AN ELECTROMYOGRAPHIC STUDY OF ARTICULATORY MOVEMENTS

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An electromyographic study is being conducted on the activities of some articulatory muscles under control of the speed of utterance. From a physiological point of view, nerve impulses come from the central nervous system as motor commands and reach the peripheral muscles to elicit specific movements of the articulatory organs. One of the most interesting problem in the study of articulatory movements is how the sequence of motor commands which are inherent to a phoneme, or some other phonological unit, is converted into a series of articulatory gestures and subsequently to acoustic events. The aim of the present study, in particular, is to find the time relationship between the muscle activity and the corresponding acoustic event in speech utterance.

As the object muscles, the orbicularis oris and the anterior belly of the digastric are selected in the present study.

The major portion of the orbicularis oris consists of fibers arranged in a sphincteric fashion around the mouth (Fig. 1-A). The orbicularis oris is known to be responsible for articulatory gestures of rounding, protrusion and closure of the lips. Among five Japanese vowels /a/ /i/ /u/ /e/ /o/, /o/ is rounded and is characterized by an appreciable amount of activity of the orbicularis oris.

The anterior belly of the digastric arises as a tendon that attaches to the hyoid bone. The tendon continues through this point into the posterior belly of the muscle. The anterior end of the muscle attaches to the lower and inner surface of the mandible in either side of the midline (Fig. 1-B). The digastric is active in opening the jaw. Among the Japanese five vowels, the digastric shows marked activities for /a/ and /o/.

Experimental Procedures

In the present study, non-sense Japanese words are used as test words. Each word is selected so as to contain the pertinent Japanese vowel for the activity of either the orbicularis oris or the digastric. Thus, /ka'etori/ is used in a series of measurements on the orbicularis oris, while /'uri'arito/ is used in those on

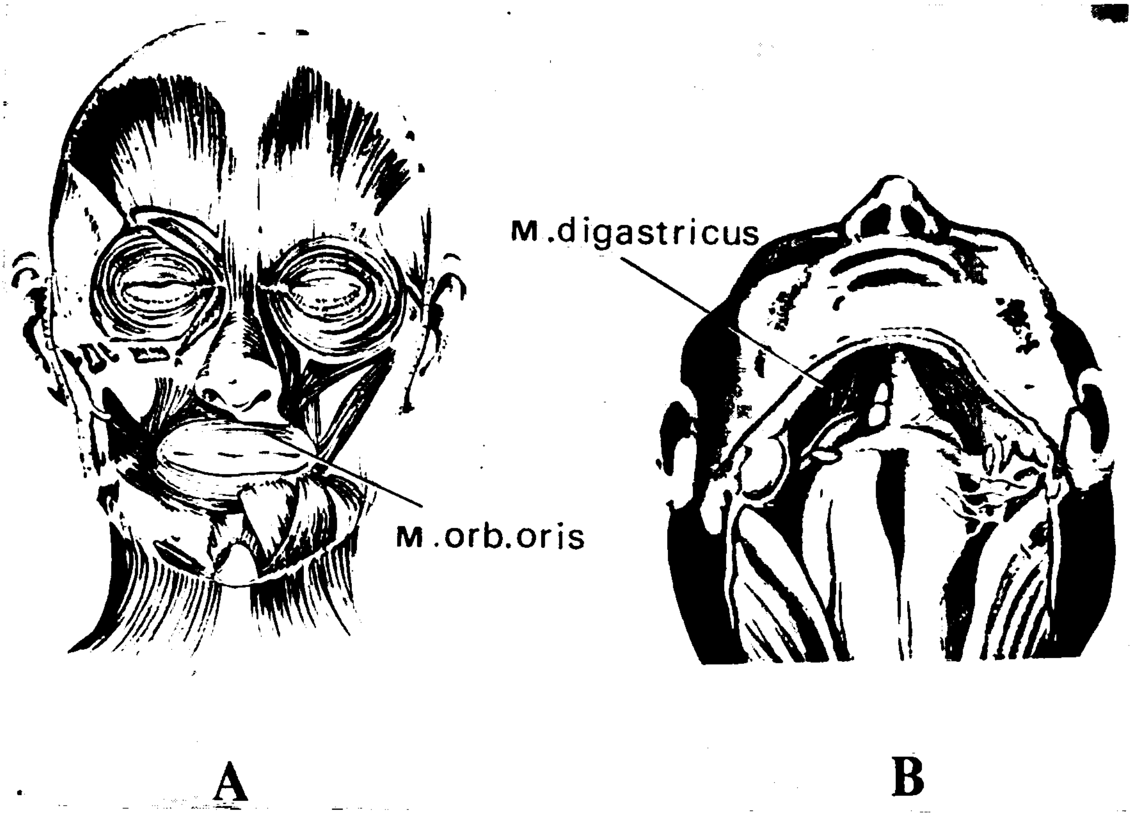

Fig. 1 Anatomical locations of the object muscles.

the digastric. The muscle activity is expected for the underlined vowel in each test word.

The subject sets three different speeds of utterance designated as slow, moderate and fast, respectively. For each speed, the test word is uttered in isolation and is repeated with pause ten times in series, keeping the speed of utterance as constant as possible. In the series of fast speed, the subject is instructed to articulate the word in his maximal speed of speech.

The subject is placed in an electrically shielded room. A special monopolar needle electrode is used throughout the present study. The needle electrode is made out of a Japanese acupuncture needle, the diameter of which is about 0.2-mm with a very sharp tip. It is insulated except for the tip measuring approximately 0.5-mm. The needle of this type is so thin and pliable that the insertion of the needle does not cause too much discomfort to the subject and that it does not affect normal articulatory movements.

The E.M.G. signals and the acoustic signals are recorded simultaneously on a two-channel tape recorder. Fig. 2 shows examples of raw data of the E.M.G. and acoustic signals recorded for the test words.

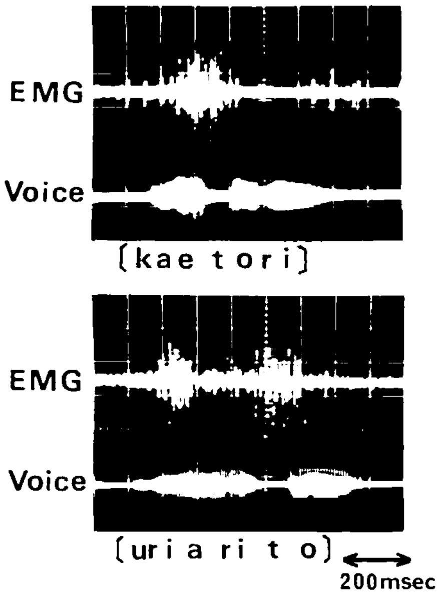

Fig. 2 - Examples of raw data of simultaneously recorded E.M.G. and acoustic signals for the test words.

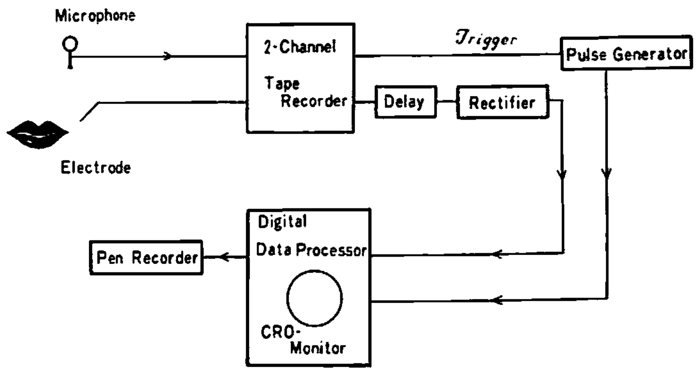

Fig. 3 - A block diagram of the system for E.M.G. data processing.

Fig. 3 shows a block diagram of the system employed to obtain averaged E.M.G. data. The tape is played back continuously for one series of utterances. The E.M.G. signal is fed into a digital data processor. A trigger pulse is generated at the onset of the acoustic signal of each utterance.

The E.M.G. signal is processed for a one-second interval following the trigger pulse and is integrated for every 10-msec to obtain 100 sampled values in one second. The values are averaged for eight utterances out of the ten in each series. Averaged E.M.G. data are either displayed on a monitor oscilloscope or recorded by a pen recorder.

Fig. 4 shows examples of averaged E.M.G. data for one, two, four and eight utterances. The E.M.G. data averaged for eight utterances still show some irregularities, but its peak position can be determined within a range of 20-msec in most cases.

The time intervals between the onset of the acoustic signal and characteristic acoustic events are measured on the sound spectrogram for each utterance. For each characteristic event, the values are averaged for the eight utterances and the reference points are marked off on the time axis of the E.M.G. curves (Fig. 5).

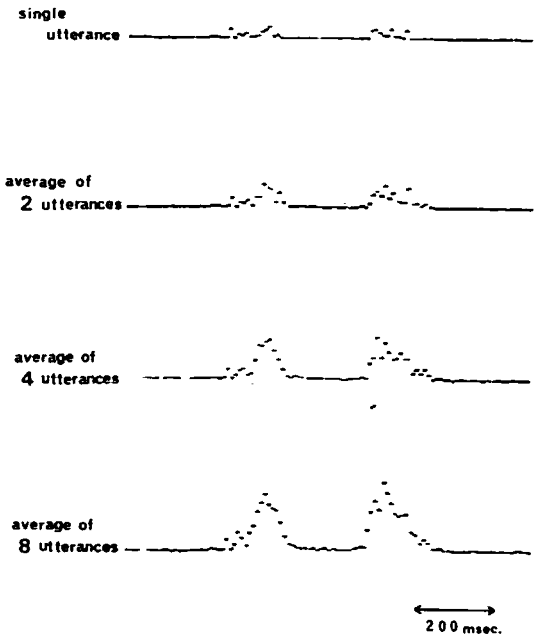

Fig. 4 - Averaging E.M.G. signals for 1, 2, 4 and 8 utterances (example).

Results and Remarks

Fig. 5 shows averaged E.M.G. data in three different speeds of utterance in reference to representative time moments averaged for the sample utterances of the acoustic signals. It is noted that the E.M.G. signals always appear to lead the acoustic signals of the pertinent vowels /o/ (left) or /a/ (right). It is also noted that the time interval between the voice onset of the speech signal after [t] in [kaetori] and the peak of averaged E.M.G. signal for the labial gesture becomes shorter as the speed of utterance increases. The rate of shortening is in excess of what might be predicted from the proportional speed up of the articulatory events. A similar phenomenon is found in the case of the digastric. Thus, in a slow utterance the peak of the averaged E.M.G. signal is found approximately at the beginning of the acoustic manifestation of the corresponding phoneme, while in a fast utterance it is within the domain of the preceding syllable, i.e. [e] in [kaetori] and [i] in [uriarito] .

A possible interpretation of these results is that there is a comparatively constant time interval between the peak of the E.M.G. activity and the center of

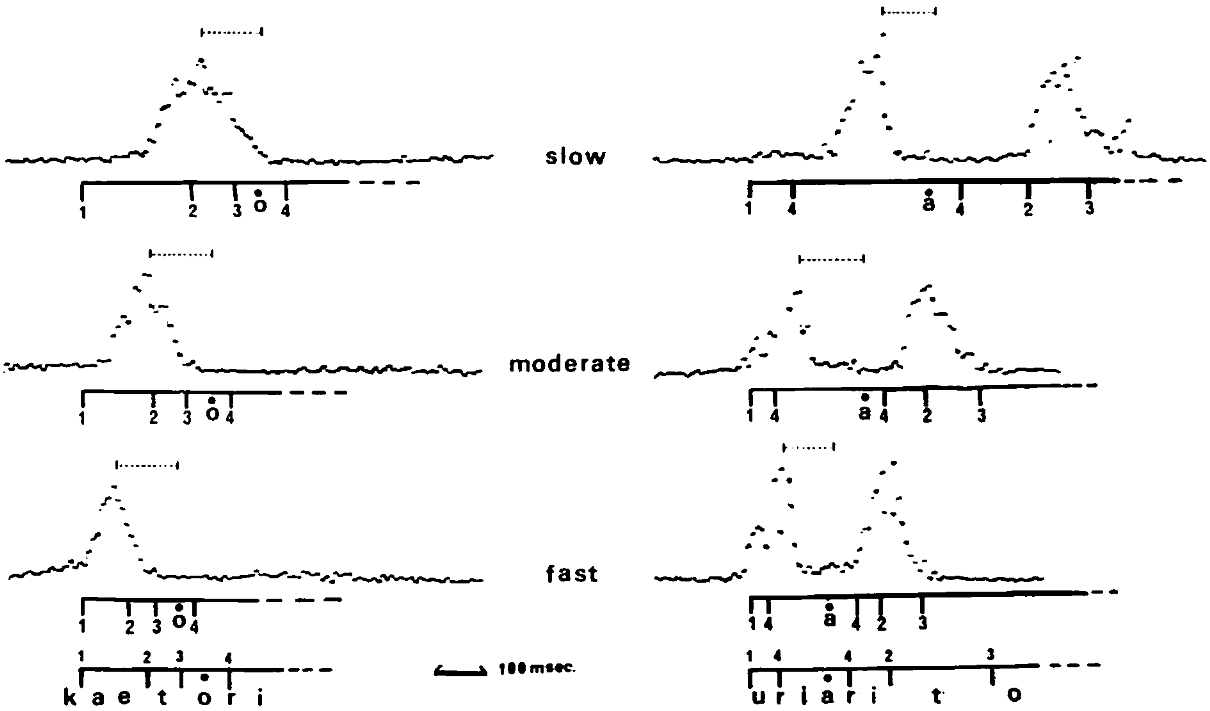

Fig. 5 - Averaged E.M.G. data with reference to representative acoustic events:
1. onset of the speech signal
2. implosion into the stop
3. voice onset after the voiceless stop
4. flap of /r/.

the corresponding acoustic event irrespective of the speed of utterance. As shown in the examples in Fig. 5, the time interval is found to be almost the same for both muscles examined and is approximately estimated at 110-msec.

For further analyses of the characteristics of the time relations, direct observations of movements of the articulatory organs associated with the E.M.G. recording are in schedule, as well as a more extensive and systematic collection of similar E.M.G. data.

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