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INTRAORAL AIR PRESSURE VARIATIONS FOR CONSONANTAL VOICING DISTINCTION IN SPEECH WITHOUT LARYNGES

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Introduction

In consonant production, when some articulatory resistance exists against the upcoming pulmonary air flow, variable amounts of air pressure are generated in the talker's mouth. This pressure is called intraoral air pressure. Numerous studies have shown that values of intraoral air pressure vary with consonantal voicing status (Arkebauer, Hixon, and Hardy, 1967[1]; Subtelny, Worth, and Sakuda, 1966[2]; Brown and McGlone, 1969[3]; Lisker, 1970[4]; Lubker and Parris, 1979[5] ; Muller and Brown, 1980[6]). There is general agreement among these studies that voiceless consonants have greater peak intraoral air pressure values than their voiced cognates.

These pressure variations associated with voicing contrasts have been attributed primarily to the control of laryngeal and respiratory functions in normal speech (Malecot, 1966[7] ; Arkebauer et al, 1967[1] ; Netsell, 1969[8] ;Klich, 1982[9]). In the production of voiced consonants, the vocal folds are adducted for vibration and the transglottal airflow from the respiratory system is reduced. Therefore, little air pressure is built up in the mouth. In voiceless consonants, on the other hand, the glottis is open and there is more transglottal airflow to generate higher intraoral air pressure. Thus, glottal resistance and intraoral air pressure have been claimed to be closely related. Support for this concept is found in the studies on whispering. In whispering, where there is less glottal resistance contrast, there is less intraoral air pressure difference reported between voiced and voiceless (Soda, Nishida, and Suwoya, 1967[10]; Malecot, 1970[7]; Murry and Brown, 1976[11]). Moreover, in the studies of subglottal pressure by Netsell (1969)[8] , similar subglottal and supraglottal pressure values were recorded for voiceless consonants, but there was less supraglottal pressure than subglottal pressure for voiced consonants. These data have strongly supported the concept that glottal resistance is one of the major factors causing the intraoral air pressure differences between the voiced and voiceless consonants.

Evidence of some supralaryngeal adjustments contributing to the intraoral pressure differences for the consonantal voicing distinction have also been reported by Kent and Moll (1969)[12] , Perkell (1969)[13] , Bell-Berti (1975)[14] , and Westbury (1983)[15] . The relationship between supraglottal cavity size and consonantal voicing is expected mainly because the expansion of the supralaryngeal cavity during the articulatory closure period can explain the maintenance of vocal fold vibration for voiced stops. In stop consonant production, complete articulatory closure is formed at some point above the glottis and high intraoral or supralaryngeal pressure is generated. Consequently, the transglottal pressure gradient, which maintains the vocal fold vibration will be decreased during the consonantal closure of voice stops. As one of the possible aids for sustaining the vibration during the closure period, the supralaryngeal pressure can be decreased by increasing the volume of the supralaryngeal cavity size. Bell-Berti (1975)[14] suggests some active articulatory control for the volumetric expansion of the supralaryngeal cavity.

A challenge was tried by Brown and McGlone (1979)[16] to the notion that the values of intraoral air pressure are varied as a result of articulatory resistance given to the pulmonary air flow. In their experiment, normal adult subjects produced consonant cognate pairs while tightly closing the glottis with a valsalva maneuver. In the peak intraoral pressure values of the voicing pairs, they found the voicing distinction which is typically observed in normal speech. Considering the laryngeal conditions used in this experiment (i.e., the valsalva maneuver), the result indicates that the pressure differences were achieved above the laryngeal resistance. From that result, together with previous studies which suggest strategies for the volumetric change in the supralaryngeal cavity to create the pressure drop for voiced consonants (Rothenberg, 1968[17]; Bell-Berti, 1975[14]), it could be posited that intraoral air pressure is not generated merely as a result of laryngeal resistance. Brown and McGlone even suggest a possibility that intraoral air pressure is phoneme specific. Although this view of intraoral air pressure control is extremely interesting, we need more data to confirm it.

The purpose of the present study was to investigate whether intraoral air pressure for consonantal voicing contrasts can be controlled without aids of pulmonary or laryngeal function. The subjects were alaryngeal talkers who speak with an electric larynx. In alaryngeal speech, the talker's larynx is surgically removed and he breathes through a tracheostoma. When an alaryngeal talker speaks with an electric larynx of a transcervical type, there is no connection between the supralaryngeal and respiratory systems. Neither laryngeal nor respiratory control of speech is available to them. Therefore, controlled variables for the generation and variation of intraoral air pressure in this type of talker is of special interest.

Method

1. <u>Subjects</u>

The subjects for this study were three male laryngectomees, F.B. (63 years), A.S. (66 years), and D.B. (65 years). They speak Standard American English with electric larynges of the transcervical type. They were selected because they have good intelligibility of speech with the electric larynges and because they are unable to use esophageal speech for daily communication. No use of esophageal air was desired in order to avoid contamination in air pressure data. All three subjects have been using the electric larynges for more than two years.

2. Speech materials

The speech materials were 12 utterance types consisting of consonant-vowel-consonant sequences with /p/, /b/, /t/, /d/, /k/, and /g/ for consonants and /ɔ/ and /I/ for vowels (Table 1). For the perceptual experiments of this study, which are not reported in this paper, these utterance types were preceded by a schwa, /ə/, in order to remove Voice Onset Time as a cue for the voicing distinction for the initial consonants. Each utterance type was repeated twenty times, thus making 240 tokens that each subject produced.

3. Data acquisition

Simultaneous aerodynamic, EMG, movement, and acoustic recordings were obtained during the production of the tokens. Intraoral air pressure was recorded with a miniature pressure transducer inserted through a nostril into the oropharynx. EMG signals from the anterior and posterior genioglossus muscle and/or mylohyoid muscle were also recorded for the future investigation of articulatory movements for controlling the supralaryngeal cavity size. These physiological and acoustic signals were amplified and recorded on a multiple instrumentation data recorder, and they were later digitized for computer analyses. All of the experiments, data processing. and analyses were performed at Haskins Laboratories in New Haven, Connecticut, U.S.A.

Results

Figures 1, 2, and 3 show the averaged waveforms of intraoral air pressure for subjects FB, AS, and DB, respectively. In these figures the initial peaks correspond to the intraoral air pressure increase for the initial consonants of the /əcvc/ structures. In this paper, the physiological events of these initial consonants are the point of interest. The vertical lines in the middle of the waveforms correspond to the onset of the consonant release for the initial consonants. As Figures 1, 2, and 3 show, the voiceless consonants are always associated with higher pressure amplitudes than their voiced counterparts in all three subjects. In subjects FB and AS, extremely high intraoral air pressure was produced, while producing very little or almost no air pressure for the voiced stops. Statistical analyses revealed that these differences in the pressure values for the voicing pairs were significant.

Figures 4, 5, and 6 give the distribution of peak intraoral air pressure of the initial consonants for the three subjects. These figures were constructed to show that the values of intraoral air pressure are neatly distributed in the domain of each voicing status. Little overlap is seen with the exception of some overlapping values of /k/ - /g/ contrasts in FB and DB.

Discussion

In normal speech, intraoral air pressure is generated when the outgoing pulmonary air stream meets articulatory resistance. For the increase in intraoral air pressure, the pulmonary air source is considered to be a definite requisite. The present study, however, showed that the intraoral pressure could be prominently increased in the talkers who cannot use pulmonary air source for speech. It must be some supraglottal mechanisms that are responsible for the pressure increase in these talkers.

Variations in intraoral air pressure values associated with consonantal voicing distinctions found in the present study provide an interestly controversial view to the commonly accepted notion for intraoral air pressure variations for consonant production. For all three subjects, the voiceless stops always have higher intraoral air pressure than their voiced cognates. Isshiki and Tanabe (1972)[18] reported similar aerodynamic findings in an excellent alaryneal talker, who also used an electric larynx of a transcervical type. Considering the fact that these talkers had no respiratory or laryngeal systems to control the air pressure values, it is obvious that they used some upper articulatory systems to achieve the pressure difference. It is suggested, therefore, that laryngeal resistance is not necessarily an essential factor for the pressure variations. Evidence of active articulatory control for the volumetric change in oralpharyngeal cavity size was obtained in the physiological data of the present study, although they are not reported in this paper.

Now, as Brown and McGlone (1979)[16] suggested, the role of intraoral air pressure needs to be reconsidered. Contrary to traditional notions, it is likely that the talker actively controls the intraoral air pressure values using as effectively as possible the speech mechanisms available to him. If that is the case, intraoral air pressure variations are not produced as a result of articulatory resistance to the outgoing airflow. It is possible that the talker has specific intraoral air pressure values programmed for specific phoneme production. Data in the present study provide a support to the notion that intraoral air pressure is phoneme specific because all of the alaryngeal talkers somehow managed to achieve intraoral air pressure variations for consonantal voicing distinction despite their apparent anatomical difficulties for pressure generation and variations.

Since it is proposed that intraoral air pressure can be phoneme specific, we should consider the acoustic significance of intraoral air pressure for the generation of some effective perceptual cues for voicing distinctions. It seems possible that higher intraoral air pressure would be associated with higher burst intensity for voiceless stops than for voiced stops. At this point, however, the present study has had technical difficulties in measuring some of the acoustic events. It is regrettable that no useful data can be provided now for this interesting issue.

Conclusion

This study has shown that alaryngeal talkers who speak with electric larynges of a transcervical type did generate and vary intraoral air pressure for stop consonant production. Since they are laryngectomized, it is clearly not respiratory or laryngeal systems that controlled the pressure generation and variation. It is posited that intraoral air pressure is phoneme specific rather than a result of articulatory resistance to the upcoming airflow and that it can be controlled by articulatory mechanisms without laryngeal resistance.

Table 1. Utterance types which were used for the present study.

/əpɔp/	/əpɪp/
/əbɔp/	/əbɪp/
/ətɔt/	/ətɪt/
/ədɔt/	/ədɪt/
/əkɔk/	/əkɪk/
/əgɔk/	/əgɪk/

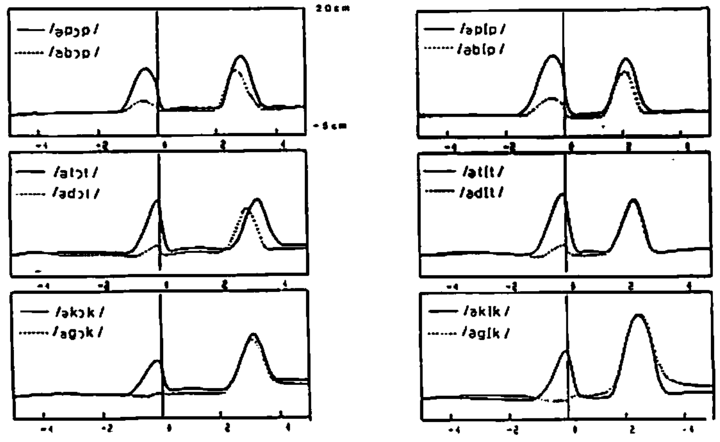

Figure 1. Averaged waveforms of intraoral air pressure for Subject FB. The solid lines represent the voiceless stops and the dotted lines their voiced counterparts.

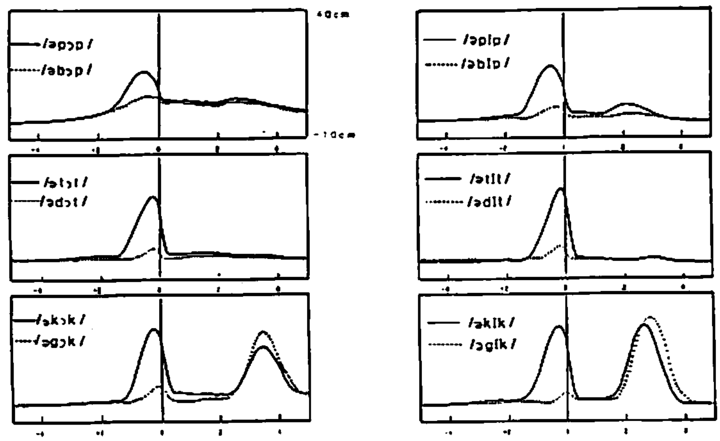

Figure 2. Averaged waveforms of intraoral air pressure for Subject AS. The solid lines represent the voiceless stops and the dotted lines their voiced counterparts.

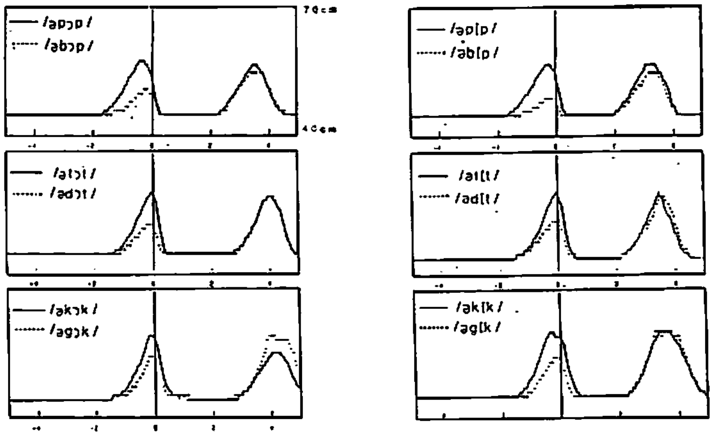

Figure 3. Averaged waveforms of intraoral air pressure for Subject DB. The solid lines represent the voiceless stops and the dotted lines their voiced counterparts.

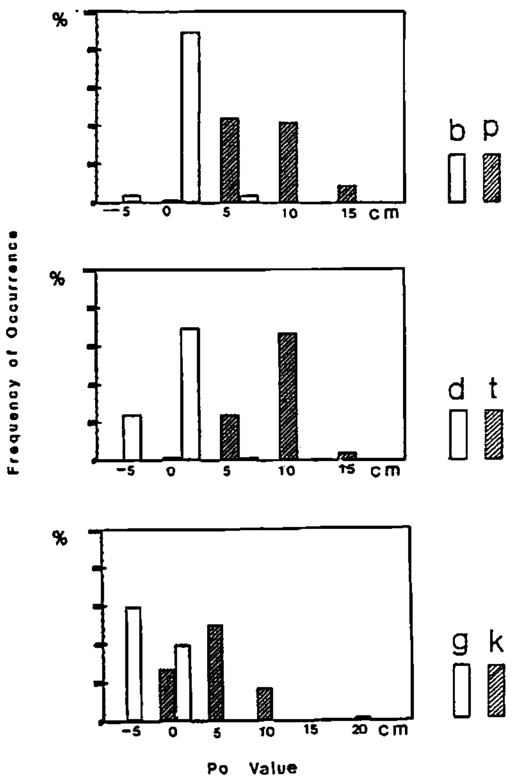

Figure 4. Distribution of peak intraoral air pressure values for Subject FB.

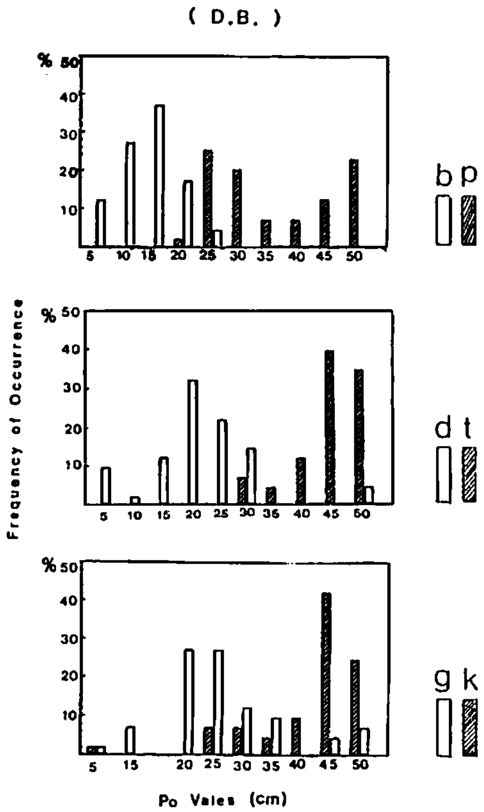

Figure 6. Distribution of peak intraoral air pressure values for Subject DB.

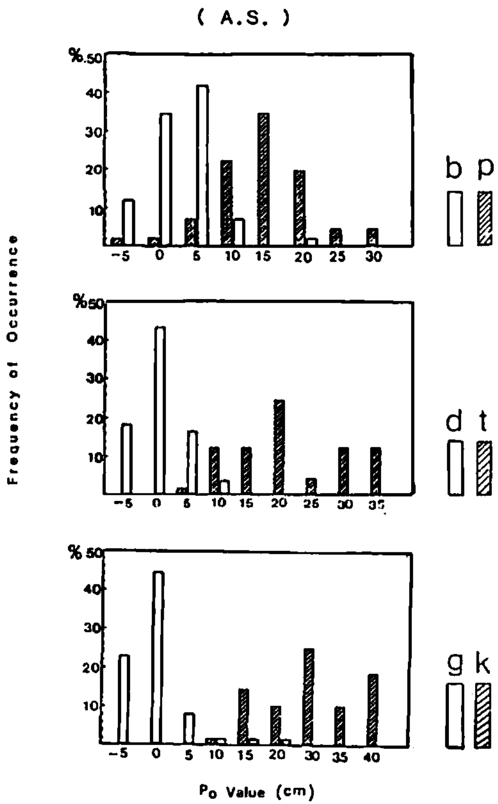

Figure 5. Distribution of peak intraoral air pressure values for Subject AS.

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