Oral Feedback, Part II: An Electromyographic Study of Speech Under Nerve-Block Anesthesia

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Electromyographic recordings were made from the lip, tongue, and certain suprathyroid muscles of four 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.

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A series of studies during the 1950s and '60s dealt with the subject of the role of tactile feedback in speech. 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 and Steer, 1963). The speech distortions were found to be subtle and were most evident in the production of fricatives and affricates (Scott, 1970; Borden, 1971; Gammon, Smith, Danieloff, and 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 of the speech effect under anesthesia revealed two factors which prompted further investigation; first was the variability of effect among speakers, with some subjects unaffected by the nerve block, although oral sensation was reported to be lost, and the second factor was 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.

Four separate electromyographic (EMG) experiments were conducted in an attempt to find out what happens to certain suprahoid and tongue muscles as subjects speak under conditions of trigeminal nerve block.¹

**FIRST ELECTROMYOGRAPHIC STUDY**

Since the nerve block seemed to produce an /s/ effect, muscles which are thought to contribute to tongue elevation were reviewed (Van Riper and Irwin, 1958; Hirano and 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 (Figure 1).

**Method**

The monopolar electrodes used were DISA concentric needle electrodes with a diameter of .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...

¹These studies were conducted over a substantial period of time, during which electrodes, insertion techniques, and data analysis were substantially altered. In particular, the first experiment, in 1969, was performed under circumstances which permitted only relatively gross statements to be made about the results. Insertion techniques for the intrinsic tongue muscles were developed just before the third experiment was performed.
Figure 1: Muscles examined in first EMG study: front and sagittal views. Arrows indicate direction of needle insertions.
mandibular blocks. A total of 7.5 cc of 2% Xylocaine was injected by a dentist, 3 cc in each side and an additional 1.5 cc on one side. 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 from the mandibular block.

For the EMG studies, material was selected from the utterances used in our previous work (Borden, Harris, and 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:

- 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 printed and mounted on large cards which were flipped as the subject read them, with equal stress attempted on each of the final two words.

A 16-channel 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 laid down 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 set the gains of the playback amplifiers at levels appropriate for the analog-to-digital converter, 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, except for two muscles, the muscular activity recorded during speech under nerve-block conditions was similar in amplitude to that recorded during the normal condition. However, the activity observed on the oscilloscope of the mylohyoid muscle and the anterior belly of the digastric muscle after nerve-block injections 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," Figure 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 of these two muscles.

A closer look at the anatomy of the injection area suggests 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 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 what is known as 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 Figure 1, Part I.

The question was 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.

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 consonant-vowel-consonant (CVC) utterances, showed no action for /i/ and /u/ and a large peak for /a/ (Harris, 1971). Since there was no perceivable 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.

The normal function of the mylohyoid muscle was found by both Harris (1971) and Smith (1970) to be highest for the production of /k/. Its contraction seems
Figure 2: EMG recording of the mylohyoid muscle (MH) and the anterior belly of the digastric muscle (AB) during normal and nerve-block conditions, Experiment I.
to lift the body of the tongue. In the more complex utterances of the present study, it can be seen that the mylohyoid muscle peaked normally in preparation both for the /s/ consonant clusters and for the velars (Figure 3). Notice the activity at the beginning of "spring," "spider," and "string," and at the end of "grapes" and "string," in the normal condition. The drop in activity of the mylohyoid muscle during the nerve-block condition 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.

The velars were not perceived as distorted in the nerve-block condition. The production of /k/ remained intact, as had been reported in all previous nerve-block experiments. The explanation may lie in the comparatively gross production of /k/ and the fact that listeners accept for /k/ a less precise gesture than for /s/.

It seemed, therefore, that the effective paralysis of the mylohyoid muscle might reasonably be related to the speech effect, since, for this subject, the mylohyoid muscle appears to be important in lifting and steadying the body of the tongue for consonant clusters, especially those with /s/ (Table 1). This subject produces /s/ with the tongue tip down, making it imperative that the body of the tongue be raised to produce the friction. Deprived of motor ability in the mylohyoid and deprived of lingual sensation, the /s/ clusters were distorted. It is impossible to conclude which of these factors, if not both, is responsible for the distorted speech.

In summary, the clear 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 suprathyoid 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 to the speech deterioration during anesthesia. However, the lack of effect on /k/ could not be unequivocally explained.

SECOND ELECTROMYOGRAPHIC STUDY

The purpose of the second EMG study was to verify the result of the first study that mylohyoid motor loss accompanies the distorted speech during the nerve-block condition, and also to study further the changes in muscle activity by comparing the muscle activity in normal speech with the potentials generated during nerve block.

There were two differences in procedure from the first study; first, since we wanted to find out if the motor loss was inevitable under the normal administration conditions of the bilateral mandibular block, the administrator (Dr. Catena) tried to avoid heavy infiltration of the mylohyoid nerve, within the bounds of the previously described injection technique. Second, we wanted to look at block conditions which more nearly corresponded to those used by Scott (1970).
Figure 3: Mylohyoid muscle (MH) peaks under normal conditions for /s/ consonant clusters and for velars. The orbicularis oris (OO) is included as a reference, Experiment I.
| TABLE 1: Peak values in microvolts for mylohyoid muscle in first EMG experiment during nerve-block and normal conditions. |
|---------------------------------|---------------------------------|
|                                | springgrapes                     | roosterscratch                  |
| Normal                         | 345 155 285                      | Normal                          | 175 200 310 370 |
| NB                             | 30 35 20                         | NB                              | 30 40 40 20     |
| msec                           | (-225)(125)(715)                 | msec                            | (-775)(-440)(-125)(325) |
|                                | catswhiskers                     | fixedsweater                    |
| Normal                         | 315 355 380 370                  | Normal                          | 485 210 140     |
| NB                             | 35 40 40 20                      | NB                              | 45 45 15        |
| msec                           | (-800)(-505)(-140)(200)          | msec                            | (45)(325)(585)  |
|                                | thirstywasp                       | schoolblocks                    |
| Normal                         | 185 310                          | Normal                          | 380 400         |
| NB                             | 30 35                            | NB                              | 50 30           |
| msec                           | (-855)(-255)                     | msec                            | (-145) (640)    |
|                                | stgvesmell                       | squirrelnest                    |
| Normal                         | 335 355                          | Normal                          | 215 150         |
| NB                             | 30 50                            | NB                              | 50 25           |
| msec                           | (-215) (325)                     | msec                            | (-175) (635)    |
|                                | snowballssplashing               | spiderstring                   |
| Normal                         | 415 340 430                      | Normal                          | 355 300 210     |
| NB                             | (-140) (500) (900)               | NB                              | 35 40 25        |
| msec                           | (/ng/ not plotted)               | msec                            | (-210) (365)(790) |
|                                | sleepingtaxi                     |                                |
| Normal                         | 425 265 355                      |                                |
| NB                             | 30 40 40                         |                                |
| msec                           | (-155) (300)(635)                |                                |
Method

It was necessary for technical reasons to use a second subject for this experiment. The material consisted of 30 utterances in the frame "the______." They were randomized into four lists repeated alternatively four times, making 16 lists of 30 utterances each. Fifteen of the utterances were chosen from the Scott (1970) list in an attempt to observe the muscle changes in the distorted speech which might explain the phonetic changes that she had described. The other 15 utterances were words selected from the sentences in the first study and from the perceptual study. Two runs were produced, the first under normal conditions, the second under blocked condition.

The electrodes were 0.002-in wires hooked to remain in place. Correct placement was checked by observing the oscilloscope while lifting the tongue for genioglossus activity, tensing the floor of the mouth while relaxing the tongue for geniohyoid activity, saying "ka" for mylohyoid activity, opening the mouth with jaw effort for anterior belly of digastic activity, saying "pa" for orbicularis oris activity, and lifting the head or opening the mouth under pressure for sternohyoid activity. The genioglossus and geniohyoid were also checked during swallowing, as their activity differs in timing (Hirose, 1971). Electrodes were placed in both sides of the mylohyoid muscle and in both anterior bellies of the digastic muscle.

After the normal run, a total of 7.5 cc of 2% Xylocaine was injected into the oral region of the subject. A summary of the injections is given in Table 2. Details on the technique used may be found in a standard reference of dental anesthesia (e.g., Cook-Waite Labs, 1971).

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<table>
<thead>
<tr>
<th>Cranial Nerve</th>
<th>Branch</th>
<th>Amount of Solution</th>
<th>Location of Injection</th>
<th>Area of Sensation</th>
</tr>
</thead>
<tbody>
<tr>
<td>V (mand.)</td>
<td>Inf. Alveol. n.</td>
<td>1.5 cc ea. side</td>
<td>pterygomand. triangle</td>
<td>mand. alv. ridge, lip, gum</td>
</tr>
<tr>
<td></td>
<td>Lingual n.</td>
<td></td>
<td></td>
<td>ant. 2/3 tongue</td>
</tr>
<tr>
<td>V (mand.)</td>
<td>Long Buccal n.</td>
<td>.5 cc ea. side</td>
<td>1st molar</td>
<td>buccal</td>
</tr>
<tr>
<td>V (max.)</td>
<td>Infraorbital</td>
<td>.5 cc ea. side</td>
<td>infraorbital foramen</td>
<td>upper lip</td>
</tr>
<tr>
<td></td>
<td>Ant. Sup. Alv.</td>
<td></td>
<td></td>
<td>alv. ridge</td>
</tr>
<tr>
<td></td>
<td>Middle Sup. Alv.</td>
<td></td>
<td></td>
<td>ant. teeth</td>
</tr>
<tr>
<td>V (max.)</td>
<td>Nasopalatine n.</td>
<td>.5 cc midline</td>
<td>post. to central incisors</td>
<td>ant. 1/3 palate</td>
</tr>
<tr>
<td>V (max.)</td>
<td>Post. Sup. Alv. n.</td>
<td>.5 cc ea. side</td>
<td>palate 3rd mol.</td>
<td>post. 2/3 palate</td>
</tr>
</tbody>
</table>
A rough check of two-point discrimination was made, and when the experimenters and subject were satisfied that sensation was lost in the tongue and the palate, Ringel's (Ringel, House, Burk, Dolinsky, and Scott, 1970) 55-item oral discrimination test of 10 plastic forms was administered. When the subject had returned to normal, the Ringel test was again administered. The subject made nine errors in normal condition and fifteen errors in the nerve-block condition, the difference being errors of shape, not size. Confusion of shape occurred three times in normal condition and nine times in nerve-block condition. Nevertheless, the experimenters were surprised that there was so little difference in performance on this test. It was noted that the subject used the usual tongue manipulations during normal condition but relied on deep pressure against the palate when sensation was decreased. This technique was reported as the method used by successful subjects in the study on the effect of anesthesia on oral stereognosis (Mason, 1967).

The multichannel magnetic tapes produced for each of these runs were analyzed in much the same way as the first experiment. There were some refinements in the computer programs. A concise description of the analysis procedure is reported by Port (1971).

Results and Discussion

The most conspicuous result of the second EMG experiment was that the subject's articulation remained clear during the condition of nerve block. The speech sounded as acceptable under the nerve-block condition as under the normal condition. The utterances were louder under nerve block and produced with what might be described as over-articulation.

This variability of nerve-block effect among subjects was observed during the perceptual part of this series of studies. It is unclear why there was no speech effect. It might be a difference in muscle use, as this subject produces /s/ with tip of the tongue raised and might not rely on mylohyoid muscle activity as much as the first subject, who produces /s/ with the dorsum of the tongue raised, keeping the tip down. Another explanation for the lack of speech effect might be a difference in anesthesia, either in amount or in technique of injection.

Following the first EMG experiment, the investigators were particularly interested in this second study in the activity of the mylohyoid muscle. Since there were bilateral placements of electrodes in both the mylohyoid muscle and the anterior belly of the digastric muscles, the investigators had an opportunity to study the activity on both sides of these muscles. During the normal run, before the injections of anesthesia, the mylohyoid and the anterior belly showed activity similar to the first subject. The anterior belly peaked for mouth opening and the mylohyoid for velar gestures and somewhat for the /s/ clusters.

During the condition of nerve block, however, there was a change in activity in both muscles on the right side. The right anterior belly of the digastric was in all cases less active than normal after anesthesia. The right mylohyoid was consistently less active than normal for velar gestures, but for the /s/ clusters, it was sometimes less active and sometimes more active than normal. The gain in activity for the nonvelar gestures offset the loss for /k/ . The decreased activity on the right side in this experiment was not as pronounced as it had been in the first EMG study, indicating that the attempt on the part of
the dentist to avoid the motor myohyoid nerve was partially successful. The limited effect on the right side was presumed by the investigators to be the result of some infiltration of the anesthetic in the area of the myohyoid nerve, especially affecting nerve fibers which are motor to the digastric muscle.

In contrast with the instances of decreased activity observed on the right side of the myohyoid and anterior belly of the digastric muscles, the left side of these muscles was usually more active than normal while the anesthesia was in effect. Figure 4 demonstrates the asymmetry of effect. The right peak in each of the four graphs represents the labial closing for /p/ in "duckpond." It can be seen that the right side of both muscles was quite active during normal speech but dropped in activity during speech with nerve block. Figure 4 also shows that by contrast both muscles on the left side were more active than normal under block.

Figure 5 summarizes the activity for each muscle during the nerve-block condition relative to its normal activity. Taking the normal peak amplitude in microvolts of each electrode during the central 400 msec around each line-up point as 100%, the percentage of normal activity was computed for the peak amplitude during the nerve-block condition for each utterance. The average of the 30 percentages is represented in the figure.

In this figure, muscles have been arranged into three groups—those where the bilateral mandibular block might be expected to have a motor effect, those where the effects of the bilateral mandibular block should be sensory, and those where the effects observed lie outside the field of the bilateral mandibular block, though within the field of the other blocks performed. This arrangement is intended for comparison with the results of Experiments 3 and 4, although it is not logical for the data of this experiment. The meaning of the term "sensory" is discussed at greater length in the final section.

Overall, there is a widespread change in the activity of the muscles sampled, both those which are directly associated with tongue movement and those which are not. It seemed desirable to try to separate motor and sensory effects of the mandibular blocks.

**THIRD ELECTROMYOGRAPHIC STUDY**

Since the first two EMG studies with nerve block appeared to reflect the results of a mixed nerve block, that is, the injection of anesthesia apparently affected both motor and sensory fibers of the trigeminal nerve, it was considered important to make further attempts to separate these factors. The third and fourth investigations were designed to anesthetize the lingual nerve alone, producing a purely sensory block, and to anesthetize the myohyoid nerve alone, producing a purely motor block. The third EMG study was an attempt to investigate the effects of the lingual nerve block.

Furthermore, since we found that there was a change in EMG output under the nerve-block condition even without a speech effect, we wanted to be sure that we used only subjects whose speech was perceptually distorted under the block condition.

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Figure 4: Decreased right side activity and increased left side activity during nerve block of the mylohyoid and anterior belly of the digastric muscles. The orbicularis oris (00) is included as a reference, Experiment II.
Figure 5: Mean percentages of normal peak EMG amplitudes in microvolts for muscles during nerve block, Experiment II.
Method

The 11 sentences used in the first EMG study were repeated 18 times each in nine randomized lists by two subjects. Stress was placed on the first key word, "It could be the sleeping taxi." Subjects were selected by conducting a short trial run during which four candidates were given the routine bilateral mandibular injection of 2% Xylocaine with 1:100,000 epinephrine. Of the three candidates who evidenced speech distortions during the nerve block, two, both male speakers of English, were chosen as subjects. 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. By a slight modification of the injection technique an attempt was made to block only the lingual nerve using 1 cc Xylocaine with 1:100,000 parts epinephrine on each side. 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 few 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.

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 method of recording and analysis of data was the same as for the second EMG study.

Results and Discussion

Again, results may be described by grouping the muscles investigated according to whether the block effects on them 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 genio- glossus, 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; in subject PN, one side depressed and the other side evidenced 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, which normally contracts for /k/, showed greatly decreased activity on the left side. Subject PN showed almost total bilateral inactivity of this muscle for each token of each utterance type. Both subjects showed depressed anterior digastric activity during the nerve-block condition.

There is 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. Examples of orbicularis oris activity are shown in Figure 6. Changes in the level of activity peaks for /p/ can be seen in the block condition.

When the absolute peak values in microvolts during nerve block are compared to the normal peak values, and the percent of normal is averaged for each muscle, we can see the pooled difference from the normal condition which the nerve block produces. Again, only the peaks close to the averaging lineup point were chosen for analysis. Figure 7 shows that for subject DL, the nerve block produced a consistently depressed state of activity. The general depression extended even to muscle fibers that 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 (Figure 8).

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

**FOURTH ELECTROMYOGRAPHIC STUDY**

If it is difficult to isolate the lingual nerve without affecting the motor fibers of the mylohyoid nerve, it is possible perhaps to anesthetize the mylohyoid nerve alone, producing a motor block while leaving the sensory fibers of the lingual nerve unaffected. This was the purpose of the final EMG study.

**Method**

The method was a repetition of the third study with the same electrode placements, the same utterance lists, and one of the same subjects, PN. The difference was that .5 cc of 2% Xylocaine with 1:100,000 parts epinephrine was
Figure 6: Reduced activity of the orbicularis oris during nerve block for one subject and increased activity for another subject, Experiment II.
SUBJECT: DL

MUSCLES SERVED BY MOTOR FIBERS $V^3$

MUSCLES ASSOCIATED WITH SENSORY FIBERS $V^3$

MUSCLE INDEPENDENT OF FIBERS $V^3$

Figure 7: Mean percentages of normal peak EMG amplitudes in microvolts for muscles during nerve block, subject DL, Experiment III.
SUBJECT: PN

Figure 8: Mean percentages of normal peak EMG amplitudes in microvolts for muscles during nerve block, subject PN, Experiment III.
injected on each side at the juncture of the lingual mucosa and the floor of the mouth at the level of first molar. Data analysis was the same as for the second and third experiments.

Results and Discussion

The injection of the anesthesia directly into the mylohyoid muscle on each side produced much more of an effect on the left side, which was completely inactive after the block, than on the right side, which was depressed in activity but remained active (Figure 9). The left anterior digastric electrode was misplaced.

The intrinsic tongue muscles did not greatly alter activity, although the left side of the superior longitudinal was generally less active than normal and the right side more active than normal. The orbicularis oris was also somewhat more active during the nerve-block condition.

The subject's speech remained as well articulated as normal. The subject was not conscious of any sensory or motor changes as a result of the injection of anesthesia.

It seems to be as difficult to obtain a bilateral motor effect as it is to obtain a purely sensory nerve block. There were changes in the amplitude of the muscles sampled, however, even when there was little or no sensory loss.

**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 demonstrated the possibility of compensatory activity coupled with a lack of perceptible effect of the nerve block upon the articulation of speech. The third study confirmed the finding of the motor effect of the nerve block and increased the evidence 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 motor or sensory loss, or a more central effect of the anesthesia. It does not seem, from the results of the fourth study, that the motor effect alone is sufficient to distort the speech, although the fourth study also shows that 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, 1972). On anatomical grounds, it is plausible that the block would affect motor innervation; indeed, it is quite difficult to make the sensory block while avoiding the motor innervation of two of the
Figure 9: Mean percentages of normal peak EMG amplitudes in microvolts for muscles during nerve block, subject PN, Experiment IV.
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. Furthermore, as we showed in Experiment IV, a block of the mylohyoid nerve will not apparently produce a perceptible speech distortion, at least in gross terms.

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; they are not. Turning to the experiments reported above, the muscles most affected should be the superior longitudinal intrinsic 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, of muscles lying 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 had 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 and 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, as we found in our third study.

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 affect those consonants which require the greatest degree of articulatory finesse.

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 EMG signals may change size radically under the block; 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.
Recent work by Scott and Ringel (1971) has shown that the speech of subjects under block does not resemble that of a group of dysarthric speakers studied by Lehiste (1965) and Tikofsky and Tikofsky (1964). Their argument is that the effects cannot be motor, and hence, must be sensory.

Another possibility which probably should be considered is that the effect may be due to an additional factor, a generalized depression of central activity 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, Moya, Wikinsky, and Usubiaga, 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 experimental 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, EMG studies should be aimed at exploring other blocks to see if the patterns of their effects are similar to those of the bilateral mandibular block.

REFERENCES


