ACTIVITY OF THE EXTRINSIC LARYNGEAL MUSCLES IN RELATION TO JAPANESE WORD ACCENT*

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In order to investigate the function of the extrinsic laryngeal muscles in vocal pitch control during speech, activities of the selected intrinsic and extrinsic laryngeal muscles associated with Japanese word accent were observed electromyographically.

Experimental Procedure

A nonsense Japanese word consisting of four syllables (or morae) /namanama/ was pronounced with different word accent patterns by a male adult Japanese (one of the authors).

In the first series of speech samples, the word was pronounced in isolation with four word accent patterns, namely, with an accent kernel placed on the first, the second, and the third morae and with no accent kernel. In the second series, the word was pronounced in the phrase /'ano --- no'atode/ (after that ---). In this series, another accent pattern with an accent kernel on the fourth mora was examined as well as those used in the first series. In both series, the word accent patterns were repeated ten times, each in a randomized order.

In addition to the word utterances, sustained vowel /a/ with changes in vocal pitch along an ascending and descending musical scale in the chest register was repeated several times.

Five pairs of hooked wire electrodes[1)] were placed in the cricothyroid, vocalis, thyrohyoid, sternothyroid and sternohyoid muscles of the subject, and the EMG signals were recorded in a multi-channel FM tape recorder simultaneously with the speech signals.**** The tape was played back later and the

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EMG signals were processed by a computer programmed pulse counting method* in order to obtain the pattern of muscle activity for each utterance.

Results and Remarks

Results obtained for the utterance of the nonsense Japanese word in isolation with an accent kernel placed on the first, the second and the third morae and with no accent kernel are shown in Figures 1, 2, 3 and 4, respectively. In each figure, the EMG pattern of each muscle, the fundamental frequency contour, the speech envelope, and the speech wave for the ten utterances are superposed with the line-up point at the syllable boundary where the accent kernel is placed. A solid vertical line indicates the line-up point. Dotted lines indicate the mean timings of the onset and the end of speech waves respectively.

In Figure 1 where the accent kernel is on the first mora, the pitch contour shows a steep rise during the first syllable to reach a peak, and a descent in the pitch associated with the accent kernel is observed during the second syllable. The descending curve then continues, showing a gradual slope, to the last syllable of the word, where another descent in the pitch corresponding to the end of the utterance is observed.

Figure 2 is for the utterance with the accent kernel on the second mora. In this case, there is a steep rise in the vocal pitch during the second syllable, and a descent in the pitch is observed during the third syllable. The accent kernel is placed on the third mora in Figure 3. There is also a rise in vocal pitch during the second syllable, but to a lesser extent as compared with Figure 2. The pitch contour then shows a plateau through the third mora. A marked lowering in the pitch is noted during the fourth syllable where the effects of the accent kernel and that of the end of utterance are combined. Figure 4 is for the utterance with no accent kernel. The pitch contour in this case shows a nearly identical pattern with that of Figure 3 except for the fourth syllable where the pitch descent is very slight.

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* This method was first tested by Z. Simada in 1969, and recently evaluated by Imaizumi and Hiki. [2)]

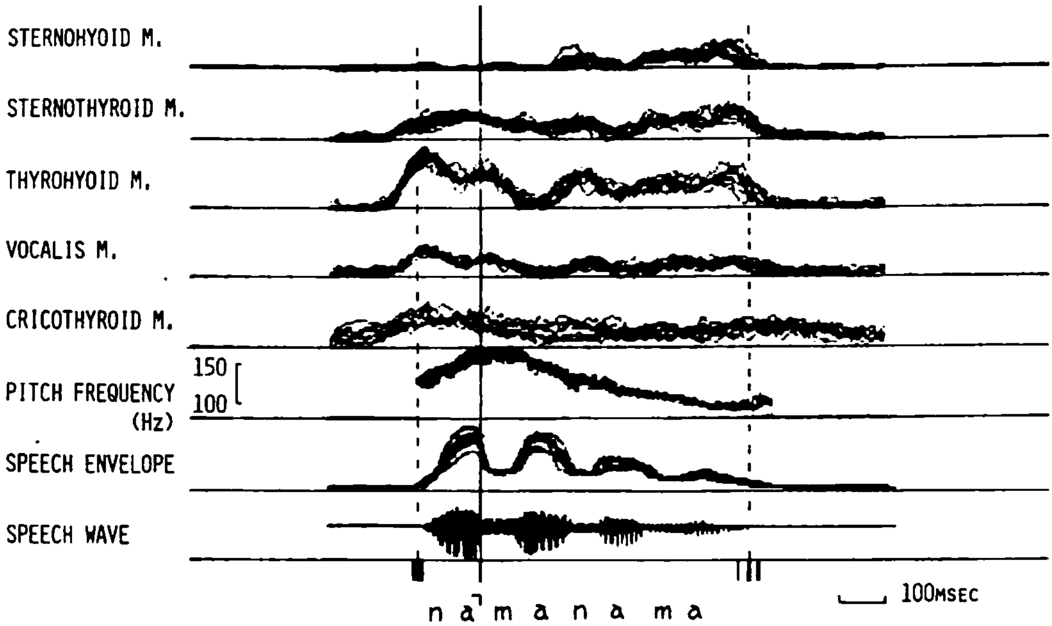

Fig. 1. Simultaneous display of EMG patterns, the fundamental frequency contour, the speech envelope and the speech wave in repeated utterances of /namanama/ in isolation with the accent kernel on the first mora. Ten utterances are superposed.

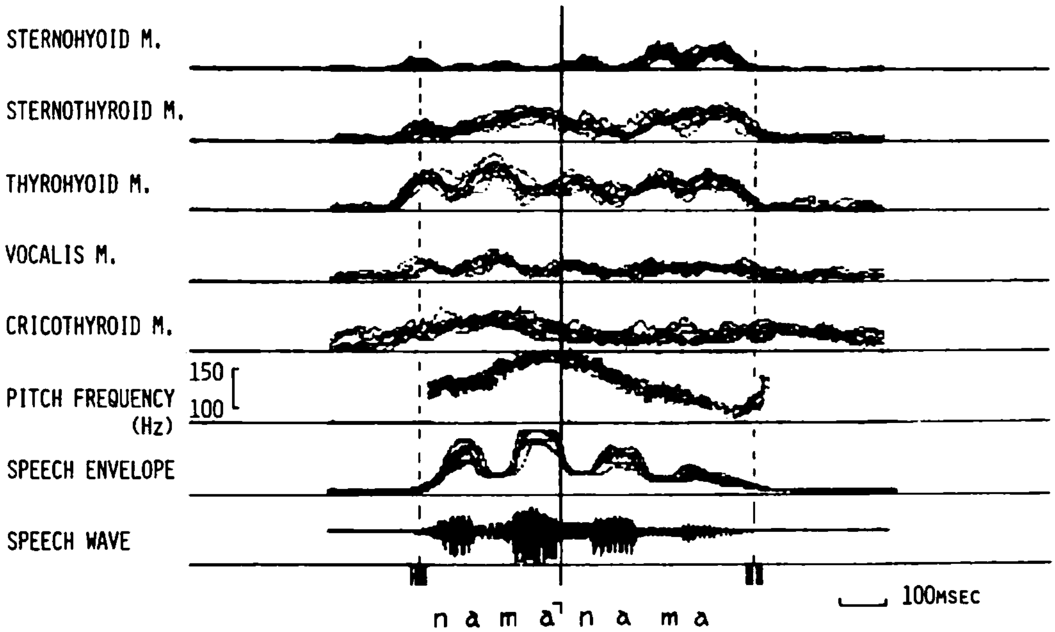

Fig. 2. Same as Fig. 1 with the accent kernel on the second mora.

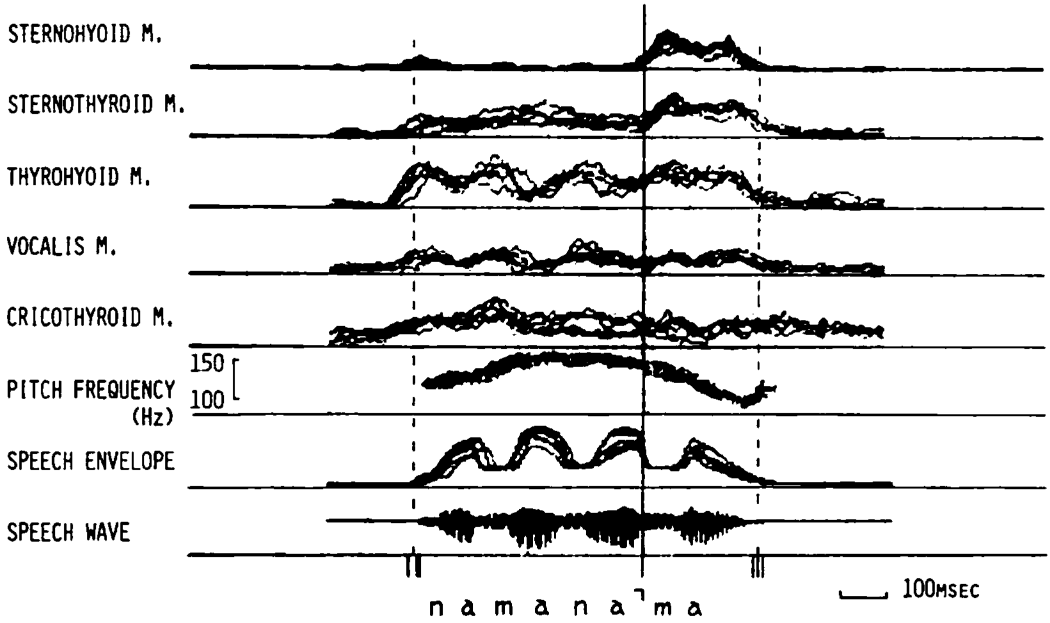

Fig. 3. Same as Fig. 1 with the accent kernel on the third mora.

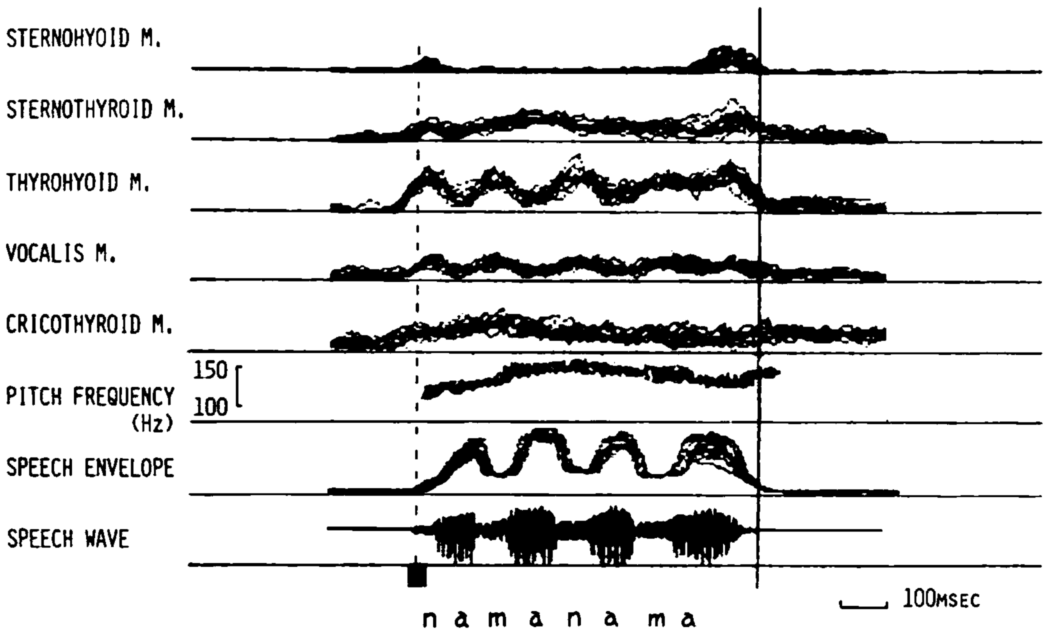

Fig. 4. Same as Fig. 1 with no accent kernel.

Comparing these four types of accent patterns, we can examine the relationship between the activity of each muscle and the vocal pitch in the syllable utterance.

The activity pattern of the cricothyroid muscle is clearly correlated with a pitch rise, the increase in the activity being in advance by approximately 100 msec. In Figures 1 and 2, the peak activity is followed by a relatively sharp depression which corresponds to the pitch descent representing the accent kernel. In Figures 3 and 4, the activity decreases gradually during the plateau in the pitch contour.

The activity of the vocalis muscle shows a general pattern which roughly coincides, with a timing lead of approximately 100 msec, with the pitch contour. Fluctuations in the activity superposed on the general pattern seem to represent the syllabification of the word, and the activity at the end of the utterance probably corresponds to a tendency for the glottal stop gesture.

The thyrohyoid muscle shows a pattern of activity which is similar to that of the vocalis. A rhythmic fluctuation in this case seems to reflect supraglottic articulatory movements for each syllable.

The sternothyroid muscle also shows a pattern that coincides, with less timing lead as compared to the muscles mentioned above, with the pitch pattern except for the additional peak for pitch lowering at the end of utterance. Fluctuation of the activity in correspondence to articulatory movements seems to appear in the lower pitch range.

The sternohyoid muscle shows no activity before the pitch begins to be lowered. The activity appears to increase along the downward slope of the pitch contour and reaches its peak at the end of the utterance. The reflection of articulatory movements is also observable in the activity of the muscle. In Figure 4 where the pitch drop is very slight, the peak activity is also very small.

Although the samples obtained for utterances with the carrier phrase are not displayed here, the data showed general agreement with those of utterances in isolation.

In sustained phonation of vowel /a/ with ascending and descending scale in vocal pitch, activity of the cricothyroid, vocalis and the thyrohyoid muscles showed an increase in higher pitch and a decrease in lower pitch. The results in these three muscles were consistent with those in syllable utterances. But it was not true for the sternothyroid and the sternohyoid muscles. These two muscles showed almost identical pattern of activity with each other in the sustained vowel. Utterance to utterance variability in the pattern of activity was observed to some extent. The general tendency was that the activity was not necessarily correlated with the pitch but was prominent through the time span of the descending scale.

Activity of the extrinsic laryngeal muscles in relation to pitch control in sustained phonation has been reported by several authors.[3-7] There are some disagreements on the results among the authors. This seems to suggest that the results may be affected by the type of phonation or the range of vocal pitch examined.

EMG patterns of some of the intrinsic and extrinsic laryngeal muscles in connection with different accent patterns in Japanese have been observed by Simada and Hirose.[8,9] Their findings on the cricothyroid muscle are in agreement with our present data. According to these authors, a consistent increase in the activity of the sternothyroid muscle was observed in association with pitch lowering, the activity being suppressed for pitch rise. This pattern is rather comparable with that in the sternohyoid in our subject, but is clearly different from that in the sternothyroid. The activity of the sternohyoid as reported by those authors, on the other hand, showed no consistent correlation with pitch lowering. There was a considerable influence of the articulatory gestures instead.

These discrepancies in the results of the extrinsic muscles may be accounted for, to some extent, by factors such as differences in the test words and individual habits in speech gestures. Our data also revealed that the activities of the sternohyoid and the sternothyroid showed different patterns in syllable utterances while they were quite similar in sustained vowels. This suggests a variability in the activity pattern of some of the extrinsic muscles with different phonatory types within the same subject.

As it was reported by Simada and Hirose, the timing of the activity observed here also suggests that the extrinsic muscles, even though some of them showed activity in pitch lowering, are secondary supporters rather than primary effectors of pitch. It is assumed that the extrinsic laryngeal muscles can exert several different combinations of muscle activities, in coordination with other muscles, to achieve a supporting effect for a given pitch change. Further study is necessary in this respect.

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