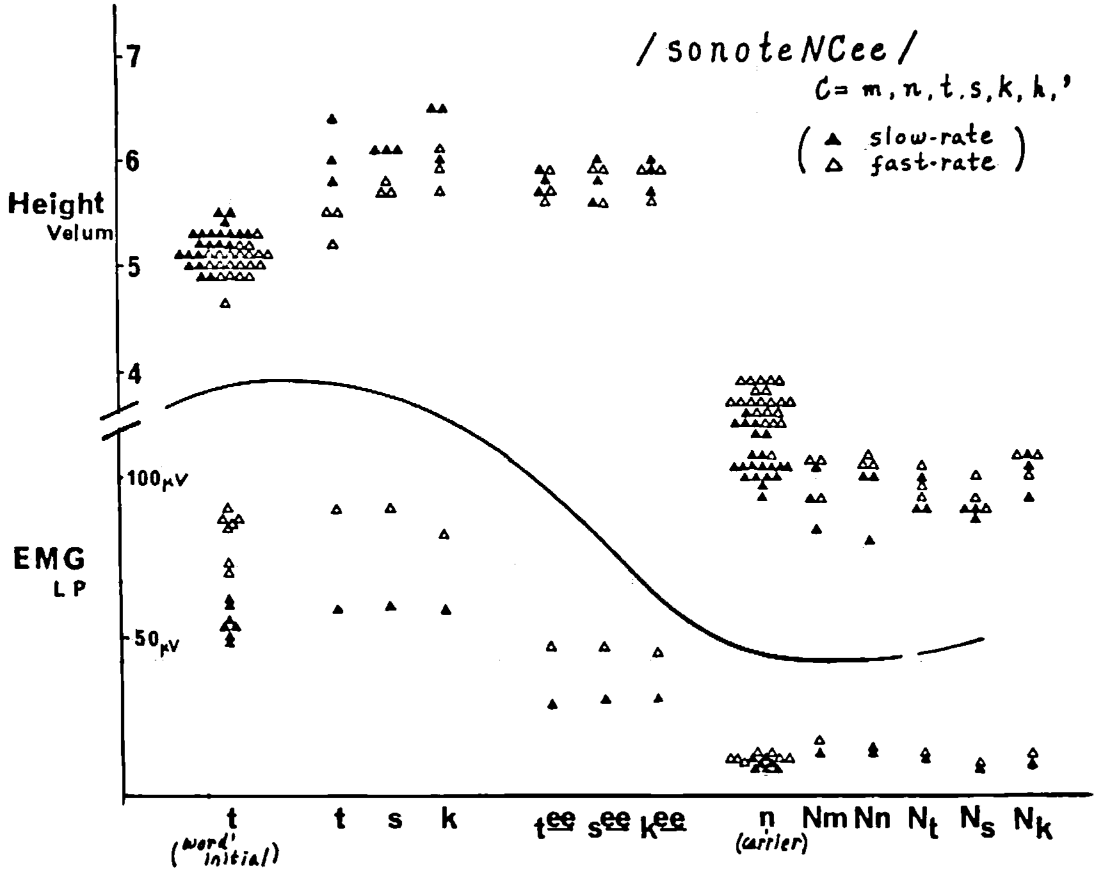

Figure 4. Comparison of velar height with EMG value.

4. Comments

Even if a speaker utters the same speech materials at different speaking rates, complete velopharyngeal closure is always required for the production of the high-velum consonants. It was found in the present study that the amount of neural command to the velum in terms of EMG activity seems to be organized (or reorganized) in such a way that the density of the neural input to the levator palatini is increased correspondingly to the increase in the speaking rate. Such an increase in the EMG peak values for the faster speaking rate has already been reported concerning the articulatory movements of the lip and jaw in English. 8)

The next interesting finding concerns the degree of EMG activity for the vowel sequences placed at the end of each speech sample (tee, see, kee- in Figs. 3 & 4, Table 3). There is also a tendency toward increased muscle activity for these vowel sequences in the faster speaking rate and the EMG values are in between those for the non-nasal consonants and the nasals. However, the ratios of increase are almost the same as those for the non-nasal consonants.

As for the degree of EMG suppression for the nasals, there is no remarkable difference between /n/ in the carrier and /N/ in the test words

(Figs. 3 & 4, Table 3). However, a closer look at the EMG patterns reveals that there is a difference in the shape of the dip for the suppression between /n/ and /N/. Particularly, the dip is sharper for /n/ than for/N/. In other words, for /N/ the duration of suppression is longer than for /n/ (Figure 3). This difference in the shape of the average EMG pattern can be related to the difference in the degree of the velar lowering between the two nasals, which becomes more marked in the fast-rate speech as shown in Figure 5.

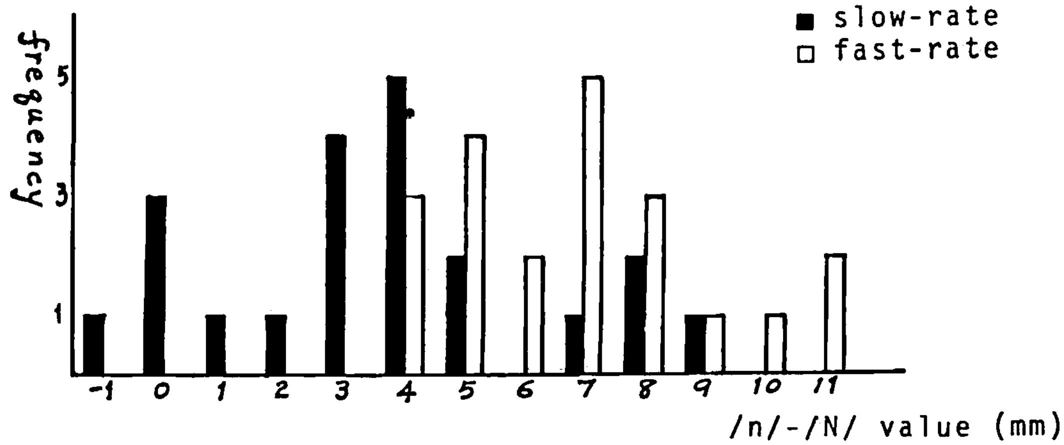

Figure 5. Difference in velar height between /n/ and /N/ within the same sample.

The present results would then indicate that the speaking rate is controlled by a well-developed precision at a higher level of the central nervous system, not only in terms of timing, but also in terms of the degree of muscle activity. The results also indicate the significance of the mechano-inertial factor in velar control. In the fast-rate speech, a slightly lower velar height for /t/, /s/, and /k/ was observed in spite of the increased EMG peak activity, and a lesser degree of velar lowering for nasals was also found in spite of the same degree of suppression of muscle activity as in the slow rate. These two findings can be taken as the results of the mechano-inertial factor in the dynamic control of velar atriculation.

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