DYNAMIC PALATOGRAPHY OF SELECTED SYLLABLES

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Palatography is a classic method of describing the tongue position within the oral cavity which is necessary for the production of specific speech sounds. The addition of tongue contact sensing elements to an artificial palate permits a more detailed description of the dynamics of these utterances. A system using strain gage pressure transducers as sensing elements has been developed and utilized by the authors for several years. The purpose of this paper is to describe the present system and present data obtained from that system.

Miniature pressure transducers are constructed with two Micro-Measurements foil strain gages mounted on opposite sides of a cantilever beam. On one tip of the beam is welded a small pellet which the tongue contacts, while the other end of the beam is sealed rigidly into an acrylic artificial palate. Five custom constructed transducers are placed in a palate, each of which is made for each subject from a cast of his maxillary arch. After the transducers are attached to the palate they are individually calibrated.

For data collection the palate, with its transducers, is positioned in the subject's mouth replacing a 'dummy' plate of similar dimensions, but containing no transducers. This was worn for several days before the recording session to permit the subject to accommodate to speaking with the plate in his mouth. The locations of the transducers are lingual and superior to the maxillary first molars, the first bicuspids and the central incisors. The wires that connect the transducers to the appropriate recording equipment are collected together on the back of the palate, curved around the last molar and out the side of the subject's mouth.

After positioning the palate, the subject is placed in a quiet, electrically shielded room and the transducers are connected with the recording equipment directly into an IBM 1800 computer. Prior to data collection, pertinent information, such as speaker identification, age, and sex, is recorded. When the subject repeats the experimental utterance, both magnitude and duration of tongue contact are recorded. Information retrieved from the computer consists of peak pressures in gm/cm^2, the integrated area under the pressure curve in gm-sec/cm^2, durational components of the tongue contact for each transducer, and the order in which these events occurred within the mouth.

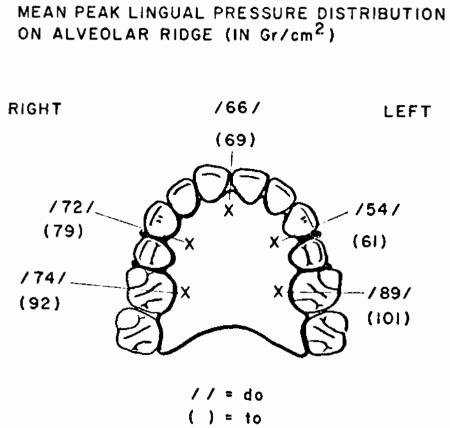

Fig. 1. Mean peak lingual pressure distributions on the alveolar ridge for syllables /to/ and /do./

Figure 1 presents mean peak pressures obtained from seven speakers who uttered the syllables /do/ and /to/ three times respectively. Peak pressures were asymmetrical with the average pressure magnitude for /do/ greater on the left side than on the right, and the smallest mean peak occurring left of center. The same trend occurred for /to/.

Comparison of the pressures for the two syllables indicates a consistently larger pressure recorded by all transducers associated with /to/ than with /do/. To explore the possibility that greater pressures occur for /t/ than /d/ when placed in a syllabic context, the same group of subjects produced these consonants in CV, VCV and VC syllables. The resultant mean peak pressure, as recorded by the transducer behind the central incisors, are presented in Table 1. Again a slight but greater pressure was found for syllables containing /t/ than those containing /d/.

Table 1 also gives the mean length of time the tongue was in contact with the alveolar ridge. The difference between the two was 244 milliseconds, with the /t/ syllables producing the longer contact. Combination of these factors suggests that,

TABLE 1

Lingual pressure and tongue contact means for /t/ and /d/ calculated from 63 utterances by seven subjects.

	Consonants	
	/t/	/d/
Mean peak lingual pressure (in gm/cm^2)	56.64	52.52
Mean length of tongue contact (in sec.)	1.345	1.101

for the slow single syllable utterance of the kind used in this study, a physiologically distinguishing feature between these linguo-alveolar component cognates is tongue contact. But this difference is probably secondary to the activity of the vocal fold.

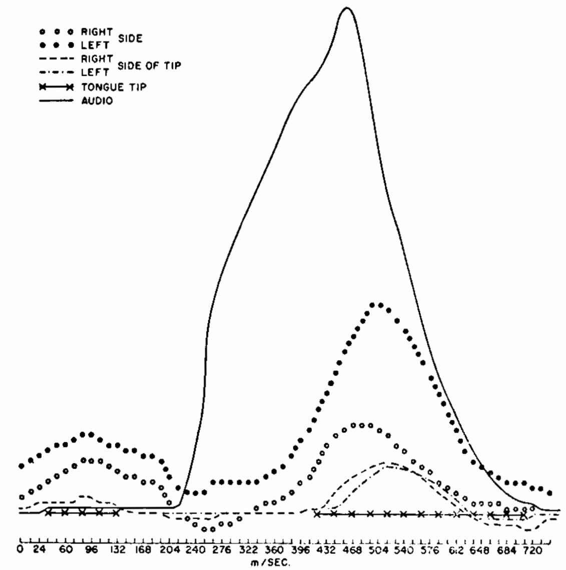

Fig. 2. Normal utterance of 'see'. The illustration was traced from a computer plot print, showing the five channels of lingual pressure and the audio trace on the same time base.

Figure 2 shows a computer produced pressure plot of one speaker saying the syllable /si/. Prior to and associated with the initial part of the syllable is bilateral tongue contact in the molar region. This is followed by pressure reduction probably related to the shift in tongue posture as adjustments are made to utter the vowel portion of the syllable. The amplitude of the lateral pressure curves increase and peak in close time proximity to the amplitude of the voice signal. The dynamics of the tongue activity during the vowel portion of the acoustic signal is well illustrated for such a display. These would be obscured by standard palatography or mid-line radiographic procedure.

To further illustrate the dynamics of tongue action, Figure 3 presents a plot of the attempted utterance /si/ by a child with a 'frontal lisp'. For the speaker the entire tongue moves against the alveolar ridge with essentially the same amount of pressure for the initial part of the syllable. The tongue tip is withdrawn from the transducer just before the utterance of the vowel portion of the signal. A change in tongue control also is noted from the signals from the other transducers, although they never return to base line. The activity seen in this plot could be considered to be internal activity which probably relates to minor muscle adjustments. Because of the close correspondence to the acoustic signal however, the adjustment must be considered as part of the speech event and related to the muscle activity that produces speech

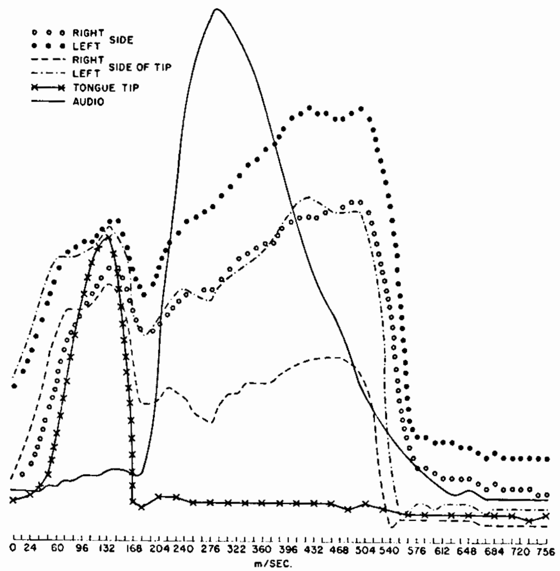

Fig. 3. Lisped utterance of 'see', from a computer plot print. The pressure traces differ from the normal in that pressure by the sides of the tongue tip are greater and are prolonged abnormally long in respect to the audio trace.

sounds. Pressure starts building for this utterance at approximately the same time as for the utterance of the non-lisped /si/. However, pressure continues to build toward a peak after the peak amplitude of the audio signal. The pressure peak is reached after the child has almost finished his utterance.

As illustrated in the above figures, the records obtained from the lingual pressure transducers provide descriptive information about production of speech sounds and syllables in unique dimensions. These dimensions are time and magnitude of tongue contact.

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DISCUSSION

BERRY (Boston)
Do subjects show a left/right asymmetry in non-speech activities such as swallowing?

MCGLONE
Yes, for both spontaneous and command swallow asymmetry in lingual pressure was found.

ROGERS (Toronto)
Have you found anyone with a strongly lateralised [s], where one side of the tongue is quite high and the other low?

MCGLONE
So far from our observations of persons with acceptable speech a strongly lateralized tongue position for /s/ production has not been observed. Greater pressure may occur on one side or the other but tongue contact was present on both sides.

SMITH, T.S. (San Diego, Calif.)
Have you investigated on right handed and left handed subjects?

MCGLONE
Greater lingual pressure on one side or the other in the oral cavity appears to vary regardless of the handedness of the speaker. About half of the subjects studied so far exhibited greater pressure on the left side while most were right handed.

ABRAMSON (Storrs, Conn.)
It would be interesting to run your experiment with the speech sounds in question embedded in running speech. Some of the "secondary effects" that you observed may well turn out to be unstable.

MCGLONE
Collection and analysis of tongue-contact patterns during running speech using the procedure described above is technically difficult. However, we have obtained some of these kinds of data. In running speech, lingual pressure deflections corresponding to phonemic units of the phrase have been observed. A replication of the above study (voiced-voiceless comparisons) using phrases has not yet been conducted. We agree that this would provide a meaningful test of the stability and importance of the "secondary effects" observed for syllables.