ANN.Bull.RILP(1990)No.24, 65-75

PARTICIPATION OF THE STERNOHYOID MUSCLE IN PITCH LOWERING: EVIDENCE FROM OSAKA JAPANESE

Shiro Kori*, Miyoko Sugito**, Hajime Hirose and Seiji Niimi

Abstract

An EMG experiment was conducted to determine the physiological correlates of two distinct kinds of sharp pitch falls in Osaka Japanese: a slower fall triggered by the accent nucleus (as in Tokyo Japanese), and a steeper fall at the boundary between a word ending with a High-pitched mora and a following word which begins with a Low-pitched mora. The results indicate that the sternohyoid is active during both types of fall, confirming the findings of Sugito and Hirose (1978) that the sternohyoid is active both at the accent nucleus and at the word-initial Low-pitched mora. Moreover, it is shown that the sternohyoid is more activated during the steeper fall than the slower fall, whereas cricothyroid activity does not show a significant difference. The results provide further evidence that the sternohyoid is actively involved in pitch-lowering, and show that its activity is indispensable in realizing Osaka Japanese prosody.

Introduction

Tonal idiosyncrasy of Osaka Japanese

The varieties of Japanese spoken in Osaka and its neighboring area, which are generically called the 'Kinki' dialect or 'Kansai' speech, have two distinct kinds of sharp pitch falls, one slower and another steeper, from a phonologically High-pitched mora to the following Low-pitched mora [1]. The slower fall occurs at the offset of the mora bearing the accent nucleus, as in Tokyo Japanese, while the steeper fall occurs at the boundary between a word ending with a High-pitched mora and a word beginning with a Low-pitched mora. Such an idiosyncrasy derives from the fact that these varieties of Japanese phonologically distinguish, unlike Tokyo Japanese, 'High-beginning' words and 'Low-beginning' words with the same location of the accent nucleus.

High-beginning' words and 'Low-beginning' words

A 'High-beginning' word commences with a phonologically High-pitched mora and all the following moras are High-pitched until the pitch shifts to Low after the mora bearing the accent

* Osaka University of Foreign Studies
** Osaka Shoin Women's College

nucleus. Thus, in High-beginning *syootosi* (HHHL) 'small city', the moras 'syo', 'o' and the nucleus-bearing 'to' are High-pitched and the last 'si' is Low-pitched.

On the other hand, a 'Low-beginning' word commences with a Low-pitched mora and all the following moras are Low-pitched except for the nucleus-bearing mora which is High-pitched. Thus, in Low-beginning *tyuutosi* (LLHL) 'middle-sized city', the moras 'tyu', 'u' and 'si' are Low-pitched, and the nucleus-bearing 'to' is High-pitched.

Two kinds of sharp pitch falls

When a Low-beginning word is preceded by a word which ends with a High-pitched mora, as in *sono tyuutosi* 'that middle-sized city' (HH#LLHL), where sono is a High-beginning nucleus-less word and *tyuutosi* is a Low-beginning word with the nucleus on 'to', the pitch falls both at the word boundary and at the accent nucleus.

An acoustic analysis revealed that these two kinds of pitch falls are different in steepness [2]. The pitch fall triggered by the accent nucleus is less steep and usually has an upper convex curve on the logarithmic scale, while the pitch fall at the boundary between a word ending with a High mora and a Low-beginning word is steeper and assumes a linear or upper concave pitch shape. Figure 1 illustrates this difference using the pair 'Are-wa umemonaka desu' (That is a cake named 'umemonaka') and 'Are-wa ume-no naka desu' (That is in the ume tree). The pitch fall in 'umemonaka' (HHHLL; dotted line), which is triggered by the accent nucleus on 'mo', is less steep than that in 'ume-no #

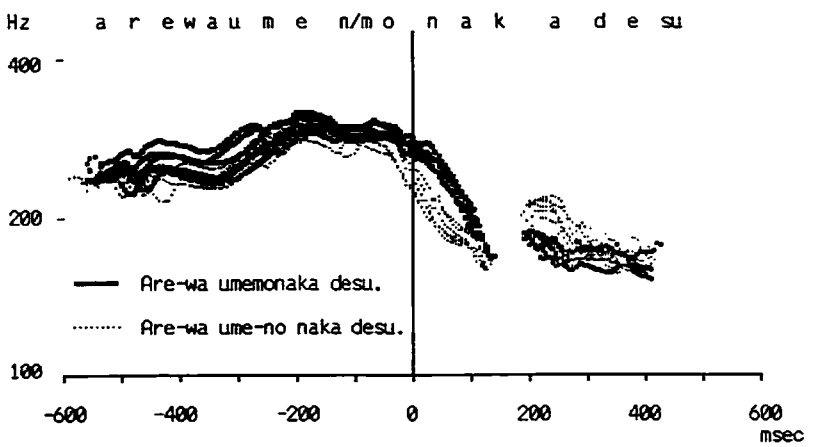

Figure 1 Two kinds of pitch falls in 'Are-wa umemonaka desu' (solid lines; fall triggered by the accent nucleus) and 'Are-wa ume-no naka desu' (dotted lines; fall triggered by Low-beginning 'naka'). Six utterances of each sentence are lined up with respect to the onset of 'na'.

naka' (HHH#LH; solid line), which is caused by the Low-beginning 'naka'. Moreover, in some speakers the fall starts earlier at the boundary to a Low-beginning word than at the accent nucleus. The pitch fall at the boundary to a Low-beginning word becomes steeper when focus (linguistic emphasis) is put on the following Low-beginning word. It seems as if the Low-beginning word forcibly pulls down the pitch. The fall at the accent nucleus, in contrast, seems a gentle gliding down of the pitch.

It is plausible that the acoustic differences between these two kinds of pitch falls reflect differences in laryngeal gestures. It is known that the sternohyoid muscle is active during low and falling pitch [3.4.5.6.7]. However, researchers disagree as to whether it actually lowers pitch or just accompanies the inhibition of the activity of the cricothyroid, a pitch-raising muscle. A previous study by two of the present authors (Sugito and Hirose (1978)) [8] has shown that in two of three speakers of Osaka Japanese the sternohyoid was active not only during the pitch fall due to the accent nucleus, but also prior to the onset of Low-beginning words uttered in isolation, therefore without preceding cricothyroid activity, suggesting that the sternohyoid has its own function in pitch control. A recent investigation on Tokyo Japanese conducted by Simada and Hirose [9] suggests that the sternohyoid assumes the role of maintaining lowered pitch rather than lowering pitch. Can the difference in the steepness of the two kinds of pitch falls in Osaka Japanese be accounted for by the behavior of the sternohyoid? The answer to this question will provide a better knowledge of the role of the sternohyoid in pitch control.

In this study, EMG recordings from the cricothyroid muscle and the sternohyoid muscle of a male speaker of Osaka Japanese are analyzed in order to determine the physiological correlates of the two types of pitch falls.

Speech material

The speech material consisted of three sets of utterances.

1) A set of four words having the same segmental phonemes /imi/ but different tonal patterns.

	nucleus-less	nucleus-bearing
High-beginning	imi H-H	imi H-L
Low-beginning	imi L-H	imi L-HL

N.B. In Low-beginning nucleus-bearing /imi/, the pitch rises and falls in the last mora.

This is the same set of words as used in the study of Sugito and Hirose. The words were uttered in isolation. The systematic participation of the sternohyoid was expected both at the accent nucleus and at the onset of Low-beginning words.

2) 'Kaminomatu desu' and 'Kami-no matu desu' [kaminomatudesu]

In 'Kaminomatu desu' (HHHLLLL; 'It is Kaminomatu'), 'Kaminomatu', a fictitious place-name, is a High-beginning word with the nucleus on 'no', and 'desu' is tonally neutral and functions as a copula. The pitch fall from 'no' (H) to 'ma' (L) in this sentence is triggered by the accent nucleus. On the other hand, in 'Kami-no matu desu' (HHHLLLH; 'It is a pine tree made of paper'), the High-beginning nucleus-less 'kami-no' (HHH; 'of paper') is followed by the Low-beginning 'matu' ('a pine tree'). Here, the pitch fall from 'no' to 'ma' is due to the Low-beginning word. Therefore, the pitch fall is expected to be steeper in 'Kami-no matu desu' than in 'Kaminomatu desu.' If the sternohyoid actively lowers pitch, the activity of the muscle should be more intense during the steeper fall, namely in 'Kami-no matu desu', than during the slower fall, namely in 'Kaminomatu desu.'

3) 'Yumi nonderu-wa' and 'Yuminon deru-wa' [juminonderuwa]

In 'Yumi nonderu-wa' (HLLLLHL; 'Yumi is drinking'),'Yumi' (HL), a female name, has the accent nucleus on the first mora 'yu', and 'nonderu-wa' (LLLHL; 'to be drinking') is a Low- beginning word followed by the sentence final particle 'wa'.

In 'Yuminon deru-wa' (HLLLLHL; 'Something of Yumi is coming out'), 'Yuminon' (HLLL; 'something which belongs to Yumi') has the accent nucleus on the first mora and 'deru-wa' (LHL; 'to come out') is a Low-beginning word followed by 'wa'.

In this pair of sentences, only the location of the word boundary is different. The phonetic outcome of the difference is that in 'Yumi nonderu-wa' the pitch falls more steeply at 'mino' than in 'Yuminon deru-wa.' [10] Since 'mino' in 'Yumi nonderu-wa' contains the word boundary to the Low-beginning 'nonderu', the steeper fall in this sentence suggests that the Low-beginning word pulls down the pitch even when the pitch is beginning to descend after the accent nucleus. If the sternohyoid functions as a pitch-lowering muscle, it should be more activated at the steeper fall in 'Yumi nonderu-wa' than at the slower fall in 'Yuminon deru-wa.'

Method

EMG signals from the cricothyroid and the sternohyoid were obtained via bipolar hooked-wire electrodes inserted percutaneously in the neck [11]. F0 data were obtained using a F-J Electronics FFM-6502 F0 meter.

Test utterances were repeated more than thirty times. The recordings were listened to by the speaker himself to single out nine tokens in which the speaker's intention was realized in a satisfactory manner. The EMG and acoustic data for the nine tokens were averaged in order to reduce the noise components.

Results and discussion

The data are given in Figures 2 to 9. In each figure, the speech signal (amplitude), F0 contour (linear scale), cricothyroid activity and sternohyoid activity are plotted from the top to the bottom.

1) Set of four tonally opposing 'imi': As seen in Figures 2, 3, 4 and 5, in agreement with the findings of Sugito and Hirose, the cricothyroid was active during the High-pitched moras, and the sternohyoid was active both at the accent nucleus and at the onset of the Low-beginning words. However, the sternohyoid was active, though not very intense, also during the High-pitched moras of the High-beginning nucleus-less word.

2) 'Kaminomatu desu' and 'Kami-no matu desu': Figure 6 shows the data for 'Kaminomatu desu', Figure 7 for 'Kami-no matu desu.' The difference in the steepness of the fall from 'no' to 'ma' between the two sentences was not clear in the tokens analyzed here. This was probably because of the difficulty in realizing this subtle distinction in such a particular experimental situation as EMG recording. Moreover, since the two sentences differed also in the pitch of the sentence-final 'su', which is Low in 'Kaminomatu desu' and High in 'Kami-no matu desu', the subtle difference in the steepness of the fall at 'noma' is redundant.

However, as can be seen in the figures, the sternohyoid at 'noma' was more activated in 'Kami-no matu desu', whose pitch fall was triggered by the Low-beginning 'matu', than in 'Kaminomatu desu', whose fall is due to the accent nucleus on 'no'. On the other hand, the cricothyroid activity did not show significant differences.

The results suggest that sternohyoid activity is relevant to the distinction between the two kinds of pitch falls: the Low-beginning word, which normally triggers a steeper fall, resorts more to the sternohyoid than the accent nucleus does.

The failure in realizing acoustically the difference of the two kinds of falls may be interpreted as a result of the insufficient increase in sternohyoid activity. In fact, the quantitative differences in sternohyoid activity between 'Kaminomatu desu' and 'Kami-no matu desu' are smaller than those found between 'Yumi nonderu-wa' and 'Yuminon deru-wa', in which, as will be seen in the next section, the physiological differences correspond clearly to the differences in pitch.

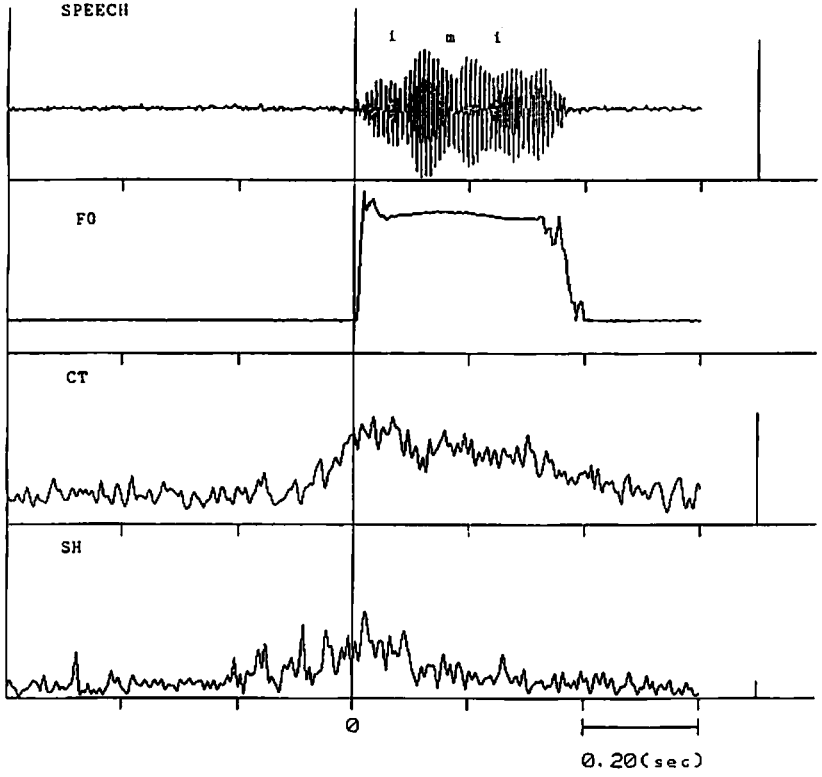

Figure 2 Averaged speech signal (SPEECH), F0 contour (F0), cricothyroid activity (CT) and sternohyoid activity (SH) for the utterances of *imi* with H-H pitch pattern. Nine utterances are aligned with respect to the onset of the word.

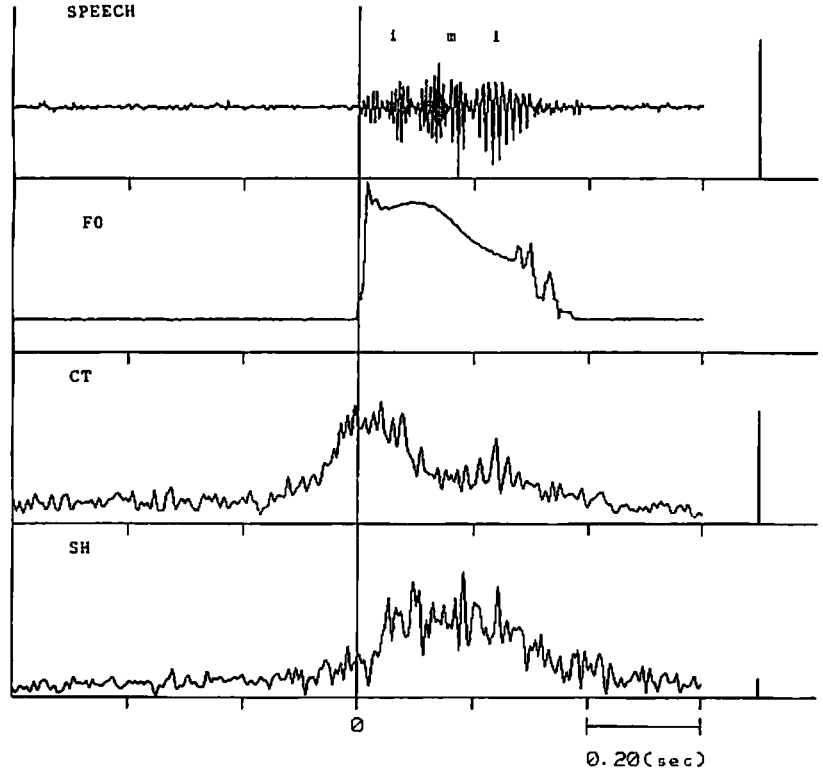

Figure 3 The same as Figure 2 for utterances of *imi* with H-L pitch pattern.

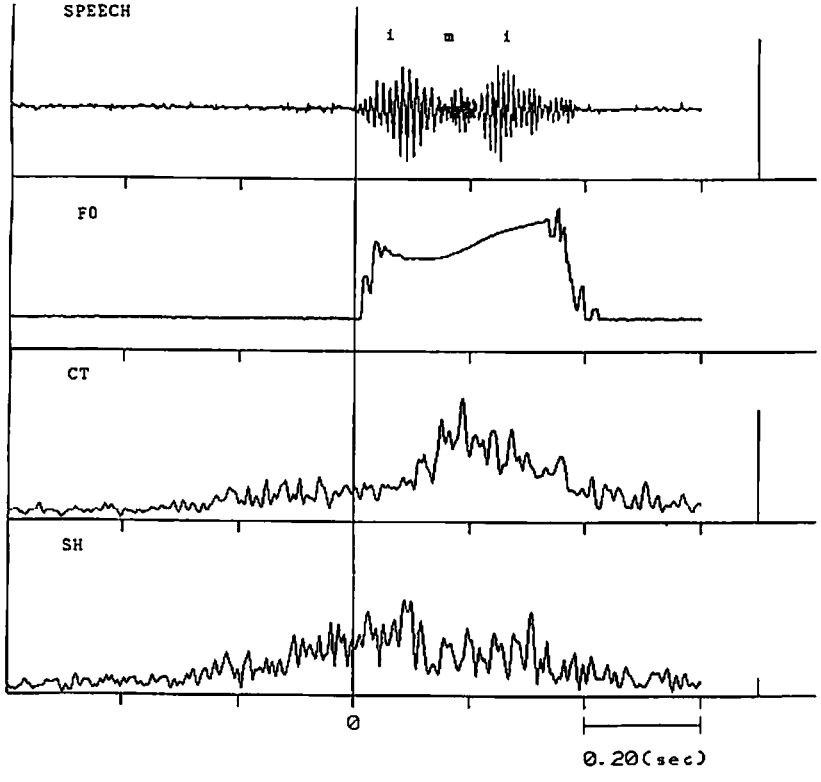

Figure 4 The same as Figure 2 for utterances of *imi* with L-H pitch pattern.

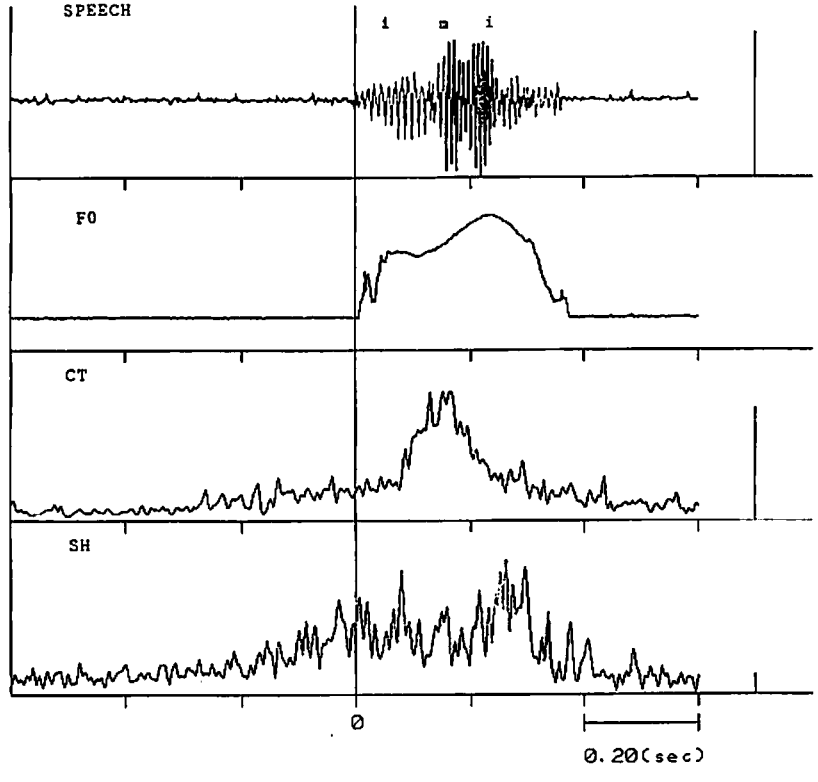

Figure 5 The same as Figure 2 for utterances of *imi* with L-HL pitch pattern.

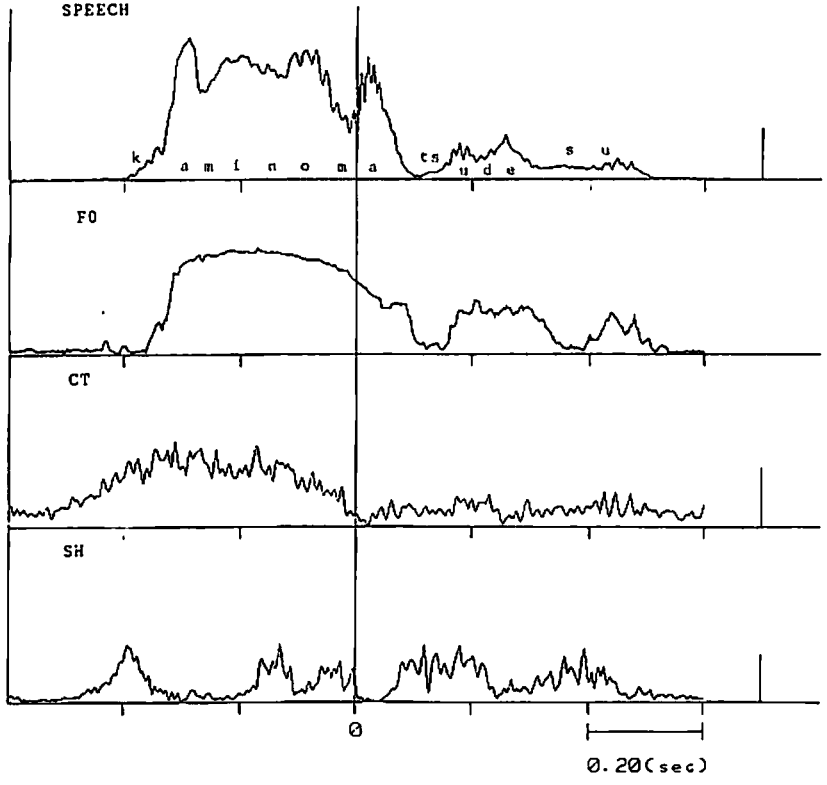

Figure 6 Averaged speech amplitude (SPEECH), F0 contour (F0), cricothyroid activity (CT) and sternohyoid activity (SH) for nine utterances of *Kaminomatu desu.* The utterances are aligned with respect to the onset of the /a/ in /matu/.

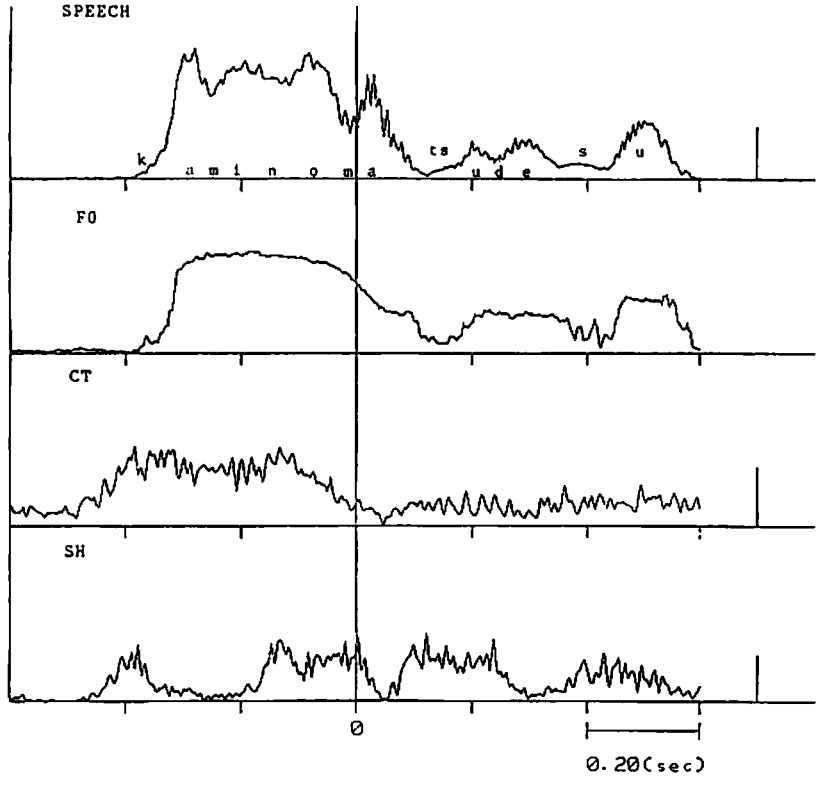

Figure 7 The same as Figure 6 for utterances of *Kami-no matu desu.*

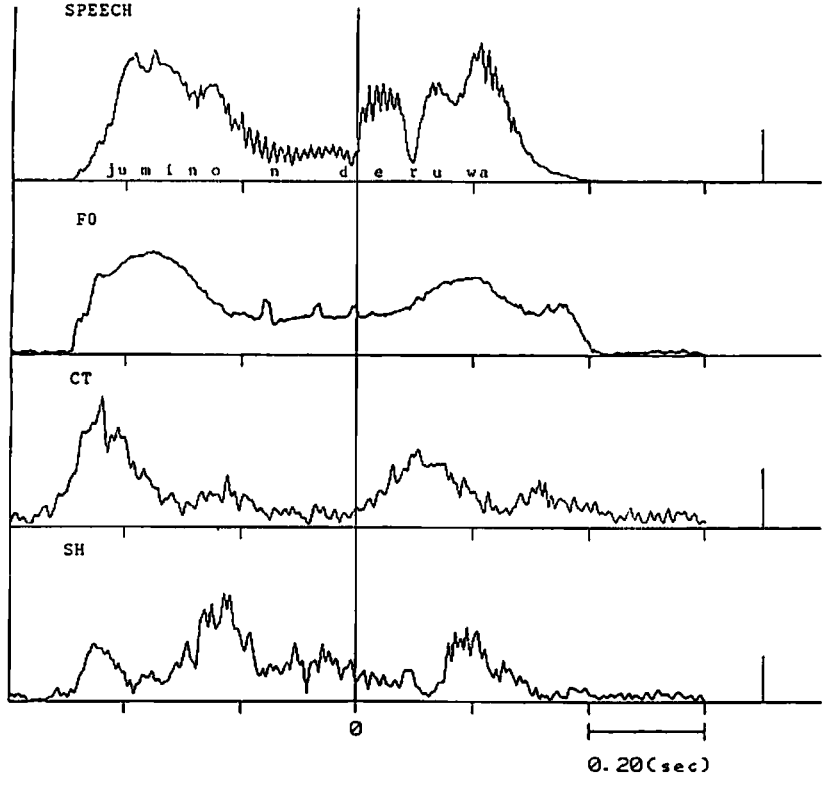

Figure 8 Averaged speech amplitude (SPEECH), F0 contour (F0), cricothyroid activity (CT) and sternohyoid activity (SH) for nine utterances of *Yumi nonderu-wa.* The utterances are aligned with respect to the onset of /d/.

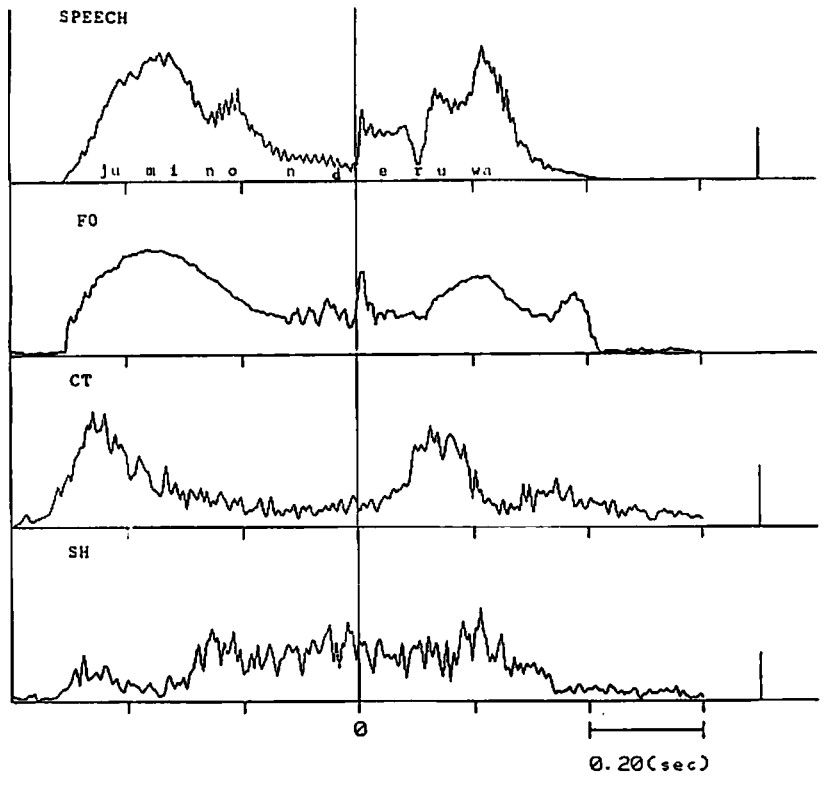

Figure 9 The same as Figure 8 for the utterances of *Yuminon deru-wa.*

3) 'Yumi nonderu-wa' and 'Yuminon deru-wa': Figure 8 shows the data relative to 'Yumi nonderu-wa', and Figure 9 those to 'Yuminon deru-wa.' As expected, the pitch fall at 'mino' was steeper in 'Yumi nonderu-wa' than in 'Yuminon deru-wa.' Differences in EMG pattern were observed both in the cricothyroid and the sternohyoid.

Cricothyroid activity decreased a little more quickly at 'mi' in 'Yumi nonderu-wa' than in 'Yuminon deru-wa.' However, this difference seems insufficient to account for the clear-cut con trast in the steepness of the fall in pitch.

On the other hand, the sternohyoid showed clearly different patterns. The muscle was more activated at 'mino' and less activated around 'de' in 'Yumi nonderu-wa' than in 'Yuminon deru-wa.' In other words, sternohyoid activity became more intense at the onset of the Low-beginning word.

The results show that the Low-beginning word resorts to the sternohyoid to realize its word-initial Low pitch even when the pitch is already falling in order to give it a boost.

Conclusion

The Low-beginning word, which triggers a steep fall, resorts to the sternohyoid to realize the word initial Low pitch more than the accent nucleus does to realize a slow pitch fall. The acoustic difference in steepness between these two kinds of falls in 'Yumi nonderu-wa' and 'Yuminon deru-wa' is better accounted for by the sternohyoid activity pattern than by the cricothyroid activity pattern. Thus, the sternohyoid has an active role of lowering pitch, which is indispensable to realize Osaka Japanese prosody.

Disagreement among previous studies on various languages, including Tokyo Japanese, English and Dutch, as to the role of the sternohyoid probably derives from differences in the rigidity of the pitch control among the languages studied. For example, Osaka Japanese is more like a tone language than is Tokyo Japanese, and requires a more precise control of pitch. On the other hand, Tokyo Japanese, and probably English and Dutch, don't require such a precise control of pitch as Osaka Japanese does, and resort less frequently to the active pitch-lowering mechanism, which is auxiliary for them, and leave the use of the sternohyoid to the speakers's option. This at the same time suggests that even in Osaka Japanese the sternohyoid may not be involved in pitch-lowering when context does not require a precise pitch control.

References

1) Kori, S.: The tonal behavior of Osaka Japanese. Working Papers in Linguistics, Dept. of Linguistics, The Ohio State University, 36, 31-61, 1987.
2) Kori, S.: 'Tamanoumi'(LLHLL) and 'Tama-no umi'(LLHLL): two kinds of pitch falls in Osaka Japanese. Bulletin of the Language Laboratory, Osaka University of Foreign Studies, 11, 68-79, 1988. (in Japanese)
3) Simada, Z. and H. Hirose: The function of the laryngeal muscles in respect to the word accent distinction. Ann. Bull. RILP, 4, 27-40, 1970.
4) Ohala, J. and H. Hirose: The function of the sternohyoid muscle in speech. Ann. Bull. RILP, 4, 41-44, 1970.
5) Atkinson, J.E. and Erickson D.: The function of strap muscles in speech: pitch lowering or jaw opening? Haskins Laboratories: Status Report on Speech Research SR-49, 97-102, 1977.
6) Erickson, D., M. Liberman and S. Niimi: The geniohyoid and the role of the strap muscles. Haskins Laboratories: Status Report on Speech Research SR-49, 103-110, 1977.
7) Collier, R.: Physiological correlates of intonation patterns. J. Acoust. Soc. Am., 58, 249-255, 1975.
8) Sugito, M. and H. Hirose: An electromyographic study of the Kinki accent. Ann. Bull. RILP, 12, 35-51, 1978.
9) Simada, Z. and H. Hirose: Kyookotuzekkotukin-wa tookyoogo-no ontyoo-no zitugen-ni dookakawatteiruka (How the sterno-hyoid muscle is involved in pitch control in Tokyo Japanese). Status report on the actual state and the teaching problems of Japanese prosody (Research supported by the Grant-in-Aid for Scientific Research on Priority Areas (01642012) from the Japanese Ministry of Education, Science and Culture), 1, 19-20, 1989. (in Japanese)
10) Kori, S.: 'Yumi nonderu-wa' and 'Yuminon deru-wa': concatenation of word accents in Osaka Japanese. Paper presented to the 16th meeting of the Kinki Society for Phonetics, 1989.
11) Hirose, H., T. Gay and M. Strome: Electrode insertion techniques for laryngeal electromyography. J. Acoust. Soc. Am. 50, 1449-1450, 1971.