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A PRELIMINARY REPORT ON THE ELECTROMYOGRAPHIC STUDY OF THE ACTIVITY OF LINGUAL MUSCLES. [1]

Kuniko Miyawaki, Hajime Hirose, Tatsujiro Ushijima, and Masayuki Sawashima

Abstract: The activity patterns of tongue and other related muscles, both during speech and non-speech gestures, were investigated by means of electromyography. [2] Specifically in speech production, the electromyographic signals obtained simultaneously from five different locations of the genioglossus muscle differed characteristically in their activity patterns. These differences in activity patterns were interpreted to be in correlation with differences in tongue configurations during various articulatory gestures. Some neurophysiological implications are also discussed in relation to the results of the electromyography.

0. Introduction.

Based on the anatomical knowledge of the musculature of the tongue, such as was reported on in the previous issue of the Annual Bulletin (Miyawaki, 1974), the activity patterns of lingual muscles and other suprahyoid muscles that are related to tongue gestures were investigated by use of electromyography (EMG). The results presented below pertain to one subject, a native speaker of Japanese (the Tokyo dialect), who sat for three experimental sessions (Experiments I, II, and III). The data were obtained by use of an EMG data collection and processing system at Haskins Laboratories. A detailed technical description of the system is given in Kewley-Port (1973, 1974). The EMG signals were recorded by use of bipolar hooked-wire electrodes, simultaneously with sound signals. The use and insertion of wire electrodes are discussed in Hirose (1971). In the present experiment, a peroral approach to the genioglossus muscle through the floor of the mouth was employed in addition to the conventional percutaneous route.

The paper is divided into two parts. The first part (I) gives a brief overall description of the activity of various articulatory muscles both during speech and non-speech gestures. The second part (II) deals specifically with the activity of the genioglossus muscle, and the results are then discussed in the light of some neurophysiological considerations.

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1) An extended version of a paper presented at a Meeting of the Physiological Society of Japan, April 1975.

2) The electromyographic experiments were conducted at Haskins Laboratories, U. S. A., partly supported by Grant No. DE-01774 from the National Institute of Dental Research, National Institutes of Health.

I. Experiments I and II.

I. 1. Non-speech gestures and isolated speech gestures.

Table 1 presents the EMG activity of selected lingual and suprahyoid muscles for various tongue gestures recorded in Experiments I and II.

muscle / gesture	Experiment I								Experiment II							
	AD	SG#	GH1	GH2	GG1	GG2&	TV#	SL&	AD1	AD2#&	SG#	GG1	GG2	GG3&	TV#	SL&
1 breathing in	0	0	0	0	0	1	0	0								
2 " out	0	0	0	0	0	@	0	0								
3 jaw opening	3	0	2	2	0	@	0	0	3	2	0	0		0	0	0
4 jaw closing	0	0	0	0	@	@	1	@	0	0	0	@		0	1	1
5 tongue retraction	0	0	@	0	@	0	0	0	0	0	1	0	0	@	0	@
6 repositioning	0	0	@	0	0	1	0	0	0	0	0	@	1	0	1	1
7 taking in water	2	0→@	1	1	0	0	@	1								
8 keeping water in mouth	@	0	@	0	0	0	0	1								
9 swallowing water: a*	0	1	1→0	1	2	@	1	2								
" b*	0	0	3	3	0	1	@	2								
10 swallowing saliva: a*	1	@	1	2	3	0	1	2								
" b*	@	0	3	3	0	1	@	1								
11 tongue protrusion	2	1	1	1	1	1	4	4	3	1	2	1			3	3
12 tongue ventroflexion	3	1	2	2	2	2	2	2	3	2	2	@		0	2	3
13 /k/-like gesture									@	1	@	1	2	@	3	2
14 repositioning									0	0	0	0	1	0	1	0
15 /θ/-like gesture	2	0	1	1	@	1	2	1								
16 /s/-like gesture	0	0	0	0	@	1	1	1								
17 /ʃ/-like gesture	0	0	0	@	@	1	1	@								
18 /t/-like gesture	0	0	@	1	1	2	2	1								
19 /a/	1	0	1	1	0	1	1	0	1	1	1	0	0	@	0	2
20 /i/	0	0	@	@	1	2	@	0	0	0	@	@	1	1	0	@
21 /u/	0	0	@	@	0	2	0	0	0	@	@	0	1	0	@	@
22 /e/	0	0	1	@	0	1	0	0	@	0	@	@	1	0	@	@
23 /o/	0	0	1	1	0	1	1	1	0	@	1	0	0	0	1	2

#: noisy channel. &: possibility of contamination with other muscle activities. 0: no activity. @: very low activity. 1-4: four degrees of activity determined arbitrarily for each channel (low to high). blank: lack of data. a*: getting ready. b* sending water/saliva into lower pharynx.

Table 1 EMG activity of lingual and suprahyoid muscles for various tongue gestures.

The gestures were repeated two or three times each with a 1-2 second interval in between. The EMG signals did not show any significant variability among different samples of an identical gesture.

The EMG signals were obtained from the following muscles: the anterior belly of the digastric muscle (x3), the geniohyoid muscle (x2), the styloglossus muscle (x2), the genioglossus muscle (x5), the transverse and vertical muscle complex (x2), and the superior longitudinal muscle (x2). Among these 16 channels, some were noisy (#), and some showed signs of possible contamination with other muscle activities (&). A zero indicates an absence of activity, '@' very low activity, and 'blank' a lack of data. The numbers 1 through 4 stand for the EMG activity in four degrees (low to high) arbitrarily determined for each channel by inspection of the raw EMG traces. (Inter-channel comparisons are, therefore, not possible.) The activity of each of the above-mentioned muscles may be summarised as follows:

Anterior belly of the digastric muscle (AD): This muscle is clearly related to jaw opening. Thus, it is active in gestures such as tongue protrusion and ventroflexion, that naturally involve opening of the jaw. In Experiment II, the channel identified as AD_2 shows some activity for the bunching of the tongue in a /k/-like gesture, suggesting a possible contamination with the mylohyoid muscle.

Geniohyoid muscle (GH): This muscle shows, on the one hand, activity for jaw opening and, on the other, activity for tongue bunching as in swallowing. It also shows activity in relation to a /t/-like gesture where the tongue tip is pressed against the hard palate.

Styloglossus muscle (SG): This muscle shows activity e. g. tongue protrusion (Exp. I, II) and tongue retraction (Exp. II). However, since both SG channels indicate signs of artefact it is hard to draw a definite conclusion about the activity pattern of this muscle.

Genioglossus muscle (GG): This muscle is active in bunching of the tongue and in tongue protrusion. It is involved, along with other superhyoid muscles, in swallowing and in /i/- and /k/-like gestures. Also, it shows activity, along with the intrinsic lingual muscles as well as some other muscles, for /θ/-, /s/-, and /t/-like gestures where the tongue tip has to make a constriction or a closure in the anterior part of the oral cavity. The channel identified as GG_2 in Exp. I shows some activity for /a/; it may possibly be contaminated with GH.

Transverse-vertical muscle complex (TV) and superior longitudinal muscle (SL): These muscles are active in tongue protrusion and in /θ/ /s/-, and /t/-like gestures where the tongue tip plays an important part. TV and SL in Exp. II show activity for the return movements of the tongue to its original position after tongue retraction and /k/-like gesture. In both experiments the EMG signals for TV and SL show signs either of some artefact or of possible contamination, and a precise interpretation of the EMG signals is difficult.

I. 2. Consonants.

In Experiments I and II the EMG data for the production of selected Japanese consonants were also obtained. The consonants were embedded in various $/V_1\_V_2/$ environments and were produced in a random order in a carrier sentence /kono ___ noatodesu/('(It) is after this ___.'). No accent kernel was placed on the nonsense syllables to be embedded in the carrier sentence. There were 12 to 15 utterance samples for each of the $/V_1CV_2/$ utterance types. The raw EMG signals were full-wave rectified, integrated, and were then averaged over different samples of each utterance type with reference to a line-up point, i. e. implosion of the first /n/

in the carrier sentence. In the present report we will be concerned only with /aCa/ sequences, where /C/ = /k/, /s/, /t/, /n/, or /r/. Fig. 1 presents the averaged EMG curves of the utterance /konoatanoatodesu/.

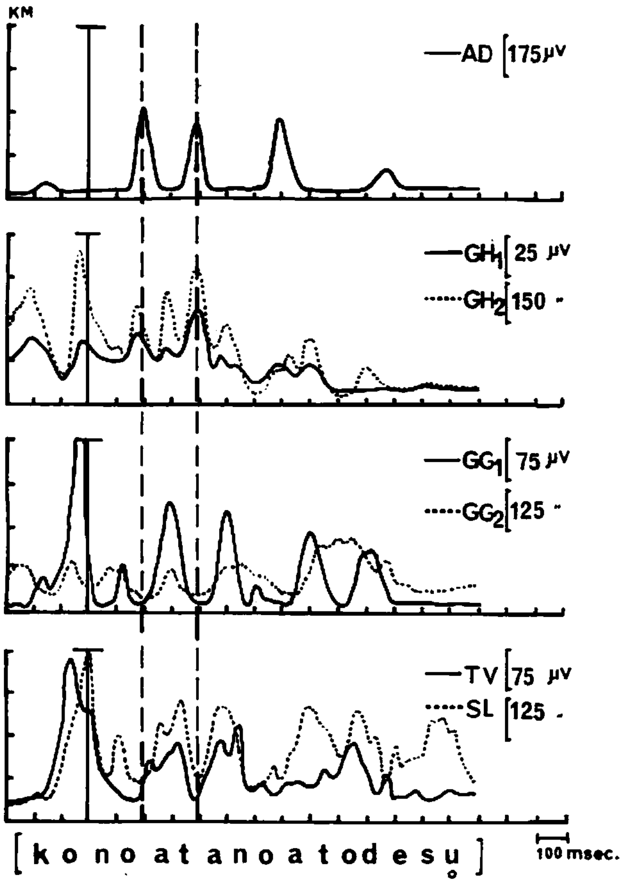

Fig. 1 Averaged EMG curves for the utterance /konoatanoatodesu/.

The two vertical broken lines correspond to the time points where the EMG curve for AD shows activity peaks for the vowel /a/ preceding and following /t/. The pattern of activity of each muscle for the consonant /t/ is expected to be observable between these two broken lines. The geniohyoid muscle (GH 1 and 2) shows activity peaks for jaw opening, on one hand, and in relation to tongue-tip gestures, on the other. The genioglossus muscle (GG 1 and 2) shows a distinct peak for /t/ and is interpreted to be active for positioning the tongue anteriorly in tongue-tip articulation. It is interesting to note that the two genioglossus curves reveal a noticeable difference with respect to /k/, /t/, and /d/ of the carrier sentence. The difference is due, presumably, to the difference in location of the electrodes in the same muscle. Both the transverse-vertical muscle complex (TV) and the superior longitudinal muscle (SL) show activity for /t/ with two little peaks at the beginning and the end. The activity peaks of the geniohyoid and the genioglossus muscles are found between these two little peaks of TV and SL. This would indicate that a tongue-tip gesture for the production of /t/ is a result of the complex coordination of a number of lingual and suprahyoid muscles.

Fig. 2 and Table 2 summarise the peak EMG activity values for the consonants /k/, /s/, /t/, /n/, and /r/ in the environment /a_a/. The data for /r/ is available only for Exp. II. The values were read from EMG curves such as were shown in Fig. 1. The activity of the genioglossus muscle increases in the order of /k/, /s/, /t/, /n/ while the activity of the geniohyoid muscle decreases in that order.[3] The intrinsic lingual muscles SL and TV demonstrate a tendency similar to that of the genioglossus muscle. When we compare /r/ with /t/ and /n/, in Experiment II, the

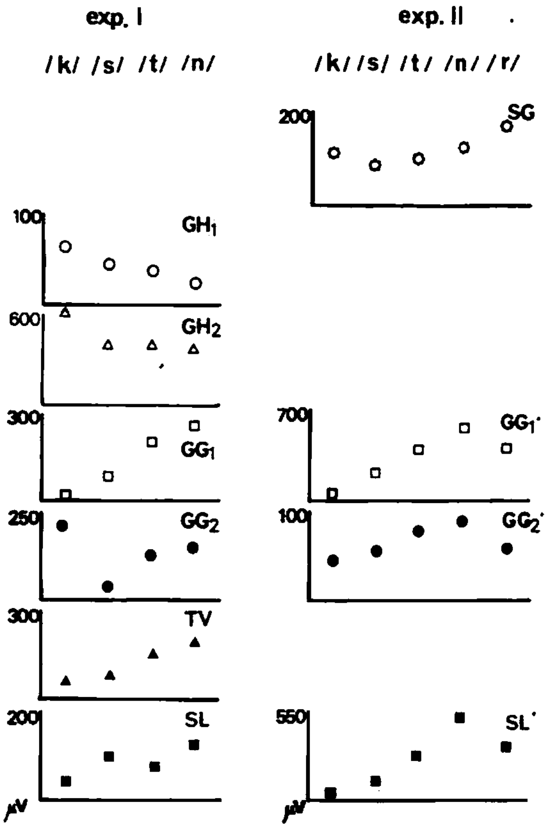

Fig. 2 EMG activity of lingual and other muscles for various consonants in the context /a __ a/.

Experiment I	/k/	/s/	/t/	/n/
GH_1	58	44	33	21
GH_2	600	398	390	375
GG_1	4	72	199	244
GG_2	213	44	125	138
TV	53	60	139	176
SL	45	99	71	103

Experiment II	/k/	/s/	/t/	/n/	/r/
SG	110	83	93	115	158
GG_1'	79	193	385	578	379
GG_2'	45	50	78	88	55
SL	41	124	275	523	330

μV

Table 2 EMG activity values (μV) of lingual and other muscles for various consonants in the context /a __ a/.

3) GG_2 of Experiment I shows an exceptionally high activity value for /k/, suggesting a possible contamination with GH.

genioglossus muscle and the superior longitudinal muscle show the highest activity for /n/ followed by /t/ or /r/ while the styloglossus muscle - the contraction of which would cause the tongue to be pulled up and backward - shows the highest activity for /r/. This is in accord with the fact that in Japanese, the place of articulation for /r/ is characteristically posterior to that of /t/ or /n/ (Miyawaki et al., 1975).

II. Experiment III.

II. 1. EMG activity patterns of the genioglossus muscle in the production of vowels.

In Experiment III, five pairs of electrodes were placed in different portions of the genioglossus muscle [4] and the EMG activity was recorded simultaneously from these locations (GG1 - GG5) during the production of various $/V_1V_2/$ sequences (Table 3) embedded in a carrier sentence

		ai	oi	ui
				ue
ia			oa	ua
io		ao		uo
iu	eu	au	ou	

Table 3 List of nonsense $/V_1V_2/$ sequences that served as speech materials in Exp. III. (Carrier sentence = /kono __ onokosimasu/ ('We keep this __.'))

/kono ___ onokosimasu/ ('We keep this ___.'). Fig. 3 and Fig. 4 show the averaged EMG curves for the production of /konoV_1V_2onokosimasu/, where $/V_1V_2/$ are /ia/ and /ai/. The number of utterance samples for each of the $/V_1V_2/$ utterance types is 12. The comparison of the portion of the curves that corresponds to the $/V_1V_2/$ sequence shows that every GG location demonstrates distinct activity for /i/ but hardly any for /a/. Fig. 4 similarly compares the vowel sequences /eu/ and /ue/. Some of the GG locations are active specifically for /e/ (GG1, 2), while some are active specifically for /u/ (GG4, 5), and the remaining active for both (GG3). Furthermore, the locations that show prominent activity for /e/ also show activity for /n/ while those that are comparatively inactive for /e/ are also inactive for /n/. Similarly, the locations that show activity for /u/ also show slight activity for /k/. In short, Figs. 3 and 4 demonstrate that different portions of the genioglossus muscle manifest different EMG activity patterns depending on the tongue configuration for different articulatory gestures.

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4) The details of the insertion and placement of the electrodes will be discussed later in II. 2.

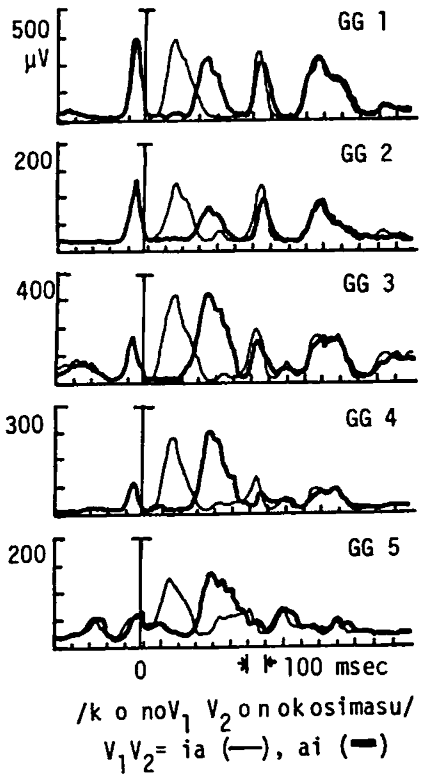

Fig. 3 Averaged EMG curves of /konoV$_1$V$_2$onokosimasu/ where V$_1$V$_2$=ia, ai.

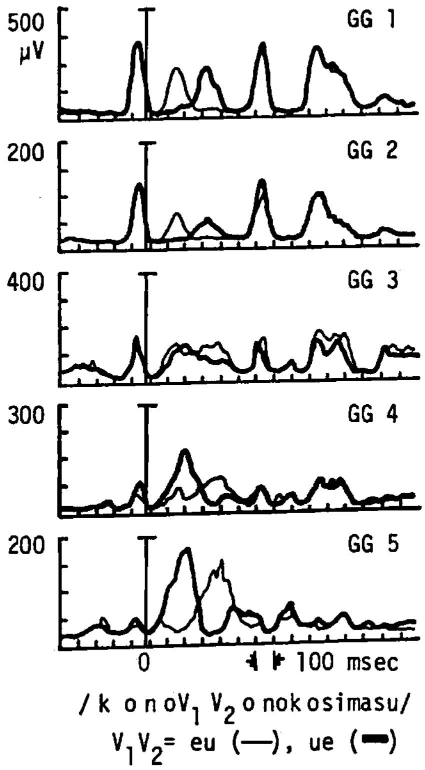

Fig. 4 Averaged EMG curves of /konoV$_1$V$_2$onokosimasu/ where V$_1$V$_2$=eu, ue.

To further examine the EMG activity of GG1 through GG5 for the five vowels, the activity values corresponding to vowels in various environments, e. g. /a/ in the environment /o__i/ and /i/ in the environment /a__o/ of the utterance /konoaionokosimasu/, were measured from the averaged EMG curves as were presented in Figs. 3 and 4. The values thus obtained were then averaged over different environments 5) for each of the five vowels and, taking the highest activity value obtained for each electrode location to be 100%, the activity values for GG1-GG5 for the five vowels were plotted as in Fig. 5 (See also Table 4).

5) Since our aim at this stage is to grasp an overall tendency, we are disregarding the finer details of contextual effects.

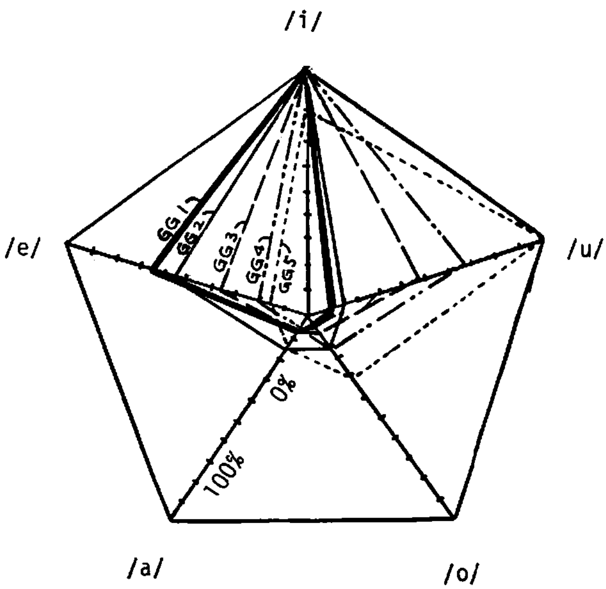

Fig. 5, Table 4
EMG activity for the five Japanese vowels, obtained from five different locations of the genioglossus muscle.

	GG1	GG2	GG3	GG4	GG5
/i/	100	100	100	100	82
/e/	64	53	36	20	15
/a/	8	16	7	5	15
/o/	4	16	7	15	30
/u/	12	16	47	67	100

%

All the GG locations show high activity for /i/ (100% for GG1-GG4 and 82% for GG5), whereas they show very low activity for /a/. GG1-GG4 demonstrate low activity values for /o/ but GG5, which indicates 100% activity for /u/, demonstrates a fair amount of activity for /o/. The activity values for /u/ and /e/ differ according to the electrode location in a systematic manner. The location that shows the greatest activity for /e/ is GG1, followed by GG2, 3, 4, and 5 in that order, whereas the location that shows the greatest activity for /u/ is GG5, followed by GG4, 3, 2, and 1 in that order. In other words, a GG location that manifests prominent activity for /e/ shows very low activity for /u/ and vice versa.

To summarise, 1) the genioglossus muscle is active for those (Japanese) vowels that are characterized by the properties 'high' and/or 'front', i.e., /i/, /e/, and /u/, while it shows only a very low level of activity for the vowels /a/ and /o/, which are neither 'high' nor 'front'; 2) the EMG signals obtained from five different locations of the genioglossus muscle vary characteristically in their activity patterns and these differences are considered to be in correlation with differences in tongue configurations in the production of Japanese vowels.

II. 2. Electrode locations.

So far, we have conveniently been putting aside the question: 'Which of the EMG signals from the five electrode locations (GG1- G5) represents the activity of which anatomical division of the genioglossus muscle?' Although it is impossible to know the absolute locations of the electrodes, we may at least attempt some speculations as to their relative placement, especially when the results presented in Fig. 5 - Table 4 suggest that these five locations are ordered in some systematic way.

When placing the electrodes in the genioglossus muscle in Experiment III, the experimenter tried to aim either at "relatively anterior fibres", i. e., those fibres whose attachment to the symphysis menti are relatively superior and which reach an anterior-to-medial portion of the tongue dorsum, or at "relatively posterior fibres", i. e. those fibres that have a relatively inferior attachment and that course towards a medial-to-posterior portion of the tongue dorsum. In the former case a pair of electrodes was inserted from a point close to the mandible, deep and anteriorly, palpating the tip of the hypodermic needle carrying the electrodes with a finger as shown in the figure (Fig. 6-a). GG1 and 3 are the results of this type of insertion. Another way of aiming at anterior fibres was to insert a needle perorally, keeping the insertion shallow enough to avoid penetrating into the geniohyoid muscle (Fig. 6-b). The insertion of GG2 was performed in this manner. When aiming at relatively posterior fibres, the needle was inserted from a point close to the hyoid bone and the insertion was kept

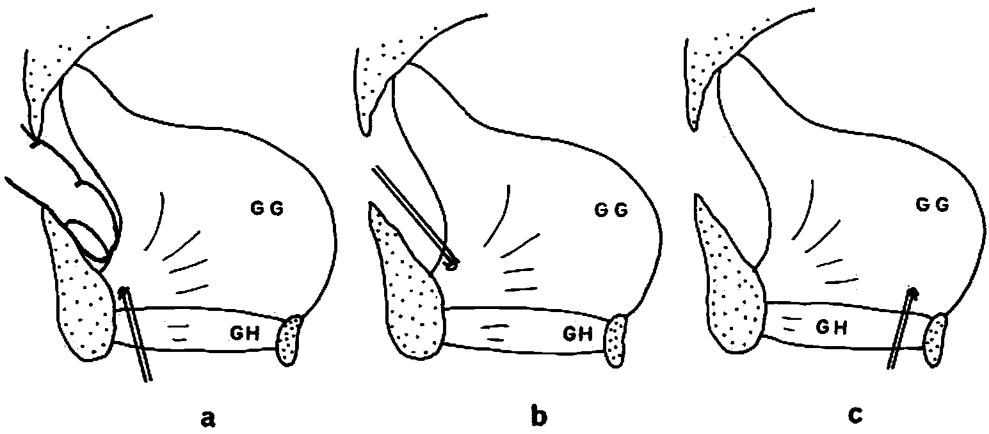

Fig. 6-a,b Insertion of the electrodes in the anterior portion of the genioglossus muscle.
Fig. 6-c Insertion of the electrodes in the posterior portion of the genioglossus muscle.

shallow[6] (Fig. 6-c). This was the case with GG4 and 5.

When we look at the results given in this section in the light of the above information concerning the electrode insertion, we may reasonably say that the electrodes, whose locations we have so far been labelling GG1 through GG5, were placed in "relatively anterior" to "relatively posterior" fibres of the genioglossus muscle in that order. We may then say that the production of /e/ involves the "relatively anterior fibres" whereas the production of /u/ involves the "relatively posterior fibres" and that the contraction of both anterior and posterior fibres results in a "high front" tongue bunching as in the production of /i/.

II. 3. "One muscle" ?

A number of speech scientists have assumed, on an anatomical basis, that the genioglossus muscle consists of at least two functionally distinct groups of fibres: the anterior fibres whose contraction would bunch the posterior portion of the tongue and the posterior fibres whose contraction would bunch the anterior portion of the tongue (Heffner, 1950; Riper and Irwin, 1958; and Zemlin, 1968). Meanwhile, Ladefoged made an attempt to deduce, on the basis of radiology data, the relative force exerted by various lingual muscles in the production of vowels (Ladefoged, 1964). In doing so he assumed that the genioglossus muscle may not function as a whole, i. e., that it may be thought of as 'exerting forces in several directions' (p. 209 Ibid). MacNeilage and Sholes performed an electromyographic study of the tongue in vowel production by use of surface electrodes (MacNeilage and Sholes, 1964). They concluded that the different portions of the genioglossus muscle appear to act selectively for three main purposes: the posterior portion contracting to move the posterior surface of the tongue forward, producing a high front tongue configuration as in e. g. [i] and [e], the intermediate portion contracting to draw the midsection of the tongue toward the jaw as in [ɝ], [ar], and [ør] (their notations), and the anterior portion contracting "to antagonize the back and upward movement of the tongue in the production of [u]" (p. 228, Ibid).

More recently, Smith conducted a series of EMG experiments using hooked-wire electrodes (Smith, 1971). Based on the EMG signals obtained simultaneously from the anterior and posterior portions of the genioglossus muscle, he reported that the former appears to be most active in positioning the tongue near the alveolar ridge for the production of alveolar stops, while the latter is active primarily for pulling the root of the tongue forward, thus "bunching" the tongue for such articulatory gestures as [i], [u], and [k]. Consequently, he states: '... electromyographic evidence indicates that this muscle [m. genioglossus] should properly be considered to be composed of several separate and independent muscles, which may be independently controlled' (p. 12 Ibid).

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6) It has to be shallow but deep enough to avoid leaving the electrode in the geniohyoid muscle. We may safely consider an electrode to be placed in the genioglossus muscle if it shows activity for /i/ but not for /a/ (or for jaw opening): the geniohyoid muscle shows activity for /a/ and for jaw opening.

To return to our findings, the EMG signals obtained simultaneously from five different locations of the genioglossus muscle differed characteristically in their activity patterns. This indicates that the genioglossus muscle consists of a number of components or subdivisions (which in turn consist of a number of neuromuscular units), each of which is theoretically capable of contracting separately, or, in other words, capable of being innervated separately. Our results are, therefore, in agreement with the current general view (and speculations) mentioned above, that the genioglossus muscle is, functionally, not "one muscle". However, we do not know how many subdivisions there are in the genioglossus muscle nor do we know in what manner these subdivisions are voluntarily controlled. [7]

II. 4. Some neurophysiolgoical considerations.

A neuromuscular unit (NMU), a basic physiological unit of muscle contraction, consists of a motor nerve cell, its axonal process and a group of muscle fibres innervated by this motor nerve. [8] The group of muscle fibres that belong to a NMU are not packed in a tight bundle but are scattered diffusely over a relatively wide region called the 'motor unit territory'. Buchthal and his colleagues, employing an electrophysiological method, investigated the motor unit territories in various human limb muscles. According to them, a territory is nearly circular and has an average diameter of 5mm in the normal brachial biceps muscle (Buchthal et al. 1957); in other limb muscles the average diameter of the territory was found to vary between 5mm and 11mm (Buchthal et al. 1959). That the muscle fibres are scattered diffusely within a territory suggests that there is a fairly extensive overlapping of NMU's within a given area. Buchthal and Rosenfalck extimated a possible overlap of 10 - 25 different NMU's in a territory (Buchthal and Rosenfalck, 1973). Brandstater and Lambert, using the anterior tibial muscle of the rat, made a histological examination of the type and spatial arrangement of the muscle fibres belonging to a NMU. They report that the mean area of a motor unit territory measured 6. 6mm^2 (approximately 12% of the total cross sectional area of the muscle) and that an average single motor unit territory would theoretically accommodate nearly 20 motor units (Brandstater and Lambert, 1973). Edström and Kugelberg report the mean area of a motor unit territory of the anterior tibial muscle of the rat to be 17% of the total cross sectional area of that muscle (Edström and Kugelberg, 1968).

A brief survey of the literature reveals that, at present, no such data as given above are available with respect to the human tongue (or that of any

7) Kato and Tanji (1972) carried out an experiment to see if human subjects could voluntarily isolate single motor units in finger muscles. They report that 209 out of 286 motor units (73. 0%) could be isolated voluntarily within 30 minutes, on command from the experimenter.

8) The number of muscle fibres innervated by a single nerve fibre, or the innervation ratio, varies from muscle to muscle. (See, for example, Basmajian, 1962.) Generally speaking, the innervation ratio is lower in muscles that are involved in movements that require a fine control. So far, no one seems to have examined the innervation ratio in the muscles of the tongue.

animal for that matter). We can only assume the following points about the structure of the NMU and the motor unit territory in the muscles of the tongue.

A1) A number of muscle fibres belong to a single NMU.
A2) The muscle fibres of a NMU are scattered diffusely over a relatively wide region, or a 'motor unit territory'.
A3) There is a considerable amount of overlapping of the territories.

The questions that arise from these assumptions and invite answers in the future are:

Q1) How many muscle fibres belong to a single NMU in the muscles of the tongue? (What is the innervation ratio of various tongue muscles?)
Q2) What is the size of the territory in various tongue muscles?
Q3) How densely do the territories overlap with each other? (How many NMU's can theoretically be accommodated in a given area?)
Q3') In what manner do the territories overlap? Is the overlap 'continuous' as in Fig. 7-a, or is it more or less discrete as in Fig. 7-b?

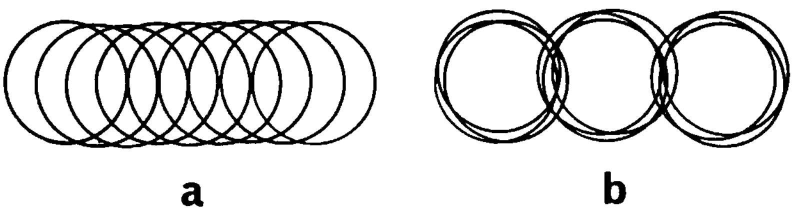

Fig. 7 Schematic drawing of two possible types of territory overlap. Each circle represents a territory.

An interesting piece of information is provided by Shimazu with respect to the last question (Shimazu, 1959). He investigated the spatial properties of the territories in the human anterior tibial muscle and found that the territories were confined either to the lateral or to the medial half of the muscle, i. e., no territory straddled across the two halves of the muscle. He suggests that each half of the anterior tibial muscle, which is considered anatomically as one muscle, may well receive a separate motor control.

A tentative experiment has been conducted by the authors to see if the stimulation of the distal twigs of the hypoglossal nerve that supplies the genioglossus muscle would cause <u>localized</u> contractions of limited portions of this muscle.

A dog weighing approximately 10 kgs. was anaesthetized first by an intramuscular injection of a dose of Ketaral 50 (0. 2cc per kg. body weight) and was then given an intravenous injection of Nembutal (10 mg. per kg.

body weight). An additional dose of Nembutal was given intravenously several times during the experiment in order to maintain a stable condition in the animal.

The hypoglossal nerve trunk was dissected at a point where it curves anteriorly along the lateral surface of the hyoglossus muscle and was followed distally, observing its branches to various lingual muscles. Among the twigs that supply the genioglossus muscle, four fairly thick ones, apparently supplying the medio-posterior fibres of the genio glossus muscle, were identified visually and were carefully isolated from the surrounding tissues (Fig. 8). The nerve trunk was kept intact. Each of the twigs was then

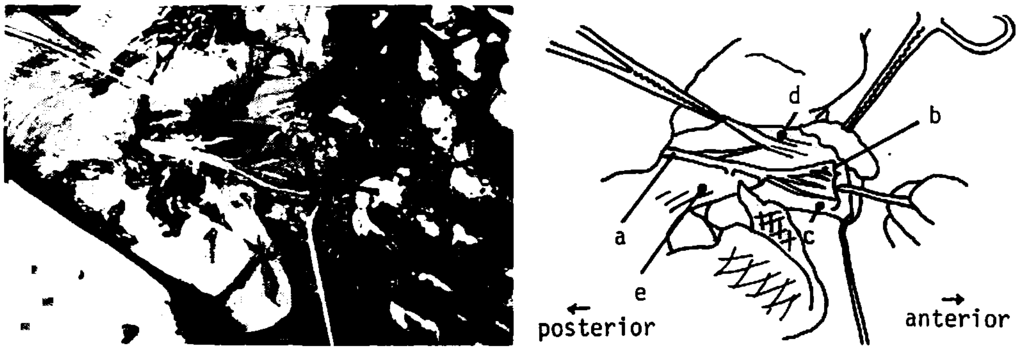

Fig. 8 The four twigs of the hypoglossal nerve supplying the medio-posterior fibres of the genioglossus muscle.
a) hypoglossal nerve trunk; b) the four twigs; c) genioglossus muscle; d) styloglossus muscle; e) hyoglossus muscle

stimulated individually. A train of square wave electrical stimuli (0.3 msec in duration and 50 p. p. s. in frequency) was given for 0.5 sec at an interval of 2 sec. through bipolar silver electrodes. The intensity of the stimulation was kept just above the threshold that elicited a visible contraction of the muscle fibres.

It was observed that the stimulation of a twig causes a distinctly localized contraction of a limited portion of the genioglossus muscle, i. e., the portion that is apparently supplied by the twig that is being stimulated.

Although this observation was made on the tongue of a dog, employing an artificial stimulation, and is of a rudimentary nature, it may be considered to provide indirect support for the observed fact that the EMG signals obtained simultaneously from five different locations of the genioglossus muscle differed characteristically in their activity patterns, and consequently for the interpretation that the genioglossus muscle consists of a number of components or subdivisions which are capable of contracting separately.

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