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Oral feedback

I. Variability of the effect of nerve-block anesthesia upon speech

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Abstract: The effects of bilateral mandibular nerve blocks on speech were judged by a group of listeners and by two transcribers. Seven adult male speakers repeated under normal and nerve-block conditions 66 sentences heavily weighted with consonant clusters known from pilot studies to be vulnerable to nerve-block distortion. Although all subjects reported loss of sensation, the effects on speech as judged by listeners varied widely from completely unaffected to markedly affected. Employing narrow phonetic transcription, distortions as a function of the nerve block were noted in 23 % of the speech elements transcribed. The most prominent distortions occurred in /s/ clusters. The elements most likely to be affected are similar to those reported by other authors using a more extensive series of blocks.

The question of whether skilled speech is an open loop system requiring little or no feedback from the periphery, or a closed loop system requiring sensory information to control the production is provocative and basic to our understanding of speech patterning. One feedback channel, that of sensation from the oral cavity, can be studied by examination of the effects of sensory deprivation. One approach is to examine the speech of subjects in which an oral sensory deficit is pathological, but this method yields contradictory conclusions (Chase, 1967; McDonald & Aungst, 1970). It is difficult to obtain specific information on the relationship between oral sensation and speech from clinical cases due to the multiplicity of handicaps.

A potentially productive way of studying the relationship between sensory feedback from the oral area and articulation is to interrupt feedback via blockade of the trigeminal nerve in normal speakers.

It is a frequently observed fact that after dental procedures involving nerve blocks there is often a disturbance of speech until the effect of the anesthesia has disappeared. It is understandable, therefore, that investigators interested in afferent control of speech should block the sensory nerves of normal speakers with anesthesia in order to study the relationship between feedback from the oral area and articulation of speech. Presumably all feedback channels are used in language acquisition: audition, taction and proprioception. Do normal adult speakers depend upon these feedback possibilities during ongoing speech and to what degree or under what circumstances does each channel play a role? McCroskey (1958) was the first to report that blocking oral sensation with mandibular and intraorbital injections of anesthesia had an adverse effect on articulation. Substitution and distortion errors were reported (McCroskey, Corley & Jackson, 1959). Ringel & Steer (1963) confirmed the findings of McCroskey. It was assumed that the articulatory deterioration was due to the interruption of a closed loop control system. Locke (1968) questioned the technique as it might have both motor and sensory effects. Schliesser & Coleman (1968), however, reported that mandibular blocks and the application of a topical anesthetic to the anterior palate not only produced complete elimination of tongue sensation as tested by oral stereognosis measures, but also very little if any interference with the motor control needed to lateralize the tongue or to perform diadochokinetic tasks. Several investigators interested by the McCroskey study and the Ringel & Steer study attempted to further specify the effects of the nerve block. Work was done on this subject somewhat concurrently by Gammon, Smith, Daniloff & Kim (1971), Scott (1970) and by the authors. Gammon *et al.* found a 20% rate of misarticulation with anesthesia. Errors were more prominent in labial and alveolar place of articulation with fricatives and affricates especially distorted. Scott noted that sibilants were "less closely produced" and other phones were produced with a more retracted position than normal. The intended manner of articulation, however, was maintained. The material used were 24 spondee words.

The purpose of this study was to investigate further the distortion of phonemes vulnerable to nerve block. Is the effect upon speech slight or severe? Does it affect subjects similarly? What phonemes are distorted? Will the effects of the mandibular block alone be similar to those previously observed for more extensive blocks?

Method

Two pilot studies, the first using a list of CVC utterances with all English phonemes and the second using words containing fricatives, revealed that speech deterioration under nerve block was in many cases evident only in rapid connected speech. Sixty-five sentences were, therefore, constructed for the final study (Borden, 1971). The subjects were seven university students, all normal speakers of standard English. The recording was done in a quiet interior room at the University of Pennsylvania School of Dentistry. The data were collected from each subject in two sessions, one session with nerve blocks and the other without nerve blocks. Nerve-block and normal conditions were counterbalanced to control order effects. During each session, the subject repeated the sentences after a recorded speaker, heard through earphones from a second tape recorder. The anesthesia was administered by a dentist using the standard dental technique for producing a mandibular block (Cook-Waite Labs Inc., 1971). The puncture was made at the apex of the pterygomandibular triangle which is about 7 mm above the occlusal surface of the teeth. Half of the solution of 2% lidocaine was deposited halfway back toward the wall of the mandibular sulcus. This usually anesthetizes the lingual nerve. When the needle reaches the ramus, the rest of the solution is deposited around the inferior alveolar nerve. The method of injection is schematized in Fig. 1. The amount of anesthesia was 1·5 cc of solution on each side. When subjects reported complete loss of sensation to the dentist's probes of the tongue on each side, taping began. In some instances, an additional 1·5 cc was injected if needed to obtain bilateral symmetry of sensory effect. The effects of the anesthesia lasted well beyond the recording session which took approximately half an hour.

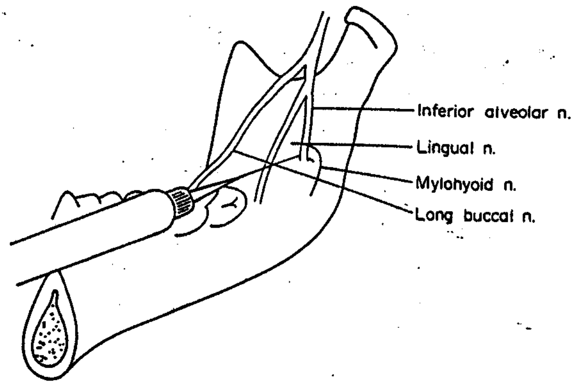

Figure 1 Inner surface of ramus with needle in the right mandibular sulcus

Listening test

A body of 38 utterance samples in the form of phrases were extracted from the recorded material to construct a listening test. This test was used for listener judgments of speech deterioration and for narrow phonetic transcriptions by transcribers. The test was heavily weighted with utterances which from pilot studies were found to be most vulnerable to the nerve block.

The tapes of each subject were presented one at a time to a group of listeners. Utterance samples of both conditions had been spliced into matched pairs, randomized, and separated by 1 s of silence between each one of a pair and 4 s of silence between each pair of utterances. The listeners were 16 university students instructed to check (a) if the first example of each pair seemed more deteriorated, or check (b) if the second example seemed more deteriorated. If a listener checked the normal condition as deteriorated, that response was considered incorrect. The incorrect responses were counted and tabulated according to speaker and according to utterance. Correspondence between those utterances sampled during nerve-block conditions and the listener response "more deteriorated" was employed as an index of nerve-block influence.

Phonetic transcriptions

Two experienced transcribers made narrow phonetic transcriptions of the listening test tapes. The transcribers worked on material and speakers not used in the study to standardize their phonetic system. It was decided that the direction of the distortions should be indicated whenever possible. For example, if the /s/ were to sound somewhat like /θ/, the transcription would be /s^{θ}/, whereas if it were more toward /ʃ/, it would be transcribed /s^{ʃ}/. If the /s/ were slurred but in an undetermined direction, the indication was /s̬/.

Results

Listener judgments

Incorrect listener responses were tabulated according to speakers and according to utterances. Two analyses of variance were conducted to investigate variation among listeners and among speakers and further the variation among utterances according to listeners (Borden, 1971).

It was found that there was no significant difference among listeners. Thus, the listeners were apparently using the same criteria in their judgments.

The variation among utterances according to speaker was significant at the 0·05 level indicating marginal significance. One speaker who evidenced no speech distortions under nerve block was removed for this analysis. The highest possible number of "incorrect" listener responses for each utterance was 96 (6 speakers as heard by 16 listeners) of which 48 would be expected by chance, even were there no nerve block. In general the single consonants deteriorate less than the clusters since listeners have more trouble identifying the block condition.

The variations among speakers was found to be highly significant as judged by listeners. Since there were 38 utterances and 16 listeners, there were 608 possible incorrect listener responses for each speaker, 304 expected by chance. It can be seen in Table I that the nerve block had no effect on speaker B (315 incorrect responses) as determined by listener judgment. Speaker C, in contrast, was most affected, as the listeners made relatively few errors of judgment (96) between the normal and the nerve-block utterances. Speakers, then, varied considerably in their performance under nerve block as judged by listeners. Even when the speaker with no perceptible effect on his speech was removed for the second analysis, a significant variation among the remaining 6 speakers was found at the 0·01 level of confidence. The extent of this variation was surprising to the experimenters as there had been no previous mention in the literature of inter-speaker variance in levels of deterioration due to oral anesthesia.

Table I **Incorrect listener responses according to speaker**

Speakers	B	A	E	F	G	D	C
Total	315	246	228	222	218	193	96
% Utterances	50	40	38	37	36	32	15

Transcriber judgments

The transcribers made the transcriptions independently. Transcriber agreement was quite high. Transcriptions were made for all seven speakers but only if a change was noted between conditions. The utterances are listed in Table II. For the possible 228 utterances to be transcribed, there was transcriber agreement that there was no effect in 67% of the data. There was agreement both that there was a distortion effect and on the nature of that distortion in another 20% of the data, bringing the transcriber agreement up to 87%. Three percent of the total number of utterances had transcriber agreement that there was a deviation but the direction or place of the distortion in the utterance was judged differently. For the final 10% of the data, one transcriber heard differences which the other did not consider to be distortions.

To determine if the transcribers were making judgments on utterances similar to the judgments made by the 16 listeners, the utterances were ranked according to transcriber judgments of deterioration to test the correlation of that ranking with the ranked utterances according to listener errors. The utterances were given scores to indicate their relative degree of distortion as interpreted by the two transcribers. An utterance received a score of zero if there was no difference noted by either transcriber between the normal and nerve-block condition in any speaker. A score of 1/2 indicated that a difference was noted by one transcriber in one speaker, and 3/4 indicated that a difference was noted by one transcriber in 2 speakers. Scores of 1, 2, 3, or 4 were assigned if there was transcriber agreement that there was a distortion in 1, 2, 3, or 4 speakers respectively. After each utterance was assigned a score, the utterances were ranked from the most affected by the block to the least

Table II Rank correlation between transcribers and listeners

Utterance	Transcription score	Transcriber rank	Listener rank
Spring	4·5	1·5	2
Stars	4·5	1·5	1
Scissors	4	3·5	12·5
School	4	3·5	15
Squirrel	3·5	5·5	10
Watching	3·5	5·5	23
Spider	3	8	3
Whiskers	3	8	18
Scratch	3	8	6
Letters	2·5	10	20
Mouse	2	11·5	28·5
String	2	11·5	7·5
Dishes	1·75	14	23
Snowballs	1·75	14	7·5
Giraffe	1·75	14	10
Blocks	1·5	18	26
Brushing	1·5	18	27
Bicycles	1·5	18	28·5
Grapes	1·5	18	16
Smoke	1·5	18	4·5
Sweeping	1	23	4·5
Sleeping	1	23	18
It's	1	23	10
Kids	1	23	25
Splashing	1	23	21
Telephone	0·75	26	12·5
Knife	0·5	28	35
Swinging	0·5	28	23
Shaving	0·5	28	31·5
Table	0	34	14
Pyjamas	0	34	18
Girl	0	34	31·5
Bird	0	34	34
Fixed	0	34	31·5
Birthday	0	34	31·5
Mother	0	34	37·5
Cans	0	34	36
Peanut	0	34	37·5

affected. Table II shows the key words removed from their embedding phrases as ranked by transcribers and by listeners. Using Spearman's Rank Correlation, the ranking of utterances given by the transcribers correlated significantly at the 0·01 level of significance with the ranking of utterances given by the sixteen listeners.

The phonemes transcribed as distorted under nerve block were /tʃ/, /dʒ/, /s/, /z/, /ʃ/, /t/, and /l/. All of the /s/ two-consonant clusters were distorted, especially /st/. Among the /s/ three-consonant clusters, only the final /kst/ remained undistorted by the block. The /s/ was the distorted portion of the cluster in all cases, with additional distortion on /r/ in two utterances with /spr/ and /skr/ clusters. There were no errors transcribed for the labials, the velars, the labiodentals, nor for /d/ or /n/.

All of the errors noted by the transcribers were errors of place. They were never sufficiently deviant to cross phoneme boundaries. The most prominent distortion was for the /s/ to deviate toward /ʃ/. In all cases the distortion seems to be the result of the tongue failing to reach target position or target precision.

Speaker variation

Transcriber judgments according to speaker indicate, as did the listeners, that the speakers varied widely in the degree of speech deterioration evidenced in the same utterances. Listeners and transcribers agreed that speaker C was the most affected, and that speaker B was not affected. As demonstrated in Table III, speakers C and D were both affected, speakers F and G somewhat less affected, and speakers E and A were judged to have very little deterioration of speech.

Table III Speaker variation as judged by transcriber agreement of no distortion

Speaker	B	E	A	G	F	D	C
% Utterances judged not distorted	100	89	82	74	58	55	45

Discussion

Several results emerged from this study of the effects of bilateral mandibular nerve block upon speech. First, the effect was found to be subtle, limited, and manifest only in rapid, connected speech. In an array of utterances heavily weighted with consonant clusters, deterioration of articulation was noted by listeners in surprisingly little of the data. Transcribers agreed upon distortions in only 20% of the data (17% if the unaffected speaker is included), agreeing that there were no perceptible distortions in 67% of the utterances (71% when the unaffected speaker is included).

The effect was discovered to be limited to certain phonemes. It would be distorting the facts to report that the effect was largely with the fricatives, because although /s/ was by far the most common phoneme to deteriorate, and /z/ and /ʃ/ also underwent changes, there was seemingly no effect upon /ð/ or /θ/ and very little upon /f/ or /v/. The affricatives were affected, but the plosives suffered very little with only /t/ noticeably slurred. The nasals were not noticeably affected. There was some distortion of /r/ and /l/, but the most conspicuous effect remained the /s/.

The techniques of analysis and the speech samples in this study are different from those used by Gammon *et al.* (1971) and Scott (1970). The rate of misarticulation, however, is quite similar to that found in the former study, while the pattern of affected phonemes resembles that found by Scott. This is particularly striking when it is noted that only a bilateral mandibular block was used in the present study. We may tentatively conclude that the bilateral mandibular block is the important component in the experimental procedure, although this conclusion should probably be verified by more direct experimentation.

Finally, the effect was found to be highly variable across subjects, a finding not mentioned in previous reports. Although all subjects reported complete loss of sensation in the anterior two-thirds of the tongue, the effects on speech ranged from completely unaffected to markedly affected. As one can see from referring back to Table III, the subjects varied from no effect to distortions in 55% of the utterances sampled with significant variation among the subjects between the two extremes.

The high degree of intelligibility of all of the speakers in this investigation gives some weight to the theory that skilled speech may be largely under open loop control. At least it can be concluded that with only one sensory channel inhibited in its function, the motor sequencing of speech remains essentially intact. Skilled speech remains highly intelligible under conditions of oral sensory nerve block. It may be that the oral sensory system used to monitor speech is of primary importance only during the learning of speech.

It is unclear why there is such variability of nerve-block effect among subjects. It may reflect a difference in the subjects themselves, such as a difference in muscle use, or individual variation in dependence upon sensory or auditory feedback. A second reason for variability may be the nerve-block injection itself. Despite subjective reports of loss of sensation, there are probable variations in depth of anesthesia and in the specific nerves affected. It would be advisable in future investigations to use more sophisticated methods of testing loss of sensation, both taction and kinesthesis. Electromyography should be used, in addition, to check motor function. The extent of the variability of speech effect after nerve-block anesthesia should caution researchers to avoid generalizations about the deterioration of articulation with sensory deprivation in the oral area.

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