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Chapter 29

STUDY OF NONSPEECH VOLUNTARY PALATE MOVEMENTS BY SCALING AND ELECTROMYOGRAPHIC TECHNIQUES

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The term "palate elevation" in this report refers to voluntary, nonspeech movements produced on command without benefit of visual feedback or of the auditory feedback that would be associated with phonation. Data reported by Shelton *et al.*[9] in the preceding chapter indicates that subjects are able to produce such movements after a few minutes' training. However, no information was provided about the discreteness or skill with which palate elevations can be performed. The study of Shelton *et al.* was also concerned with a subject's awareness of palate movements, but the procedure did not permit differentiation between a subject's awareness of his effort to move his palate and his knowledge of whether he succeeded.

The current study concerns the skill with which palate elevation can be accomplished. Study of palate elevation skill in turn bears indirectly on awareness of palate movement. A subject's success in acquiring the ability to elevate his palate to discrete heights on command would suggest better awareness than would failure in acquiring such a skill. The procedures used in this study are similar to training techniques recommended for improving palate function in speech. Thus the results reported below are pertinent to understanding the effectiveness of those techniques.

This study involves subjects' ability to elevate the palate to different heights on command without visual or auditory feedback. Both judges' ratings and electromyographic measurement of palate action potentials were used. The following problems were of primary interest:

1. Can a subject produce different degrees of palate elevation on command? If so, approximately how many distinct responses can he produce?
2. Judges' ratings of palate elevation are sometimes available where EMG information is not. Therefore, we obtained information on the relationship between EMG records and judges' ratings of palate displacemnet. The magnitude of palate action potentials has been found to correlate well with cinefluorographic measures of palate movement.[8] Finding a high correlation between EMG data and judges' ratings would serve to validate judges' ratings as a method for studying palate movements. The technique of rating palate elevations is, of course, limited to open mouth observations and does not indicate whether palatopharyngeal closure occurred.
3. How do the palate elevations obtained in response to commands compare in magnitude with palate elevations observed during speech? We compared action potential amplitudes and durations for the utterances /mɑm/, /mim/,

/pɑp/, and /pip/ with those for nonspeech palate elevations.

4. Observations are also reported pertaining to palate elevation skill with and without EMG electrode attached and with and without mirror feedback. Action potentials in structures near the palate during palate elevation are described; and finger movements are compared with palate elevations.

PROCEDURES

Subjects

Two normal adults served as subjects. They had no history of speech disorder or of oral sensory or motor difficulty. S_1 (RLS), a man thirty-eight-years-old, learned to produce palate elevations by using a mirror. He served as a pilot subject in the Shelton *et al.* study.[9] S_2, (PMD) a woman age twenty-four, also taught herself to produce palate elevation by mirror monitoring. She reported that alternation between oral and nasal respiration helped her learn to make palate elevations. Before study data were obtained, the subjects participated in several trial runs requiring palate elevation and syllable production. Palate electrodes were attached during these runs. Excess salivation occurred at first; but after two or three sessions, this lessened, and the subjects found the palate electrodes less uncomfortable.

Magnitude production technique was used to obtain nonspeech responses.[11] That is, the subjects were instructed to make a small elevation in response to the command "one," a large elevation in response to the command "seven," and proportionate elevations to the intervening command numbers. The commands were tape recorded and presented to the subject by earphone so that the palate elevation judges could not hear them. Each of the seven command numbers was presented twenty times in an order that was random except for the restriction that no number occurred more than twice in succession. The cue tape allowed for fourteen practice responses and 140 test responses.

Utterance responses were obtained by asking the subjects to repeat the utterances recorded on a tape. The cue tape contained twenty productions of each utterance all randomly arranged except that no utterance occurred more than twice in sucession.

Palate Scaling Procedure

Two judges were positioned where they could observe the subject's palate. The judges were instructed to rate the palate elevations on a seven-point scale, and the procedure was practiced several times. The ratings of the two judges were averaged, and these mean ratings were used in processing the data other than the information analyses. Reliability of judgments of palate movement was assessed by computing Pearson correlation coefficients between values assigned by each judge for each run. Coefficients of .75, .78, and .69 were obtained for a single run with the first subject and for two runs with the second subject.

Electromyography

The electromyographic equipment, including suction surface electrodes, has been described in earlier reports.[2,5] A ground electrode was attached to one of the subject's earlobes, a reference electrode to the other earlobe, and a third electrode was attached to the soft palate. For some runs, further electrodes were placed on a masseter muscle and under the chin (Figs. 29-1 and 29-2). From previous studies,[6] we assumed that data from the palate does not change much as a function of the

FIGURE 29-1. Placement of electrodes (photograph by Ida Nathan).

FIGURE 29-2. Placement of palate electrode (photograph by Ida Nathan).

position of the electrode on the palate. Electromyographic responses were recorded on tape. The recorded EMG signals were rectified and integrated before the write-out. Peak amplitude measures for one subject are reported as written-out with two different integrating time constants, 130 msec and 5 msec. Response peaks were measured in millimeters and converted to microvolts by reference to a calibration signal. For some of the data, response duration was also measured.

Two pencharts of the data for S_1's nonspeech palate elevations were written out (RC = 130 msec), and the peak amplitude for each elevation was measured independently by two persons. The full-scale EMG pen deflection is 40 mm. For the peak measures, no discrepancy greater than 2 mm was found. The mean discrepancy was .61 mm when the sign of the discrepancies was disregarded and .59 mm when attention to sign permitted cancelling some discrepancies. These data in millimeters indicate that disagreement in measurement of peak amplitude was little more than the thickness of the ink-line of the pen trace. We concluded that pen write-outs of the EMG signals and measurements of peak amplitudes were highly consistent. Measurement of EMG duration was also satisfactorily accurate in that a correlation coefficient between two sets of measures from the same data was high. However, disagreement on absolute magnitude of duration measures was greater than for peak measures. Response offset involves a gradual tailing into the baseline, and this leads to disagreement regarding termination. Thus, for a sample of fourteen response durations measured by two experimenters, a Pearson correlation coefficient of .93 was calculated. This indicates good reliability. However, a mean discrepancy of 2.71 mm was found when sign was disregarded and of .14 mm when attention to sign permitted the cancelling of some discrepancies. Duration measures permit accurate comparison of the duration of responses made to each of the seven command values. Each set of data reported below is based on measurements made by one experimenter. Palate elevation amplitudes observed during a run comparing mirror feedback and no mirror feedback conditions were much larger than those obtained on other runs. We do not know why.

RESULTS

Data for S_1 are reported in Table 29-1 and for S_2 in Table 29-2. The tables report palate EMG data for both nonspeech and speech responses as well as the mean scale values assigned by the judges. Peak EMG amplitudes are given in microvolts; durations are given in milliseconds. The time constants used in writing out each set of EMG data are also given. Nonspeech data for S_1 were written out with two different RC time constants. Results from both examinations of the single recording are reported. The nonspeech task was performed by S_2 on two occasions. Both tapes were examined, and the results are reported. The second run was obtained immediately after her speech responses were recorded. Thus, her responses on the second run could have been influenced by fatigue resulting from her participation in the earlier task.

Figure 29-3 shows the relationships between command values and EMG peak amplitude, EMG duration, and judges' mean scale values for each subject. Comparing this figure with Tables 29-1 and 29-2 shows that the peak and duration measures

TABLE 29-1

PALATE EMG DATA AND JUDGE SCALE VALUES FOR SUBJECT 1. EMG MEASURES OF RESPONSE PEAK AMPLITUDE AND DURATION ARE REPORTED IN MICROVOLTS (μV) AND MILLISECONDS (MSEC) RESPECTIVELY

	Nonspeech								*Syllables*		
	Peak Amplitude (μV)				*Duration (ms)*		*Scale Values*		*Peak Amplitude (μV)*		
	RC: 130 msec		RC: 5 msec		RC: 130 msec					RC: 130 msec	
Command Values	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Syllable	Mean	SD
1	77.7	25.9	144.1	43.7	517.9	226.7	2.5	1.3	/mam/	156.7	30.5
2	80.7	29.8	150.3	48.9	486.3	146.7	2.6	.9	/mim/	141.4	32.0
3	95.5	32.9	176.9	56.7	728.4	250.7	3.0	1.4	/pap/	199.6	25.4
4	97.3	21.2	168.8	34.8	748.0	238.3	4.3	1.5	/pip/	194.2	26.5
5	98.1	18.8	163.4	34.4	778.0	162.7	4.8	1.4			
6	121.4	17.1	193.4	31.8	1111.5	257.5	5.6	1.0			
7	138.8	15.7	207.3	19.1	1235.8	205.6	6.4	.8			

TABLE 29-2

PALATE EMG DATA AND JUDGE SCALE VALUES FOR SUBJECT 2. EMG MEASURES OF RESPONSE PEAK AMPLITUDE IN MICROVOLTS AND DURATION IN MILLISECONDS ARE REPORTED. AN INTEGRATING CIRCUIT TIME CONSTANT OF RC: 105 MSEC WAS USED FOR EACH OF THE EMG ANALYSES

	Nonspeech										*Syllables*		
	Peak Amplitude (μV)				*Duration (ms)*		*Scale Values*				*Peak Amplitude (μV)*		
	1st run		2nd run		2nd run		1st run		2nd run				
Command Values	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Syllable	Mean	SD
1	136.6	16.9	100.5	22.5	257.8	110.1	1.9	.8	1.5	.7	/mam/	170.8	26.2
2	119.9	17.4	103.7	15.4	255.0	71.0	2.6	1.0	1.7	.8	/mim/	101.4	23.3
3	145.0	28.9	111.5	17.5	294.7	74.8	3.8	1.2	2.4	.9	/pap/	191.3	23.1
4	155.1	30.7	113.7	14.9	410.6	187.9	4.5	1.4	2.8	.9	/pip/	169.1	25.6
5	164.5	28.1	114.1	15.1	475.5	182.8	5.6	1.1	4.6	1.2			
6	171.2	21.0	125.0	14.7	668.9	147.2	5.9	.7	5.3	1.3			
7	177.6	30.9	127.6	12.5	784.4	164.0	6.3	1.1	5.5	1.2			

and also the mean scale values for each subject are similar in rank to the command values to which the subjects responded. The relationship between command values and each of the other variables is reflected in the Pearson correlation coefficients reported in Table 29-3. These data indicate that both subjects were able to produce different degrees of palate elevation on command. This conclusion is also supported by the fact that amplitude and duration of EMG traces correlate well with mean scale values assigned by palate observers.

Correlation coefficients between judges' ratings and EMG peak amplitude values were .77 for S_1 (RC = 130 msec), .54 for S_1 (RC = 5 msec), .55 for S_2 (first run) and .48 for S_2 (second run). For S_1, a coefficient of .71 (RC = 130 msec) was found for scale values and EMG response duration; for S_2 (second run) a coefficient of .73 was obtained for the comparable data. We conclude that ratings of palate elevation can be used for studying palate movements.

Information analyses were used to estimate the number of degrees of palate elevation the subjects could produce.[1,4] These analyses were based both on the judges' ratings of palate elevation and on peak amplitude and duration measures. The bit values for information transmitted between command and response hovered around .8 bits. This means the speaker operates as if he could divide the palate elevation continuum into slightly less than two categories, which would indicate either that

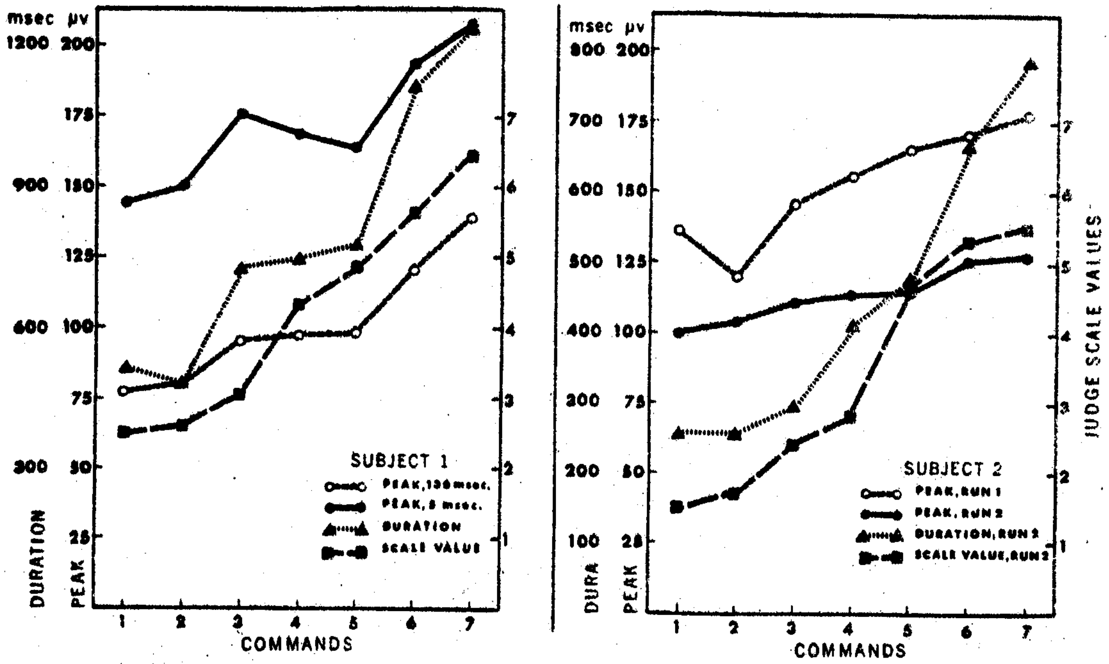

FIGURE 29-3. EMG peak amplitude measures, EMG duration measures, and judge mean scale values obtained for each command value. Peak and duration measures and scale values are shown on the ordinate. For Subject 1, peak values for the same run recording were written out with two RC time constants. For Subject 2, peak data are reported for two separate runs each with an RC time constant of 130 msec.

TABLE 29-3

CORRELATION COEFFICIENTS SHOWING THE RELATIONSHIP BETWEEN THE COMMAND VALUES TO WHICH THE SUBJECTS RESPONDED AND MEAN SCALE VALUES ASSIGNED BY THE JUDGE, EMG PEAK AMPLITUDE, AND EMG DURATION

	Subject 1	*Subject 2*	
		run 1	*run 2*
Mean Scale Value	.74*	.82	.82
EMG Peak Amplitude**	.61	.55	.48
EMG Duration	.73	—	.78

*$p < .01$ for all coefficients in this table.
**RC time constants were 130 msec for Subject 1 and 105 for Subject 2.

our response measures are poor, or that palate elevation control is very crude.

Palate elevation data for the speech productions (Tables 29-1 and 29-2) show greater peak amplitude for utterances without nasal sounds than for those with nasal sounds. Action potentials observed for the utterances tend to be higher than those observed during nonspeech elevations. Standard deviations for the speech data are not greatly different from those for nonspeech. The similarity in standard deviations indicates that variability in nonspeech and speech palate elevations is comparable.

Additional observations pertinent to understanding sensory motor aspects of palate skill are reported. The influence of an attached electrode on S_1's skill in displacing his palate in response to commands was studied. The attached electrode could provide touch and pain cues to guide nonspeech palate elevations. Consequently, early in the study the judges rated S_1's palate elevations first with the palate, ground, and reference electrodes in place and then with them removed. Almost identical correlation coefficients between mean judgments and command values were obtained under the two conditions (.59 with electrode and .58 without). However, under the no electrode condition, no judges' mean scale values of "one" were assigned and only six values of "two"; with electrodes attached, mean scale values of "one" were assigned eight times. A value of "two" was assigned twelve times. Thus it is possible that the presence of an electrode contributed to S_1's ability to make small palate elevations.

A further study of the influence of feedback was undertaken. Peak amplitudes were measured as S_1 watched his palate in the mirror and then again without the mirror. Under each condition, commands to elevate the palate to small, medium, and large heights were repeated fifteen times in random order. The same command never appeared more than twice in succession. Means and standard deviations for responses to each command value and for each condition are reported in Table 29-4. Under each condition, the subject's responses to each command value were relatively distinct from responses to the other values. However, responses under the no mirror condition were of greater magnitude than those obtained under the mirror condition.

TABLE 29-4

MEANS AND STANDARD DEVIATIONS IN MICROVOLTS FOR EMG PEAK AMPLITUDES FOR PALATE ELEVATION UNDER MIRROR AND NO MIRROR CONDITIONS. RC INTEGRATING CIRCUIT TIME CONSTANT WAS 5 MSEC

	Command Value					
	Small		*Medium*		*Large*	
Condition	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Mirror	212.9	107.8	322.1	105.9	488.7	116.0
No Mirror	340.7	117.1	524.2	191.9	672.7	57.1

For some runs, EMG data were recorded from electrodes placed over a masseter muscle and under the chin. The former was sensitive to wide opening of the mouth and to mandible clench; the latter to retraction and protrusion of the tongue. Results obtained during nonspeech palate elevation and during syllable productions are reported in Table 29-5. Neither subject produced identifiable EMG signals in the masseter during nonspeech palate elevation, and no identifiable EMG signals were recorded through the under chin electrode worn by S_1. S_2 wore an electrode under her chin during her second run. Means and standard deviations for the potentials ob-

TABLE 29-5

MEANS AND STANDARD DEVIATIONS IN MICROVOLTS FOR EMG PEAK AMPLITUDES OBTAINED AT THE MASSETER AND UNDER THE CHIN DURING SYLLABLE PRODUCTION AND NONSPEECH PALATE ELEVATION (RC: 5 MSEC)

	Subject 1				*Subject 2*			
	Masseter		*Under Chin*		*Masseter*		*Under Chin*	
Syllable	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
/mam/	263.5	66.0	171.4	38.4	186.9	45.0	411.3	52.0
/mim/	101.7	18.8	131.8	48.4	136.5	20.2	394.4	48.5
/pap/	325.7	31.6	238.7	40.9	193.8	34.4	453.7	45.3
/pip/	131.8	28.4	152.5	41.1	138.4	21.7	451.9	32.2
Nonspeech Command Value	No identifiable signal		No identifiable signal		No identifiable signal			
1							158.8	49.6
2							181.6	53.9
3							181.6	53.6
4							178.9	69.2
5							191.6	41.3
6							212.3	58.6
7							196.0	64.2

tained are reported in Table 29-5. These potentials were produced at the time of termination of palate elevation. No relationship is evident between these potentials and the command values to which the subject was responding. Greater masseter action occurred during utterances containing /α/ than during those containing /i/. This can be predicted from the fact that /α/ requires more mouth opening than does /i/. We conclude that the electrode placements were sensitive to at least some movements of the tongue and mandible and that the subjects were able to produce palate elevations with no gross movement of the mandible or of the tongue. S_2 did usually make a tongue movement as or just after she returned her palate to the down position.

Comparison of nonspeech palate movements with movements of a jointed structure may provide indirect information about palatal kinesthesis. Therefore, S_1 was instructed to displace his finger to seven heights in response to the same cue tape used to elicit the palate elevations. He was not allowed to see his hand, and while the hand was supported by an arm rest, the index finger which was studied was positioned to the side of the rest. Thus, the finger was not provided with touch cue information regarding the starting point. The correlation coefficient for agreement between the two judges rating the finger elevation was .84, and a coefficient of .88 was obtained for the relationship between mean scale values and command values. Comparison with data in Table 29-3 shows that while this is the highest agreement between judge values and command values obtained in the study, it is not much higher than coefficients obtained for palate elevations. However, information analyses computed for the judges' ratings of finger displacement indicated that about 1.1 bits of information were transmitted. This figure is substantially higher than the figure for judgments of palate elevation. The subjects can perform as if they were discriminating better than two categories perfectly.

DISCUSSION

The results of this study suggest that subjects can learn to make voluntary palate elevations of varying size as reflected in different amounts of EMG activity. Furthermore, observers' estimates of palate elevation agree fairly well with EMG measures; ratings of this kind can be of value in studying palate motor skill.

Variability in voluntary palate elevation was comparable to that observed during speech; palate elevations were produced promptly upon command; and the subjects were able to move their palates with little movement of nearby structures. These findings indicate that the voluntary palate elevations are made with some skill. However, the information analysis indicated that palate elevation movements are less skilled than finger movements under comparable conditions. Also data from S_2's second run suggested that palate elevation skill decreases under fatigue. Resistance to breakdown under stress is indicative of the development of motor skill on an automatic level.[8] Whether the degree of fatigue and discomfort experienced was sufficiently great to interfere with skilled acts other than the palate elevation under study is not known.

The degree of success at palate elevation demonstrated by the subjects suggests that sensory information about palate location is available to the subject. It may be kinesthetic in nature. Awareness of muscular tension and touch cues provided by the breath stream could also contribute. The study does not suggest that somesthetic cues comparable to those available for monitoring the fingers are consciously available to guide palate elevation. After the study was completed, the subjects were informally asked to demonstrate nonspeech palate movements. No electrodes were present to signal palate movement as electrode lead brushed against the lower lip, and no trials were provided with mirror or descriptive feedback. Under these conditions, the subjects were not confident that they had succeeded in making the movements they intended. However, once they were told that they had in fact succeeded, they could then make a series of movements of different magnitude and do so with confidence. Perhaps the practice trials with mirror or descriptive feedback that preceded experimental runs in this study provided all the sensory information required to produce the movements reported. Identification of kinesthesis in the palate is not an easy task.

The experimenters who served as subjects formed the opinion that a sense of response duration may have contributed to the acquisition and development of palate elevations. If this time sense was especially great for responses to command 6 and 7, then responses to those commands would be learned first. Subjects did receive the impression that they learned to produce the large palate elevations first. Large movements are also associated with pain cues whereas small movements are not, and large movements result in greater electrode lead displacement across the lip and thus greater touch cues. Thus acquisition of palate elevation skill may involve learning to attend to duration and pain cues and to use them to guide palate movements.

The interpretation that a sense of response duration may have contributed to response acquisition and development is supported by the finding that action potential duration correlated with judges' ratings of palate displacement. This is further shown by data in Table 29-1. Mean potential amplitudes with a large time constant agree in rank order with command values better than mean potential amplitudes with a small time constant. Similarly, the *r* between judges' mean values and EMG peak amplitudes was larger (.77) with the large time constant than with the small time constant (.54). The larger the time constant, the more sensitive the write-out is to duration effects.

Additional efforts could be made to assess palatal kinesthesis. Cinefluorography could be used to determine the distance the palate is displaced in response to commands. Training in nonspeech palate elevation could be studied for effect on accuracy on reporting reflex elevations. The effects of sensory anesthetization of the palate on nonspeech palate elevations could be studied. However, attempts to use kinesthesis in therapy for persons with palate problems does not seem warranted.

Procedures used in this study could be used in treatment studies designed to influence subjects' speech. For example, deaf speakers with electrodes attached to their palates could monitor their palate potentials while producing speech. Perhaps improved palate function could be established by rewarding production of large palate action potentials. This kind of study would require a degree of maturity on the part of the subject.

Another possible study would involve

teaching nonspeech palate elevations to persons with palate problems. The goal would be to see whether the training resulted in improved palate function during speech. Results obtained in this study indicate that higher action potentials were obtained for speech than for nonspeech palate elevations. This difference decreases the probability that practice of nonspeech elevations would contribute to speech correction. There may be a qualitative difference between nonspeech acts and speech acts involving the same structures. We once noted that normal subjects were unable to position the tongue in contact with the posterior wall of the pharynx on a voluntary basis although they do so automatically during the swallow act.[10] Speech is probably more effectively influenced by training procedures that involve speech as opposed to nonspeech acts.[7]

Acknowledgments

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