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LINGUAL ELECTROMYOGRAPHY RELATED TO TONGUE MOVEMENTS IN SWEDISH VOWEL PRODUCTION*

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Introduction

Recent physiological investigations have revealed that the activity of the extrinsic lingual muscles, the genioglossus (GG) in particular, is closely related to tongue movements in both speech and non-speech gestures. Previous electromyographic (EMG) experiments have indicated that GG is active in raising the bulk of the tongue and thus active in the production of high-front vowels.

As for English vowels, for example, Raphael and Bell-Berti (1973) investigaed the role of the extrinsic and intrinsic lingual muscles in differentiating the English tense-lax vowel pairs. They found that GG activity was less for back vowels than for front vowels and that there was greater activity for /i/ than for /ɪ/, for /e/ than for /ɛ/ and for /u/ than for /U/. They thus concluded that GG evidenced a consistent tense-lax difference between the vowels /i, e, u/ and /ɪ, ɛ, U/, although it must be pointed out that such a difference cannot be shown to be independent of differences in duration and change in vowel color.

In the production of the five Japanese vowels /i/, /e/, /a/, /o/, and /u/, GG was found to be active for those vowels characterized by either the property "high" or "front", i.e., for /i/, /e/ and /u/; while it showed only a very low level of activity for the vowels /a/ and /o/ (Miyawaki et al., 1975). It was also found that EMG signals obtained from five different locations of GG differed characteristically in their activity patterns. These differences were interpreted to be in correlation with differences in tongue configurations in the production of the Japanese vowels.

The principal purpose of the present study was to investigate EMG patterns of GG in the production of more comprehensive vowel sets of Swedish and compare the results with the patterns of tongue movements observed by means of our x-ray microbeam system.

Experimental Procedures

One of the present authors, (Olle Kjellin), a male native speaker of Swedish, the Stockholm dialect, served as the experimental subject both in EMG and x-ray studies.

The subject read nonsense test words, each of which embedded one of the 9 Swedish long vowels and the 8 short vowels, repeatedly more than 12 times for each type in random order. The vowels used were [i:], [y:], [e:], [ɛ:], [ʉ:], [ø:], [ɑ:], [u:], [o:] and their counterparts [ɪ], [Y], [ɛ], [ɵ], [œ], [a], [U], [ɔ]. Since the distinction is said to be no longer upheld between short [e] and short [ɛ] in most Swedish dialects (Harris et al. 1975), only [ɛ] was included in the present study. The vowels were embedded in two

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different frames /hab_ba / and /had_da/. Since the consonant following the short vowel becomes a so-called long consonant, they are transcribed as [hadɪdda] or [habYbba], for example. In this paper, only the data for the frame /hab ba/ will be reported. The test words were uttered with Accent II.

Conventional bipolar hooked-wire electrodes were inserted into two different locations in GG percutaneously. One of the two locations was chosen to place the electrodes in the anterior portion of GG, while the other was aimed more posteriorly. The anterior location will be called GG1 in this paper and the posterior will be GG2. Detailed descriptions of the route of insertion and verification of electrode positioning have been reported elsewhere (Hirose, 1971).

The EMG signals were amplified and recorded on an FM data-recorder together with the audio signals. They were subsequently computer-processed to obtain the averaged EMG patterns for each utterance type. The averaging was made in reference to the onset of each vowel embedded in the frame. The obtained averaged EMG curves were displayed as a function of time.

Separately from the EMG experiment, the same subject served for x-ray microbeam recording in which he read the same test words as used in EMG experiments. Before the x-ray recording, several lead pellets were attached to the tip and dorsum of the tongue, the lower lip and the upper and lower incisors using biomedical adhesive. In addition, one pellet was placed in the vallecula (Fig. 1).

A detailed description of the x-ray microbeam system has been reported elsewhere (Kiritani et al., 1975). Briefly, the system employs a high-voltage flying-spot type x-ray microbeam generator with the rating of 150Kv-2mA controlled by a computer (PDP-9). By using the present system, the movement of an articulator can be observed by tracking a few lead pellets attached to it. The data output is read into the computer memory core through an x-ray detector and an A/D converter.

For the purpose of off-line observations, the x-ray image can be displayed on a monitor oscilloscope by using a hard-ware scan signal generator. Some additional computer programs are also available for displaying the image data which are digitally stored in this mode of observation. For example, trajectories of the pellet movements can be displayed in real time. As an alternative, the coordinate values for each pellet can also be displayed as time functions or digitally printed out.

Result

Figure 2 shows the averaged EMG curves of GG1 for the production of [habi:ba] and [habIbba]. It can be seen that the activity of GG1 for [habi:ba] begins to increase approximately 230 msec before the onset of the vowel [i:] and reaches its peak 30 msec before the vowel onset. For [habIbba], the peak value and the duration of the activation of GG1 are less than those for [habi:ba]. A similar tendency is observed for the pair of [haby:ba] vs. [habYbba], except that the peak for [haby:ba] is around 30 msec after the vowel onset as shown in Figure 3.

It was found that the peak GG activity was highest for the vowel [i:] regardless of the difference in the electrode location between GG1 and GG2. Figure 4 compares the averaged EMG curves of both GG1 and GG2 for the pair [habu:ba] and [habUbba]. It is noted that GG1 is inactive for [u:] and [U], while GG2 appears to be active for these utterance types.

Figures 5 and 6 present the relative values of GG activation from the base line activity level to the peak for all the utterance types examined, taking the highest value obtained for [habi:ba] in each electrode location to be 100. As shown in Figure 5, GG1 is generally active for those vowel types which are classified as being in the front group. Activation for long vowels is always more marked than for their short counterparts. Particularly, GG1 is inactive for [ɵ] although the activity for its long counterpart [ʉ:] is relatively high. As mentioned previously, it appears characteristic that GG2 activity is relatively high for the pair[u:] and [U] (Fig. 6).

The time courses of the X and Y coordinates of each pellet for [habi:ba], [haby:ba] and [habu:ba] are shown in Figure 7. It can be seen that the pellets attached to the dorsum and the tip of the tongue (T2 and T3) shift anteriorly for [i:] and [y:] from the preceding prosition for [a], while they move posteriorly for [u:].

Figure 8 shows the pellet positions of T1, T2 and T3, connected with each other, at the moment of the mid-portion of each of the above three vowels. In this figure, the shift of T2 and T3 described above is clearly shown. In order to illustrate the displacement of the tongue pellets from the position for [a] to the other vowel types, the X and Y coordinate values of T1, T2 and T3 at the moment of the mid-portion of each vowel are separately plotted in Figures 9, 10 and 11, respectively.

Comments

It is demonstrated in the present study that GG1, the relatively anterior portion of GG, is always active for the so-called front vowel group, while it is essentially inactive for the back vowels, regardless of the difference between the long and short pairs. It is worth mentioning that GG1 is completely inactive for [ɵ], which is classified as a mid-vowel having a different feature from its long counterpart [ʉ:] (Fant, 1973).

It is interesting that GG2, the more posterior portion of GG, is relatively active for the pair [u:] and [U]. The result of the present study seems to be comparable to that of Miyawaki et al. on the Japanese vowels, in which they found that only the posterior portion of GG was active for the Japanese vowel /u/, although the vowel color for Swedish [u:] or [U] may not be exactly the same as for Japanese /u/.

It was expected in the present study that configurational correlates of tongue activity could be clarified by the x-ray microbeam study. It appears that the degree of GG1 activity for each different vowel roughly corresponds to the degree of fronting in terms of T2 and T3 displacement from the position of the preceding vowel [a].

It has been reported that GG is active for fronting as well as for bunching gestures. In the present experiment, however, the component of bunching is not clearly demonstrated, since the position of T2 pellet appears to be somewhat too posterior to the point on the dorsum of the tongue which should become highest for the [i:] gesture and, as a result, the component of bunching or elevation is hardly demonstrated but the fronting component is manifest.

As for the configurational correlates for GG2 activity, it appears that "fronting" component of T1 (the pellet in the vallecula) must be taken into consideration. As shown in Figure 9, T1 is located most posteriorly for [a] and its fronting is apparently more marked not only for front vowels but also for [u:] than for [ɑ:] and [o:] pairs. Although there is no definite correspondence between the exact degree of fronting of T1 and that of GG2 activity, the relatively high activity for [u:] can be explained by tongue root advencement which is more manifest when compared to the other back vowels such as [ɑ:], [o:] and their short counterparts.

Figure 12 shows the relationship between forward displacement of the tongue pellets and the relative values of EMG activation. It is confirmed in this figure that there is a high correlation between GG1 activation and forward displacement of the pellet T2, which is attached to the dorsum of the tongue, and between the GG2 activation and forward displacement of the vallecular pellet, T1. It is also seen in this figure that the long and short groups are clearly separated, and that, in long vowel group, the displacement is rathr small relative to the level of EMG activation.

Figure 13 compares the time courses of X and Y coordinates of the tongue dorsum and lip pellets for long [y:] and short [Y]. There is no apparent difference in the velocity of tongue pellet for vowel articulation between the long and short pair. However, the tongue has to maintain the articulatory position longer for the long vowel than for the short counterpart. The apparently higher EMG activity for long vowels might be related, at least in part, to the maintenance of articulatory position, although further study must be needed for more comprehensive physiological description of tongue movements. Simultaneous recordings of EMG and pellett tracking by menas of x-ray microbeam system are under way and this combined approach is expected to give important information for better understanding of articulatory dynamics.

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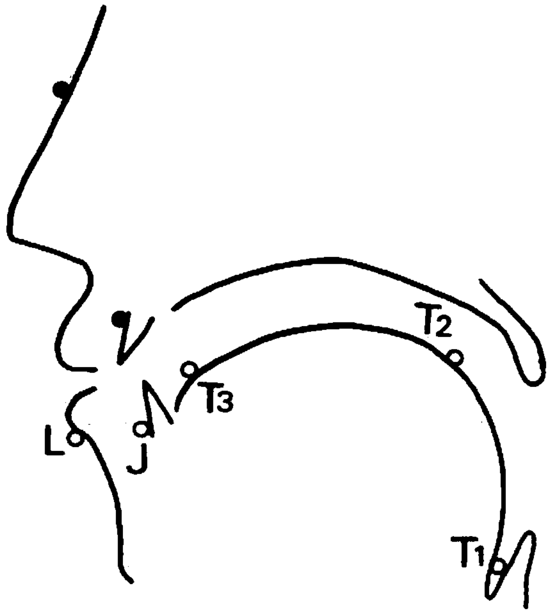

Fig. 1: Positionings of lead pellets
in the X-ray microbeam study.

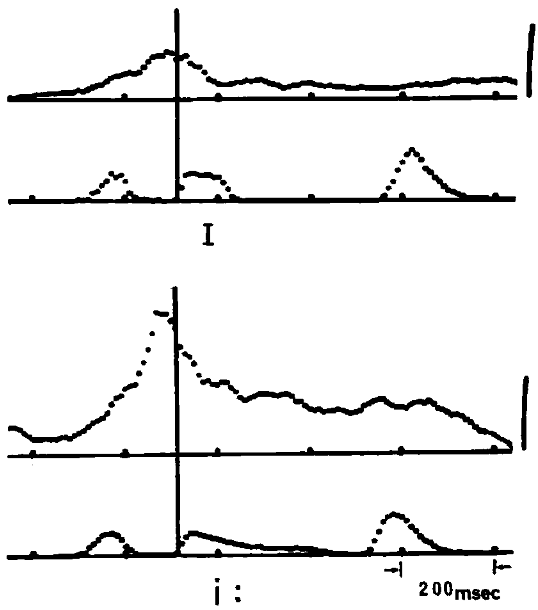

Fig. 2: Averaged EMG curves of GG1 for the test words [habIbba] (above) and [habi:ba] (below). Cal. : 100 μV

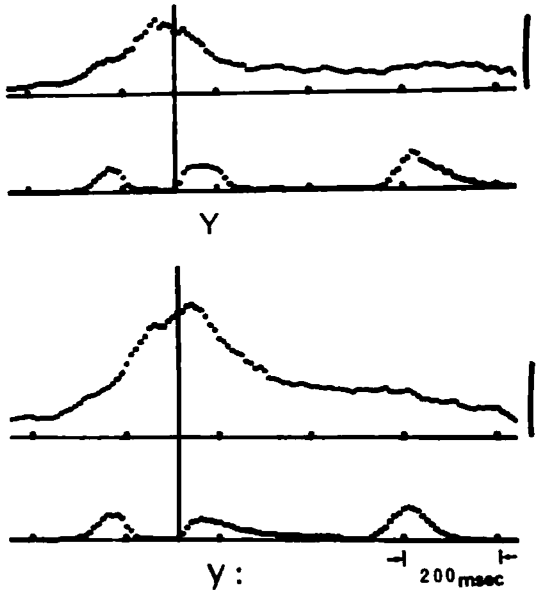

Fig. 3: Averaged EMG curves of GG1 for the test words [habYbba] (above) and [haby:ba] (below). Cal.: 100 μV

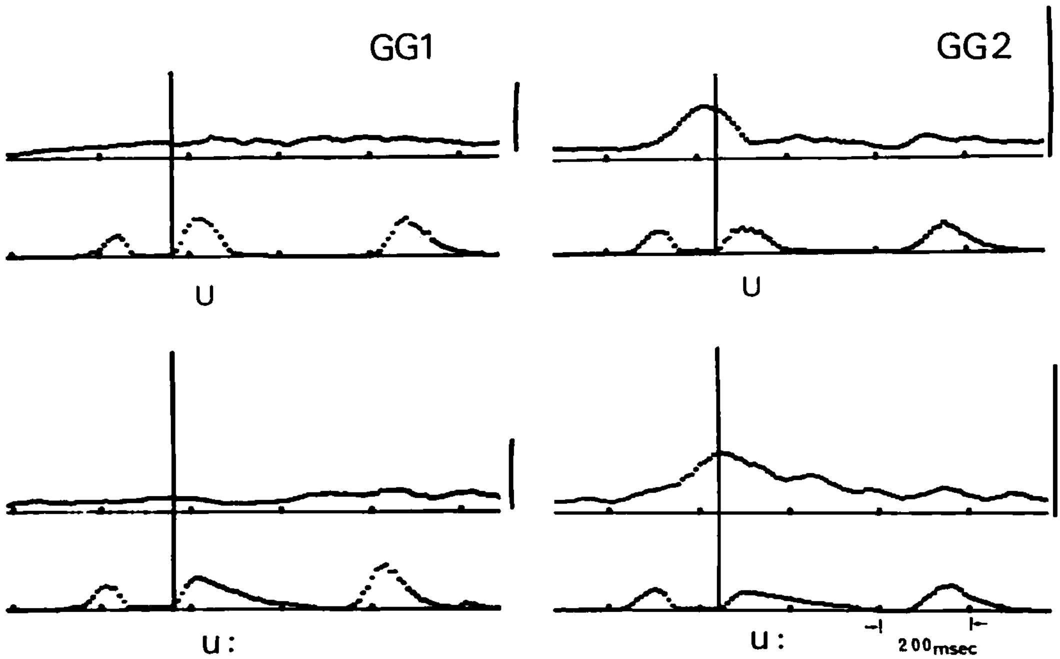

Fig. 4: Averaged EMG curves of GG1 (left) and GG2 (right) for [habubba] (above) and [habʊ:ba] (below) Cal. : 100 μV for GG1 and and 50 μV for GG2.

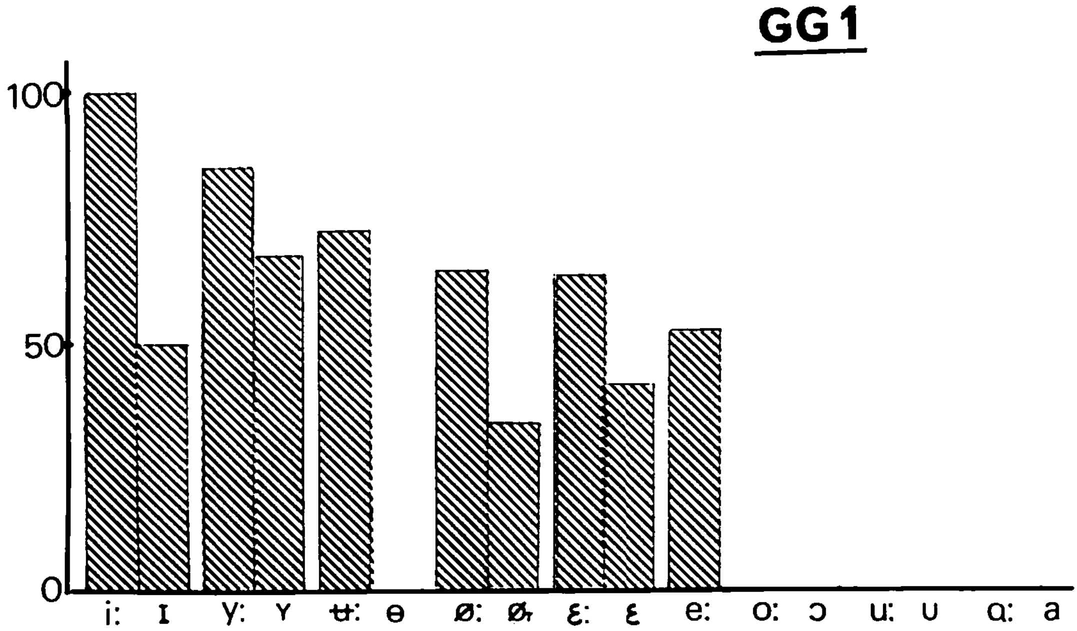

Fig. 5: Relative values of activation of GG1 for each vowel, taking the value for [i:] from the base line activity as 100.

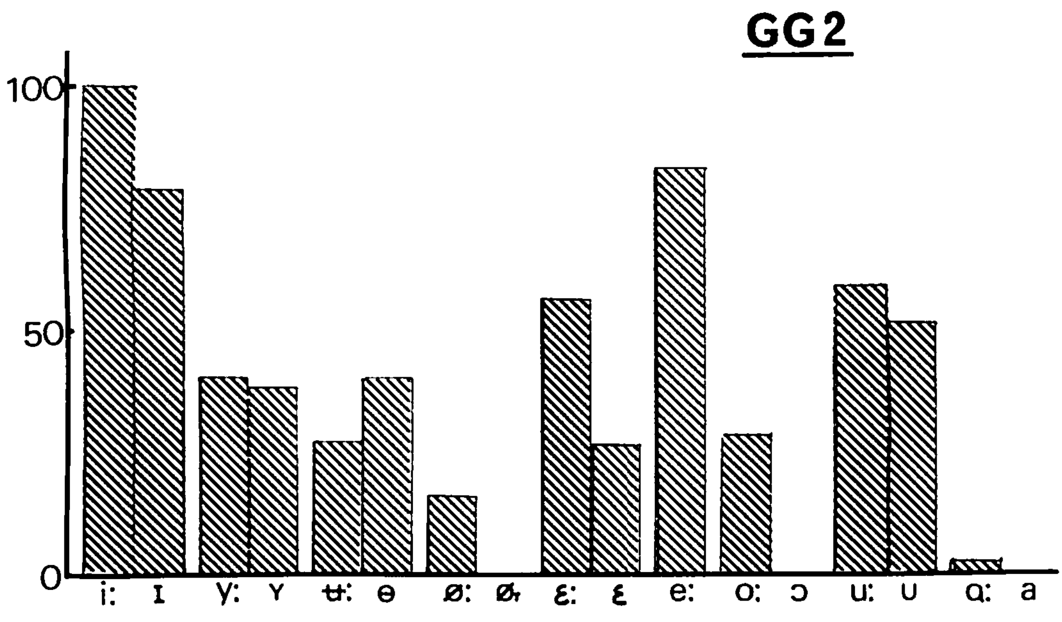

Fig. 6· Relative values of activation of GG2 for each vowel, taking the value for [i:] from the base line activity as 100.

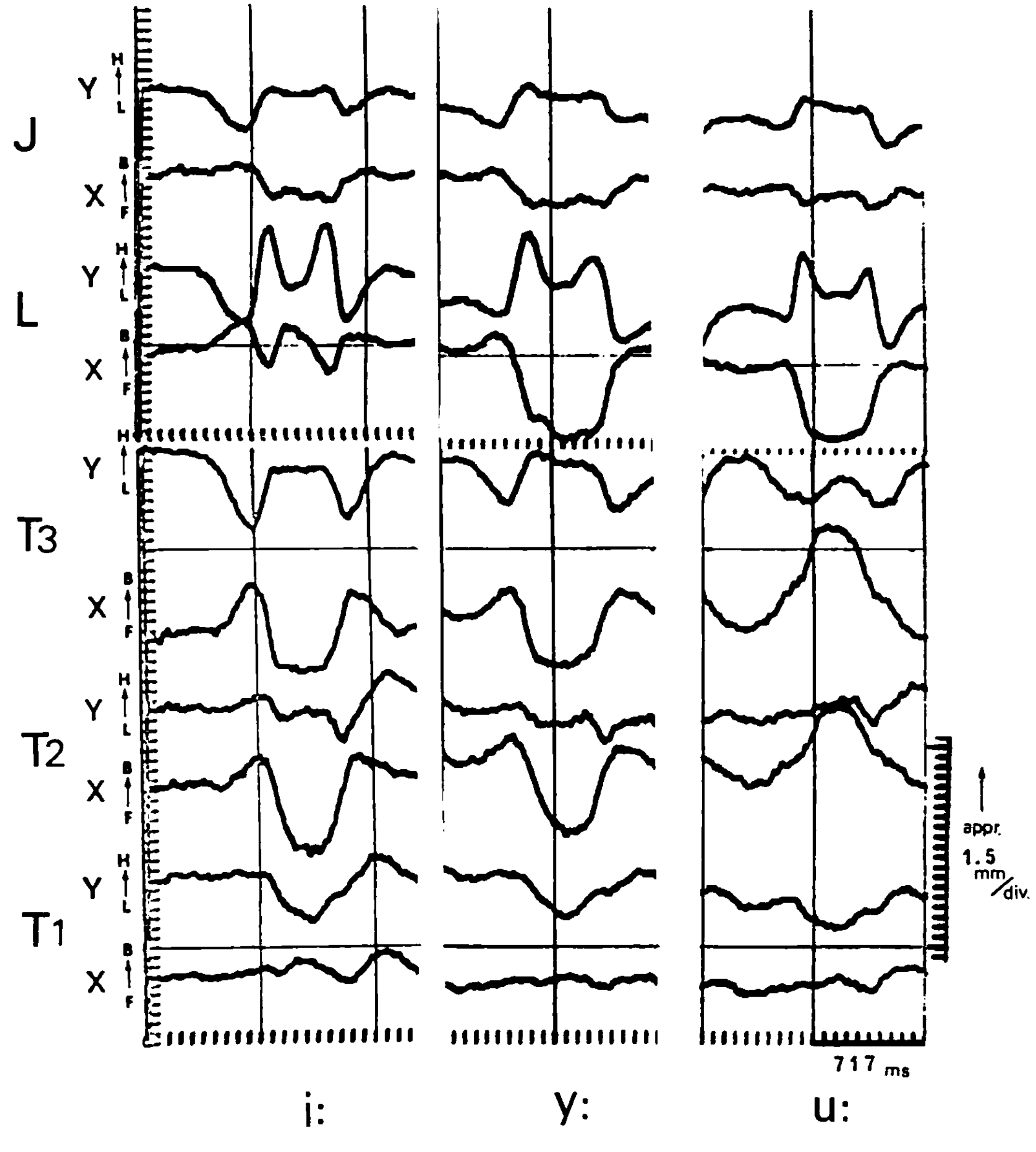

Fig. 7: Time courses of X and Y coordinates of the pellets for [habi:ba], [haby:ba], and [habu:ba].

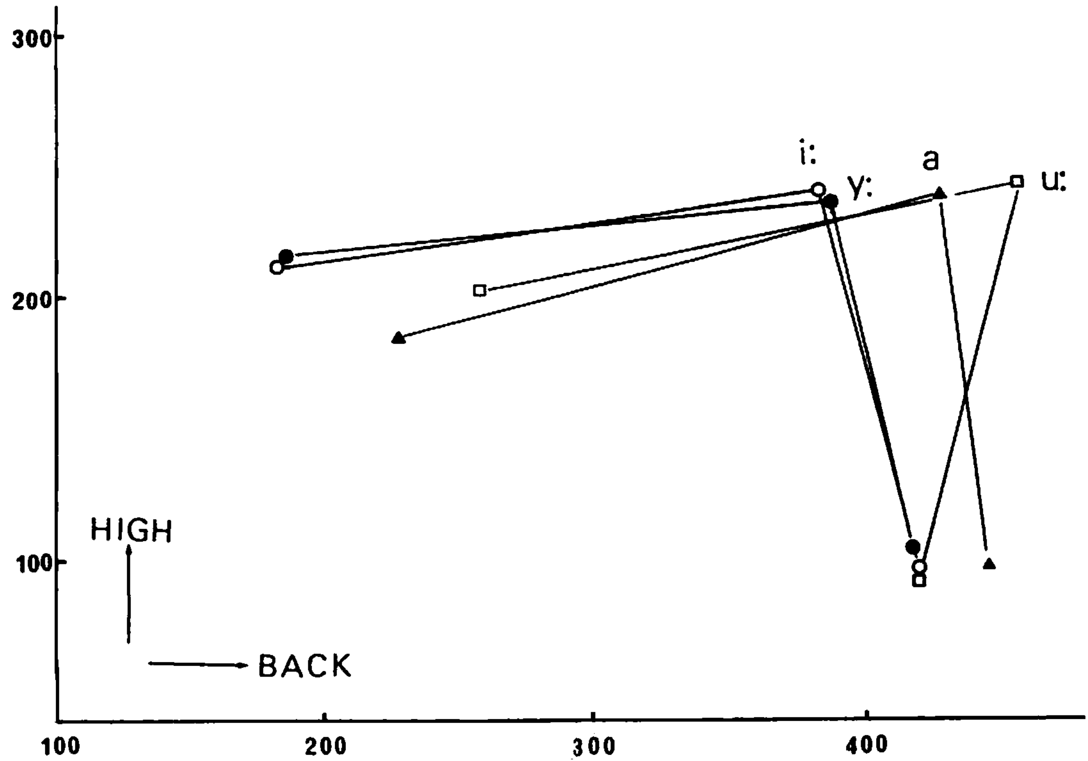

Fig. 8: Tongue configurations represented by connecting T1, T2 and T3, for [hababba], [habi:ba], [haby:ba], and [habu:ba].

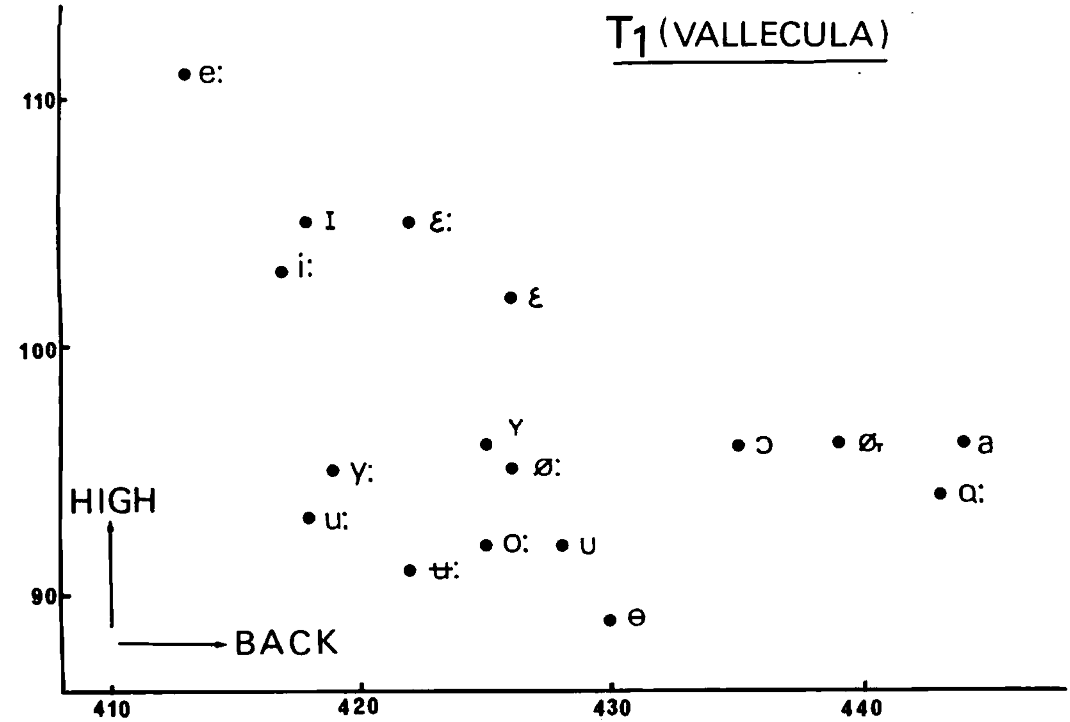

Fig. 9: Locations of T1 pellet for each vowel on the X-Y coordinates. (One coordinate value on each axis is approximately 0. 26 mm.)

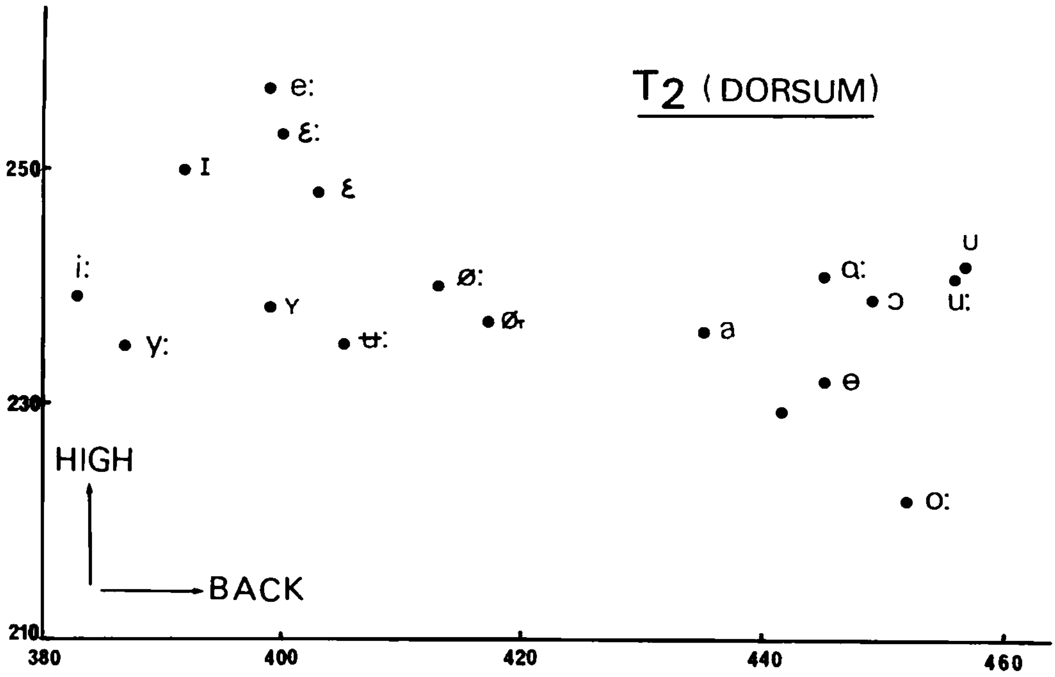

Fig. 10: Locations of T2 pellet for each vowel on the X-Y coordinates.
(One coordinate value on each axis is approximately 0. 26 mm.)

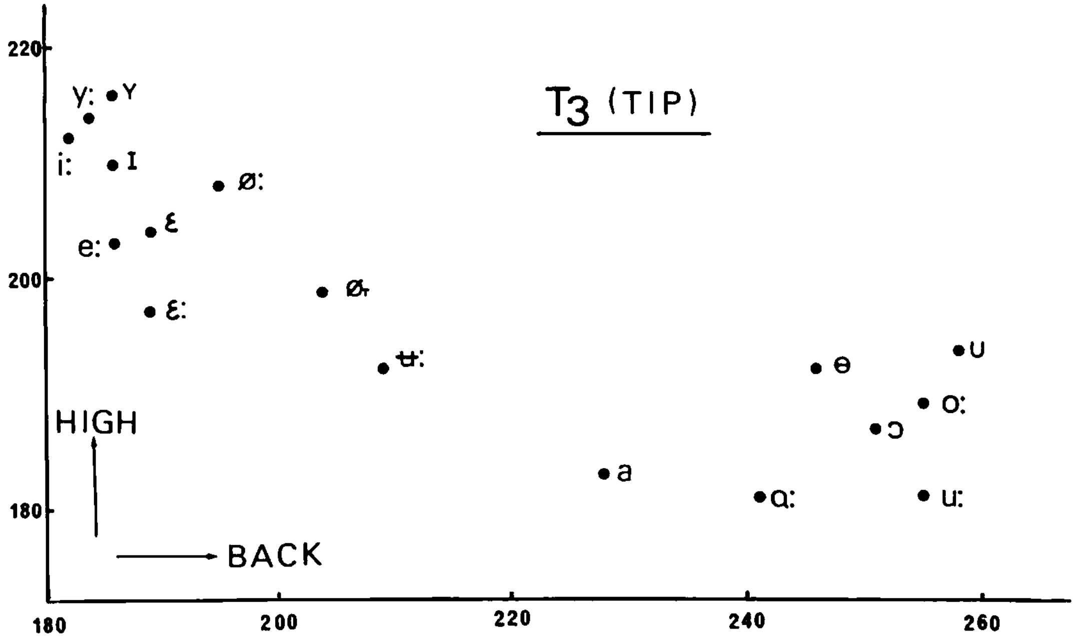

Fig. 11: Locations of T3 pellet for each vowel on the X-Y coordinates.
(One coordinate value on each axis is approximately 0.26 mm.)

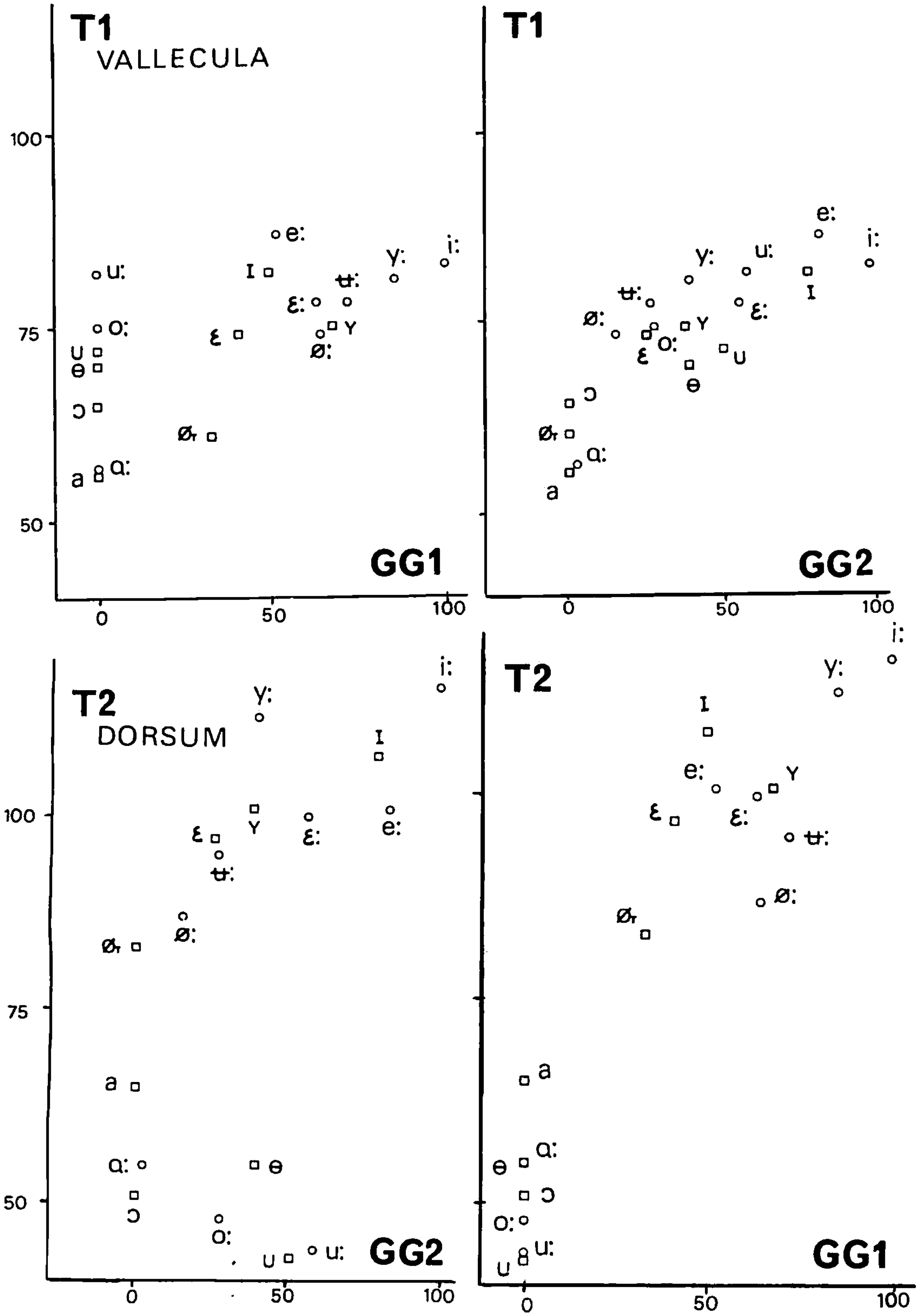

Figure 12: Relationship between forward displacement of the tongue pellets and the relative values of EMG activation.

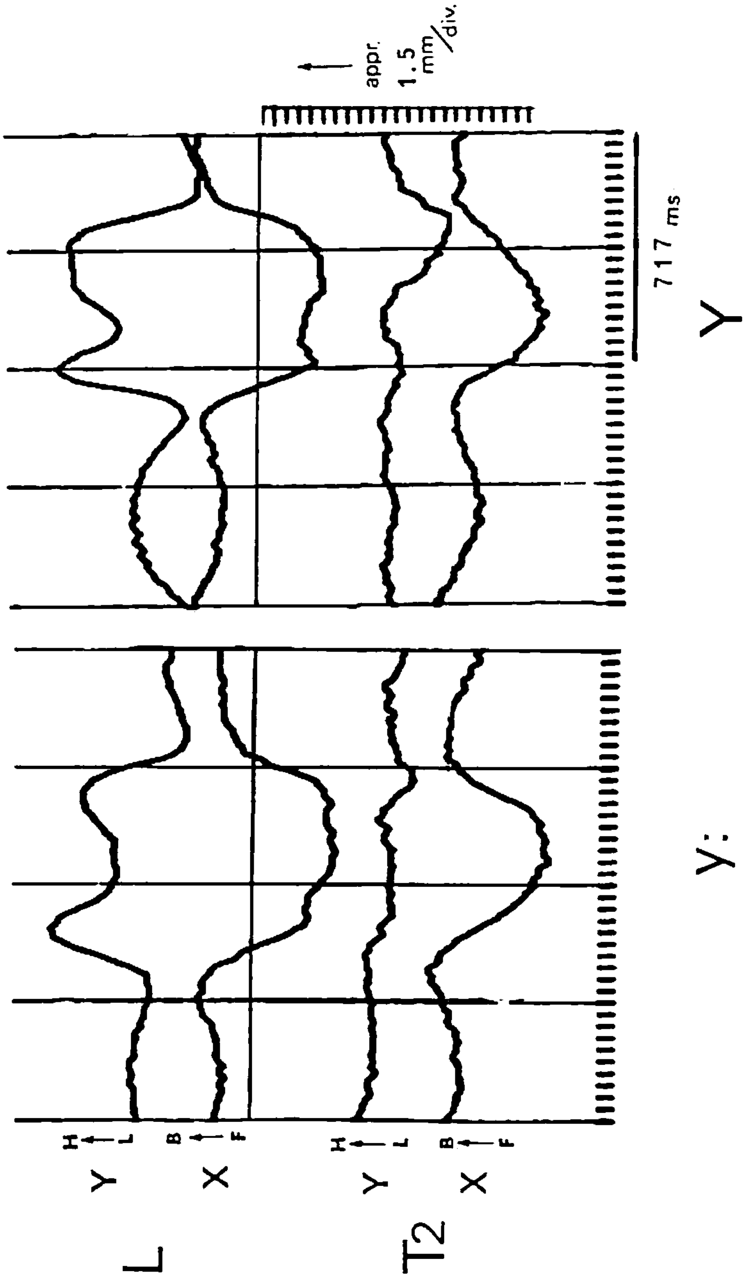

Figure 13: Time courses of X and Y coordinates of the pellets on the tongue dorsum (T2) and lip (L) for long [y:] and short [Y].

(Refer to EMG patterns in Fig. 3)

* This paper was presented at the 9th ICA meeting in Madrid, Spain, 1977.