EMG ANALYSIS OF THE MOTOR COMMANDS TO LARYNGEAL MUSCLES FOR WORD ACCENTUATION

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Continuous time patterns of neuromotor commands obtained by a pulse counting method from electromyograms of five laryngeal muscles for the uttereance of Japanese word accentuation [1] are analyzed to estimate the higher commands, and it is shown that the higher command for each muscle is represented by linear superposition of four basic components.

Extraction of a Continuous Time Pattern of Neuromotor Command from EMG

Electromyograms of five laryngeal muscles, i. e., two intrinsic muscles, vocalis and cricothyroid, and three extrinsic muscles, thyrohyoid, sternothyroid and sternohyoid, were observed in utterances of a Japanese nonsense syllable sequence /namanama/ pronounced in isolation with four word accentuation types.(Details of the EMG are given in Sawashima et al. [1])

Figure 1 shows average patterns of acitivity of the laryngeal muscles, fundamental frequency contour and speech envelope in ten repeated utterances for each of the syllable sequences with an accent kernel at the first, the second and the third mora. The patterns of muscle activity were obtained by pulse counting for differentiated waveforms of EMG signals [2] and smoothing with a time window of 190 msec shifted every 10 msec. This width of time window was sufficient to eliminate fluctuations synchronized with each mora segment in the syllable sequence.

Vertical dotted lines show the beginning and the end of the utterance The end of each mora is indicated by a vertical bold line beneath which the mora number is indicated. The number attached to each curve corresponds to the mora accented in the utterance. The curves for the utterance with the second mora accented are indicated by dotted lines.

Estimation of the Higher Command

The higher neuromotor command was derived from the average patterns of muscle activity by an Analysis-by-Synthesis method as follows.

Examining the nature of the continuous time patterns of muscle activity, it was assumed that the higher commands consist of a component which is related to the position of the accented mora; a component F(t), which shows increasing activity toward the end of the utterance; and a component B(t), which shows activity throughout the utterance. The first component is divided into two components, P(t) and N(t), which are related to increase and decrease of fundamental frequency, respectively. It is also

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assumed that the higher command is approximated by linear superposition of those four components, each of which is represented by a rectangular time pattern with the same amplitude, and the continuous time patterns of muscle activity are generated from the higher command by smoothing with a critically damped second-order delay system. Then, the ratio of these four components in the continuous time pattern of the neuromotor command for each muscle is determined so that difference between the generated continuous time pattern and the one obtained from EMG is minimized.

Timing of the beginning and the end of the rectangular time pattern of each component is changed in the course of AbS as follows: For B(t), the cessation is fixed at the end of the speech wave, and the onset is chosen before the beginning of the speech wave. For F(t), the onset is fixed at the beginning of the last mora, and the cessation is chosen within the last mora. For P(t), the onset is chosen between the beginning of the previous mora (or the onset of B(t) in the case of first-mora accentuation) and the end of the accented mora, and the cessation is chosen between the beginning of the accented mora and the end of the following mora. For N(t), the onset is synchronized to the cessation of P(t) and the cessation to that of F(t).

Discussion

Time structure of the four components of the higher command obtained as the result of AbS and the ratios among them are shown in Fig. 2 and Table 1, respectively.

In the results shown in Table 1, the rate of P(t) is larger than that of N(t) in the activities of the cricothyroid, the thyrohyoid and the vocalis muscles. This indicates that these muscles are related to the rise of fundamental frequency rather than to its fall. Activities of the cricothyroid and the thyrohyoid muscles do not contain the component of F(t), that is, they are not related to the fall of fundamental frequency near the end of the utterance. Especially for the cricothyroid muscle, the rate of N(t) is negative. This fact supports the view that the activity of this muscle is mostly correlated to the rise of fundamental frequency, as was previously reported.

However, the rate of N(t) and F(t) is larger than that of P(t) in the activities of the sternothyroid and the sternohyoid muscles. This indicates that the relation between the activities of these muscles and change in fundamental frequency is the reverse of that for the three muscles previously mentioned.

References

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2) S. Imaizumi and S. Hiki: "Extraction of Motor Command from Electromyogram by Means of Pulse Counting Method," J. Acoust. Soc. Japan, 29, (12), 727-729 (1973).

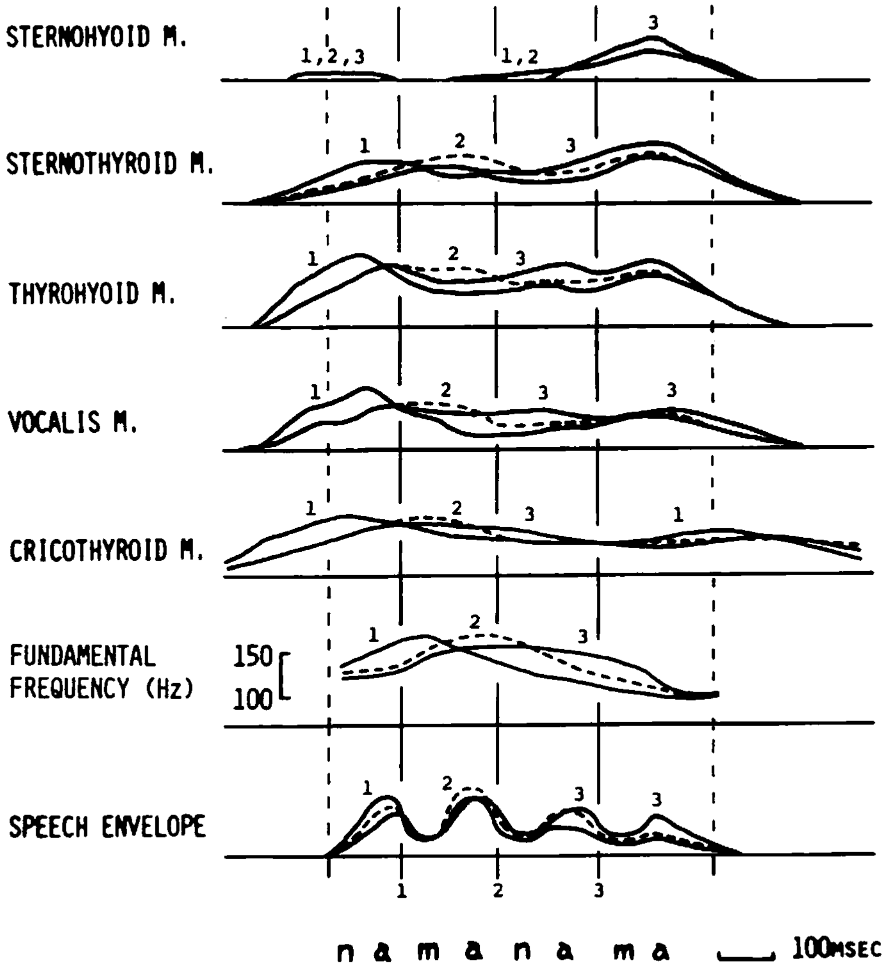

Fig. 1: Patterns of activity of laryngeal muscles for word accentuation.

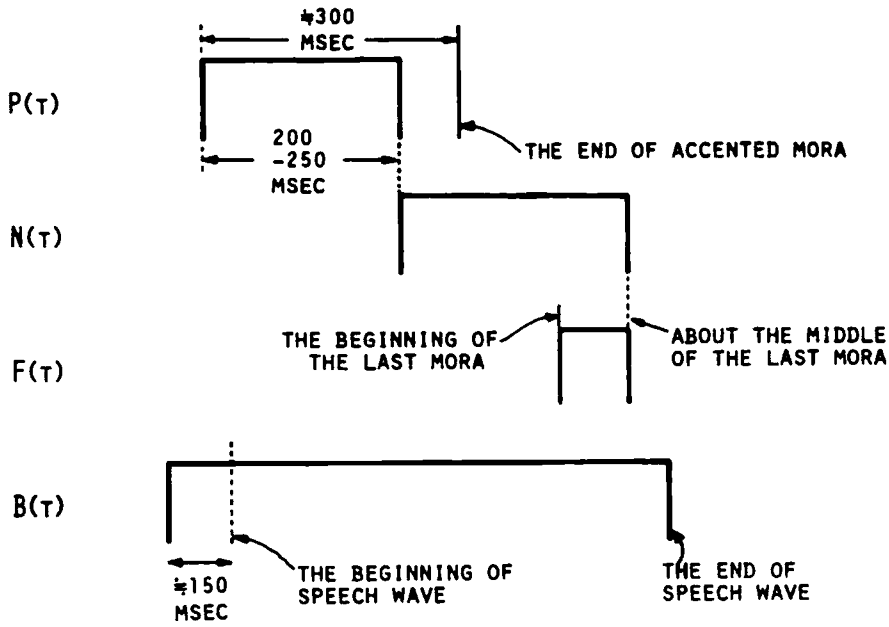

Fig. 2: Four components of higher commands for word accentuation.

	P(T)	N(T)	F(T)	B(T)
STERNOHYOID M.	0	1	2	0
STERNOTHYROID M.	1	1	1	1
THYROHYOID M.	2	1	0	1
VOCALIS M.	3/2	1/4	1	1
CRICOTHYROID M.	1/3	-1/5	0	1

Table 1: Ratio among the components of higher command.