

Oral feedback

II. An electromyographic study of speech under nerve-block anesthesia

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Abstract:

Electromyographic recordings were made from the lip, tongue, and certain suprahyoid muscles of three normal adult speakers under normal conditions and under conditions of trigeminal nerve block anesthesia. The mylohyoid muscle and the anterior digastric muscles which are innervated by motor fibers from the blocked nerve were usually depressed or inactive during the nerve-block condition. The assumption that the effects of this traditionally used nerve block are purely sensory seems unfounded. Other muscles are either depressed in activity during the block or more active than normal during the block. The amplitude of EMG recording depends upon depth and symmetry of anesthesia and upon the idiosyncratic reaction of the subject. Changes in muscle activity during the nerve block extend even to those muscles whose sensory and motor innervations cannot be affected by the block. Therefore, the effects observed indicate a more central effect or some compensatory reorganization.

A series of recent studies dealt with the subject of the role of tactile feedback in speech using nerve block techniques. It was found that bilateral mandibular and infraorbital injections of anesthesia increased the number of judged errors in articulation of adult speakers (McCroskey, 1958; Ringel & Steer, 1963). The speech distortions were found to be subtle and were most evident in the production of fricatives and affricatives (Scott, 1970; Borden, 1971; Gammon, Smith, Daniloff, & Kim, 1971). It was assumed by the investigators that the speech effect was primarily due to decreased sensory feedback as a result of blocking oral sensation from the tongue via the lingual nerve. A phonetic analysis (Part I) of the speech effect under anesthesia revealed factors which prompted further investigation, particularly the predominance of articulatory distortions among the sibilants and affricates, especially /s/ in consonant clusters, in those subjects who were affected (Borden, 1971). It was decided to study electromyographically the contraction of some of the muscles thought to be implicated in lingual movement under conditions of nerve block and under normal conditions.

Two separate electromyographic (EMG) experiments were conducted in an attempt to find out what happens to certain suprahyoid and tongue muscles as subjects speak under conditions of trigeminal nerve block.

First Electromyographic Study

Since the nerve block seemed to produce an /s/ effect, the anatomy of the muscles which are thought to contribute to anterior tongue positioning was reviewed (Van Riper & Irwin, 1958; Hirano & Smith, 1967; Zemlin, 1968). The muscles which were accessible, clearly identifiable, and of interest for this study were the genioglossus, geniohyoid, mylohyoid, and the anterior belly of the digastric muscles. The orbicularis oris was included as a reference (Fig. 1).

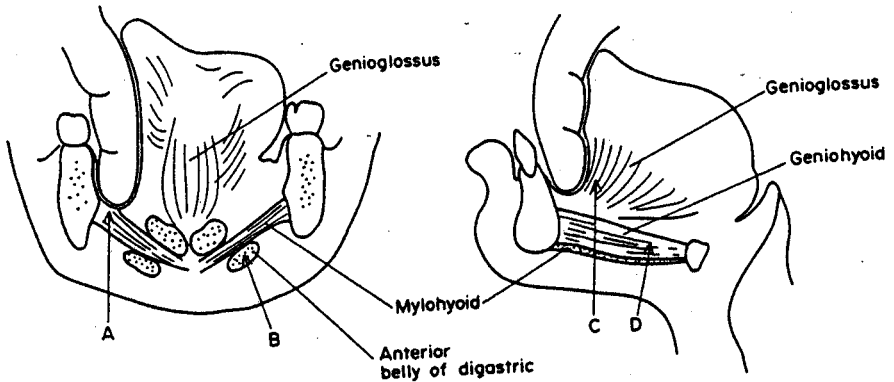


Figure 1

Muscles examined in first EMG study: Front and sagittal views. Arrows indicate direction of needle insertions.

Method

The monopolar electrodes used were DISA concentric needle electrodes with a diameter of 0.45 mm. Needle placement was made through the cutaneous tissue under the chin to the depth required. Correct placement was checked by observation of an oscilloscope while protruding the tongue for genioglossus activity, saying *ta* for geniohyoid activity, lowering the mandible for digastric activity, and saying *ka* for mylohyoid activity. Correct placement was checked periodically throughout each run.

The subject for the first experiment was a normal adult speaker. There were two experimental conditions—without nerve block, and with bilateral mandibular blocks. A total of 7.5 cc of 2% Xylocaine (without epinephrine) was injected by a dentist, 3 cc in each side and an additional 1.5 cc on one side to obtain symmetry of anesthesia. The technique was similar to that used by McCroskey (1958), the model for all previous studies. A partial run was recorded with a medial nasopalatine block of 1 cc and an anterior palatine block of 2 cc added, but this part of the study was not analyzed, as the speech effects were not noticeably different from the run with the bilateral mandibular blocks alone. It seemed that loss of sensation from the anterior portion of the hard palate and the alveolar ridge adds very little to the speech effect evidenced with the mandibular block. We had reached a similar conclusion in our earlier study—the speech effects observed with mandibular blocks were like those with more extensive anesthetization.

For the EMG studies, material was selected from the utterances used in our previous work (Borden, Harris & Oliver, 1973). Eleven utterances in sentence form, using the format "it could be the —", were used to permit normally paced connected speech. Each utterance was represented twice in a randomized list of 22 utterances. There were 10 such lists, each individually randomized. Each utterance was spoken 20 times during the course of one run. The utterances were as follows:

It could be the snowballs splashing.
 It could be the cat's whiskers.
 It could be the fixed sweater.
 It could be the school blocks.
 It could be the thirsty wasp.
 It could be the sleeping taxi.
 It could be the spider string.
 It could be the squirrel nest.
 It could be the rooster scratch.
 It could be the spring grapes.
 It could be the stove smell.

The 220 utterances for each run were read with equal stress attempted on each of the final two words.

A multichannel magnetic tape was produced, recording the electrical output of the muscles. Recordings were monopolar; that is, the voltage difference was recorded between the active tissue of the muscles and the inactive tissue of the earlobe. Some channels were used for audio signals, such as the utterances produced by the subject and the experimenters' comments for record-keeping. Each utterance was numbered by a pulse code which was recorded on the tape and eventually used for computer synchronization.

A visual record of the EMG and audio channels was made for locating and inspecting the individual tokens. Each utterance was represented 20 times during each run, and a single point in time, the line-up point, was selected so that all of the tokens of a single type could be averaged by computer for each electrode. The line-up point was chosen at a point of particular interest and marked on the simultaneous recording of the subject's audio recording.

Each tape was checked with five computer programs: to verify that the code pulses were in order, to calibrate the playback amplifiers, to make control tapes of the line-up points and distances from point zero for each utterance, to set each EMG channel at the optimum level, and finally to average the data on the control tapes. The three runs were hand-plotted (Harris, 1970).

Results and discussion

Inspection of the data revealed that the muscular activity recorded during speech under nerve-block conditions was similar in amplitude to that recorded during the normal condition with the exception of two muscles. After the nerve-block injections, it was observed that the activity represented on the oscilloscope of the mylohyoid muscle and the anterior belly of the digastric muscle dropped dramatically. The electrodes were checked and found to be in place, but as long as the anesthesia was effective those muscles were, in effect, paralyzed. The speech of the subject under nerve block revealed the typical mandibular block effect of distorted sibilants, the /s/ clusters being most prominently affected. For example, for the production of the utterance "sleeping taxi", Fig. 2 shows the activity of the mylohyoid muscle and the anterior belly of the digastric during normal and nerve-block conditions. Graphs of all 11 utterances demonstrate the same drop in activity for these two muscles.

A closer look at the anatomy of the injection area suggested a reason for this effect. The mandibular injection which has traditionally been used for these studies deposits half of the solution in the area of the lingual nerve, then moves on to deposit the rest of the solution in

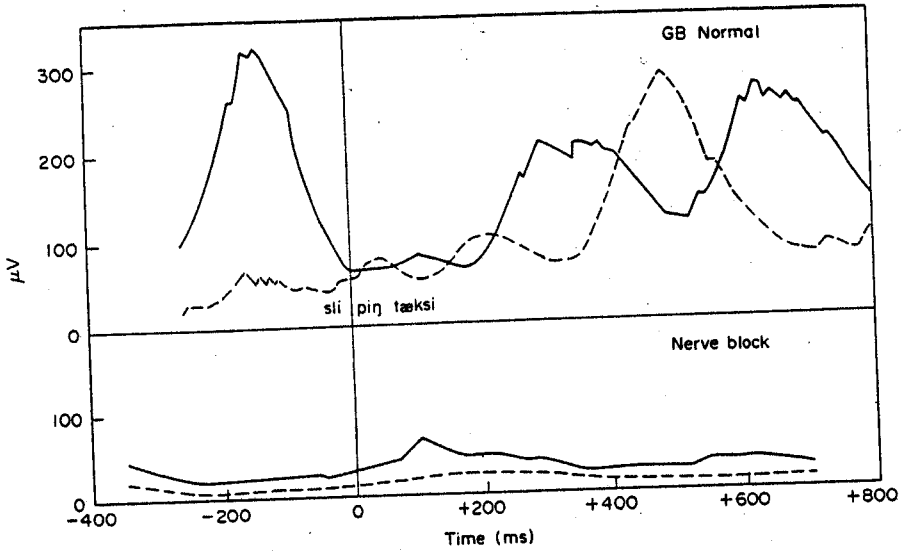


Figure 2

EMG recording of the mylohyoid muscle and the anterior belly of the digastric muscle during normal and nerve-block conditions. Experiment I.
—, MH; ----, AB.

the area of the inferior alveolar nerve. Just before the inferior alveolar nerve enters the mandibular foramen into the mandibular canal, it gives off the nerve fibers of the mylohyoid nerve, the only purely motor component of the otherwise sensory inferior alveolar branch of the trigeminal nerve. The mylohyoid nerve is motor to the mylohyoid muscle and to the anterior belly of the digastric muscle, the two muscles which dropped in activity during the nerve-block condition. The anatomy of the area is indicated in Fig. 1 (Part I).

The question arises as to whether the inactivity of either of these muscles could have contributed to the noted speech deterioration. If the speech effect is primarily due to sensory loss, then loss of feedback from the tongue tip region would probably be responsible. If it is due to motor loss, however, then the inactivity of the anterior belly of the digastric muscle and the mylohyoid muscle would probably be responsible, since it is the motor innervation of these muscles which is most likely to be affected by the block.

The normal function of the anterior belly of the digastric muscle is to open the jaw. EMG data on this muscle, obtained by recording muscle activity during simple CVC utterances, showed no action for /i/ and /u/ and a large peak for /a/ (Harris, 1971). Since there was no perceptible speech effect of the nerve block upon vowels, and since the action of the anterior belly would not reasonably be expected to affect the apical gestures which deteriorated under the nerve block, it seems unlikely that its motor loss could have caused the speech effects observed.

In the present experiment, peaks of activity occur for the mylohyoid muscle for /s/ consonant clusters and for velars. Examples are shown in Fig. 3. Note the activity at the beginning of *spring*, *spider*, and *string* and at the end of *grapes* and *string* in the normal condition. The height and approximate location of all significant mylohyoid peaks in normal and nerve block conditions are shown in Table I. The drop in activity of the mylohyoid muscle is obvious. The peaks of activity under normal speaking conditions, then, coincided with production of the segments that were distorted under the nerve-block condition, with the exception of the velars.

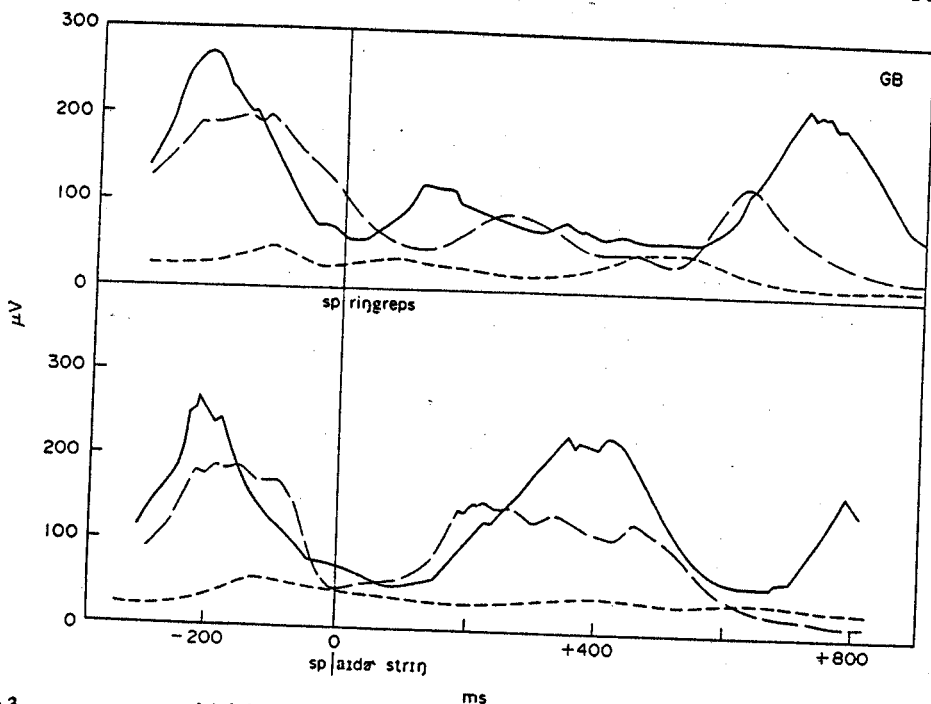


Figure 3

Mylohyoid muscle peaks under normal conditions for /s/ consonant clusters and for velars. Experiment I. —, MH normal; ----, MH nerve block; - · - ·, orbicularis oris normal.

The mylohyoid muscle has been found by both Harris (1971) and Smith (1970) to be active in the production of velars, as we find here. The activity of the mylohyoid in /s/ clusters, however, has not been previously reported. It may be noted that this subject produces /s/ with the tongue tip down and it seems anatomically reasonable that the mylohyoid should be used to raise and steady the body of the tongue in this context. The complexity of the speech sample necessary to elicit distortions under nerve block was not suitable, however, for detailed mapping.

In summary, the conclusion of this first EMG experiment was that a motor component seemed to exist in what was previously assumed to be a sensory deprivation. The motor loss was evident in two of the suprahyoid muscles, the mylohyoid muscle and the anterior belly of the digastric muscle. One of these muscles, the mylohyoid, is normally active for this subject for /s/ clusters and velars. Since this subject produced /s/ with a high dorsum, it is reasonable to assume that the motor loss in the mylohyoid muscle may have contributed in the speech deterioration during anesthesia. However, the lack of effect on velars may be explained by their comparatively gross production and the fact that listeners accept for /k/ a less precise gesture than for /s/.

Second Electromyographic Study

A second EMG study was performed for three reasons. First, we wished to replicate our earlier findings with improved electromyographic recording and analysis techniques (Hirose, 1971; Port, 1971). Second, we wished to check the sensory deprivation effects more systematically in the blocked condition. Third, we wished to include recordings from the superior longitudinal muscle, the muscle layer closest to the lingual surface.

Table I Peak values in microvolts for mylohyoid muscle in first EMG experiment during nerve-block and normal conditions

	<u>springrapes</u>			<u>roosterscratch</u>			
Normal	345	155	285	175	200	310	370
NB	30	35	20	30	40	40	20
ms	(-225)	(125)	(715)	(-775)	(-440)	(-125)	(325)
	<u>cat's whiskiers</u>				<u>fixedsweater</u>		
Normal	315	355	380	370	485	210	140
NB	35	40	40	20	45	45	15
ms	(-800)	(-505)	(-140)	(200)	(45)	(325)	(585)
	<u>thirstywaspl</u>			<u>schoolblocks</u>			
Normal	185	310		380	400		
NB	30	35		50	30		
ms	(-855)	(-255)		(-145)	(640)		
	<u>stovesmell</u>			<u>squirrelnest</u>			
Normal	335	355		215	150		
NB	30	50		50	25		
ms	(-215)	(325)		(-175)	(635)		
	<u>snlowballsplashing</u>				<u>spiderstring</u>		
Normal	415	340	430		355	300	210
NB					35	40	25
ms	(-140)	(500)	(900)		(-210)	(365)	(790)
	(ng/ not plotted)						
	<u>sleepingtaxi</u>						
Normal	425	265		355			
NB	30	40		40			
ms	(-155)	(300)		(635)			

An intervening study was conducted but will not be reported here as there was no effect upon the speech of the subject, although lingual sensation was reported lost and was verified by testing form discrimination (Ringel *et al.*, 1970). It was interesting, however, that there was a change in EMG output under the nerve-block condition even without a speech effect (Borden, 1972).

Method

The investigators wanted to be sure that only subjects whose speech was vulnerable to the nerve block would be selected. Subjects were selected by conducting a short trial run during which four candidates were given bilateral mandibular injections of 2% Xylocaine with 1:100 000 epinephrine. Three of the candidates evidenced speech distortions during the nerve block of which two were chosen as subjects, both male speakers of English. The 11 sentences used in the first EMG study were repeated 18 times each in 9 randomized lists by two subjects. Stress was placed on the first key word. "It could be the *sleeping taxi*." By injecting the anesthetic solution half way along the usual path of insertion, an attempt was

made to block only the lingual nerve using 1 cc Xylocaine (with 1:100 000 parts epinephrine) on each side.

Tests of two-point discrimination of the tongue using a Downes aesthesiometer and of oral stereognosis using the National Institute of Dental Research forms were conducted during normal and blocked conditions. During the normal condition subject DL could make accurate two-point discriminations at 3 mm in most cases, requiring up to 4 mm separation in some instances at the anterior part of the tongue and up to 1 cm separation at some points on the posterior part of the tongue. During the nerve-block condition, however, DL failed to discriminate accurately in five out of eight two-point placements even when point separation reached 1.5 cm. Oral stereognosis ability declined also. Eight errors out of 18 were scored during the normal condition and 14 errors were scored during the nerve-block condition.

The second subject, PN, made four errors of two-point discrimination at 3 mm normally but reported no sensation at all 16 placements during the blocked condition. Three errors of identification of the forms normally were increased to 13 errors out of 18 possible identifications during the nerve block. The investigators presumed success in lingual nerve isolation in the case of DL as sensation was reported lost in the anterior two-thirds of the tongue but remained on the lower lip and gingivae. The effect upon subject PN was less clear as there was some loss of sensation in the lower alveolar ridge and lower lip, indicating a partial block of the inferior alveolar nerve, thereby suggesting a possibility of infiltration to motor fibers.

The electrodes were 0.002 in wires hooked to remain in place. EMG recordings were made from the superior orbicularis oris, the anterior genioglossus, bilateral placements in the mylohyoid and in the anterior belly of the digastric muscles. New in this experiment were electrode placements in the superior longitudinal muscle of the tongue. Bilateral insertions were made approximately 1 cm from the midline and 1 cm from the tip of the tongue. The insertions were superficial with an estimated depth of 2 to 3 mm. The hooked wires were located about 1 cm posterior to the point of insertion. The addition of the superior longitudinals and the bilateral placements made in other muscles made it necessary to eliminate the geniohyoid placement due to limitations of channel capacity.

Results

Both subjects slurred /s/ in all contexts during the nerve-block condition. There were some instances of distortion of /r/, /tʃ/ and /t/, that is the traditional nerve block effect.

Electromyographic results may be summarized by comparing the activity level in the nerve block condition with the activity level in the normal condition. This procedure is an accurate reflection of the effects of the block because the peaks do not appear to shift in temporal location, but merely in amplitude. All peaks close to the lineup point were compared in magnitude and averaged in microvolt value. The results of this procedure, muscle by muscle, are shown in Fig. 4 for subject DL and in Fig. 5 for subject PN. The muscles as grouped may be considered to be sensory, motor, or indirect.

The results indicate first, that the nerve block produced a rather dramatic effect on the contraction of the intrinsic tongue muscles from which we recorded. Subject DL evidenced a drop in activity during the nerve-block condition. The superior longitudinal muscle normally peaks for /θ/ and /l/. Both left and right electrode placement showed decreased activity as did the genioglossus, another tongue muscle. Subject PN, however, reacted quite differently to the nerve block. Superior longitudinal activity was depressed on the right side in a manner similar to the first subject, but the left electrode, in contrast, recorded

much more electrical activity during the nerve-block condition than during the normal condition. The genioglossus muscle was also more active than normal. The effect of the nerve block in tongue muscles was generally depression of activity in subject DL and in subject PN, one side depressed, the other side evidencing greater effort under nerve block.

The nerve block also produces decided changes in EMG activity in muscles served not by sensory nerves involved in this nerve block but by motor nerves. The mylohyoid muscle

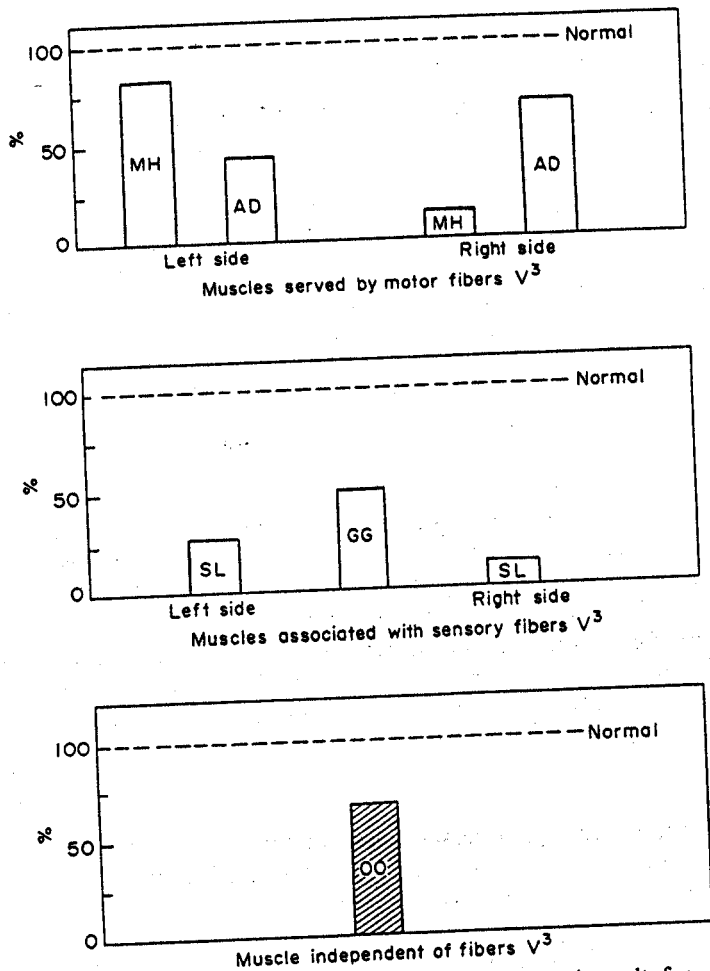


Figure 4

Mean percentages of normal peak EMG amplitudes in microvolts for muscles during nerve block, subject DL. Experiment II.

which normally contracts for /k/ showed greatly decreased activity on one side for DL, but the other side was active. Subject PN showed almost total bilateral inactivity of this muscle for each token of each utterance type, a verification of the suspected infiltration to the inferior alveolar nerve indicated by sensory testing of the lower lip and lower alveolar ridge. Both subjects showed depressed anterior digastric activity during the nerve-block condition. There was a change in the activity of a muscle whose innervation lies entirely outside the field of the block—the superior orbicularis oris. For subject DL it was somewhat depressed in amplitude during nerve block, but for subject PN it was much more active.

Figure 4 shows that for subject DL, the nerve block produced a consistently depressed state of activity. The general depression extended even to muscle fibers which should have been completely unaffected by the block. Subject PN, however, has a far more complex pattern of activity over a wide range of muscles (Fig. 5).

To summarize the effects of the nerve block in this experiment, the first class of muscles,

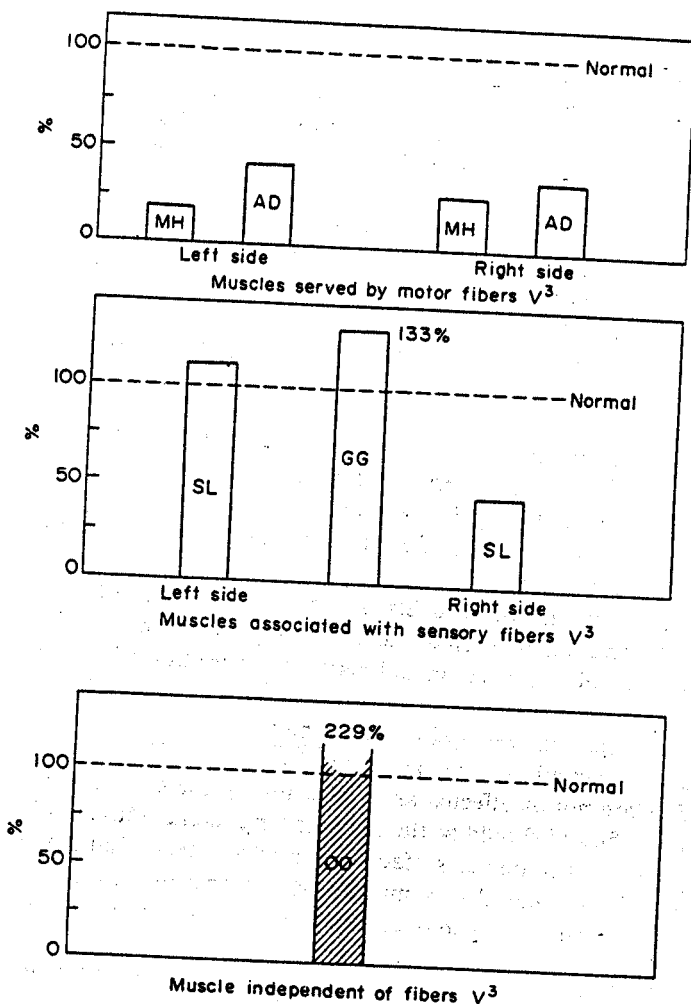


Figure 5

Mean percentages of normal peak EMG amplitudes in microvolts for muscles during nerve block, subject PN. Experiment II.

those innervated by motor fibers from the blocked nerve, were consistently depressed or inactive. Thus, it seems that despite the attempt to anesthetize the lingual nerve alone, there is evidence of infiltration of the anesthesia. The next two classes of muscles, those presumably associated with sensory fibers from the blocked nerve and those which should be independent of the blocked nerve, were sometimes less active, sometimes more active, depending upon the side of electrode placement and upon the idiosyncratic reaction of the subject.

Summary of the EMG Studies and Discussion

Although the traditional bilateral mandibular nerve block often produces distortions in some of the gestures of rapid connected speech, there is evidence that the effect may have both motor and sensory components. This was indicated by the total inactivity of the mylohyoid muscle and the anterior belly of the digastric muscle in the first study. The second study confirmed the finding of the motor effect of the nerve block and added a suggestion of compensatory reorganization. Furthermore, the results demonstrated nerve block effects upon muscles whose innervation is independent of the nerves involved. Increased activity under nerve block of muscles which are not served by either sensory or motor fibers of the anesthetized nerve, indicates either a general reorganization of activity in an effort to compensate for some motoric or sensory loss, or a more central effect of the anesthesia. It does not seem from some results of a pilot study recently conducted by the authors of isolated mylohyoid nerve block that the motor effect alone is sufficient to distort the speech, although there is some EMG reorganization without any evidence of the normal sensory effects of the block.

At this point, it seems worthwhile to try to reassess the results of these experiments in the light of the explanations usually offered for the nerve-block effect.

The primary reason for the effect may be motor, as we have previously suggested (Harris, 1970; Borden, 1971). On anatomical grounds, it is plausible that the block would affect motor innervation; indeed, we have been apparently unsuccessful in making a sensory block while avoiding the motor innervation of two of the muscles, the mylohyoid and the anterior belly of the digastric. However, the pattern of affected consonants makes a primary motor cause for the block effect unlikely. We would expect that inactivity of the mylohyoid muscle alone would make /k/ the most affected consonant; in fact there is general agreement that this consonant is spared.

The most traditional explanation of the speech effect is that it is a consequence of decreasing sensory feedback from the oral area—either tactile or proprioceptive or both.

The "tactile" explanation is that a block of the lingual nerve cuts sensation from the surface of the tongue, which leads to imprecision in its placement. Again, the pattern of affected consonants makes the explanation somewhat implausible; in this case the consonants /t/, /d/ and /n/ should be maximally affected as they require the tongue to touch the superior alveolar ridge; they are not as affected as /s/. Turning to the experiments reported above, the muscles most affected should be the superior longitudinal muscles of the tongue, which lie closest to the numbed lingual surface. There is no evidence that their activity pattern is more, or less, affected than that of muscles lying deeper in the tongue body, or, indeed, muscles which lie outside the field of the block entirely. A simple tactile explanation does not seem tenable.

Another explanation for the block effect is that it causes interference with the proprioceptive return from muscle spindles in the tongue. If each muscle adjusts to a fixed length based on the return from its own stretch receptors, as has been described by MacNeilage (1970), then interference with this pathway should have serious effects on speech. Traditionally, it has been assumed that the lingual nerve carried proprioceptive as well as tactile information from the anterior two-thirds of the tongue, because the hypoglossal nerve has no sensory root (Blom, 1960). Studies in rhesus monkeys by Bowman & Combs (1968) would indicate that nerve fibers from muscle spindles in the tongue do course along the hypoglossal nerve for part of the way and then cross to join some cervical nerves. If this is the case in humans, the block spares proprioceptive feedback, since the injection site does not lie on the pathway of the hypoglossal nerve. If, on the other hand, proprioceptive

feedback is carried in the lingual nerve, we would expect that the tongue muscles would be affected by the mandibular block, but not muscles outside the tongue.

Taking these results together, it would appear that any sensory effects of the block must be rather general. The system might be responding to an altered pattern of information sent back to the Central Nervous System with a changed motor output which affects muscles whose sensory feedback is normal—that is, there is not muscle-specific correction. These changes are most likely to alter those consonants which require the greatest degree of articulatory finesse. Indeed, this is the pattern of effect we observe.

Everyone writing on this effect recently has noted that the effect is restricted to a small class of consonants. The restricted results of all these studies provide us with some insight into the small size of the effect. The electromyographic signals may change size radically under the block; but they do not seem to change their temporal relationship to each other. Changes in relative timing of the muscle gestures would produce far more devastating effects on articulation.

Another possibility which probably should be considered is that the effect may be due to an additional factor, a generalized depression of central activity directly caused by the local anesthesia. Drowsiness is a well known side effect of Xylocaine. Pharmaceutical studies indicate that local anesthetics may appear in considerable quantities in the blood stream (de Jong, 1968), and an effect upon speech is one clinical sign of a rising level of anesthetic in the blood. Furthermore, it has been shown that local anesthetics readily cross the blood-brain barrier (Usubiaga *et al.*, 1967). It is possible that a slight loss of central control may relate more directly to the slurring of speech than either the motor or sensory effects evidenced at the periphery. The speech effect when it does exist sounds perceptually very like 'drunk' speech. 'Drunk' speech is accepted as a consequence of the alcohol having crossed the blood-brain barrier to affect the central control of speech.

Whatever the cause of the nerve-block effect, it remains an important experimental technique because it is one of the few means we have of altering speech production in normal adult speakers. Further work should be directed towards exploring the alternatives of general central effect versus sensory deprivation. Furthermore, electromyographic studies should be aimed at exploring other blocks to see if the pattern of their effects are similar to the bilateral mandibular block.

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