PHONETIC FACTORS AFFECTING INTRAORAL AIR PRESSURE ASSOCIATED WITH STOP CONSONANTS

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There presently exists in phonetic literature some confusion as to what phonetic position in which a consonant is placed yields the greatest intraoral air pressures — some studies report medial consonants exhibit greatest pressures associated with their production, while others maintain initial consonants have greater pressures. We are of the opinion that the above confusion concerning phonetic position is primarily related to the speech samples used in previous experiments. Specifically, the majority of studies have incorporated nonsense syllables as the speech sample. Indeed, it goes without saying that syllables can be articulated in a variety of ways with a variety of stresses. Furthermore, the production of nonsense syllables has little resemblance to the speech production process as it occurs during normal connected discourse.

Recently, two studies were reported in which the speech sample consisted of words and sentences. The first of these studies was reported by Lisker (1971) who had only one speaker produce a limited number of words in isolation in which the stop consonants /t/ — /d/ and /p/ — /b/ occurred in various phonetic positions. He concluded that medial consonants exhibited greater peak pressures when compared to initial consonants. In the second study, Brown and his associates (1970) had fifteen speakers repeat thirty-two sentences in which the /p/ — /b/ and /t/ —/d/ were placed in words in the initial, medial and final positions. Unlike Lisker's (1971) findings, Brown *et al.* (1970) reported that generally the consonants appearing in the initial position had greater peak pressures than medial positioned consonants, while final consonants exhibited the lowest peak pressures. It should be obvious that a potential reason for the differences between these two studies is that one used isolated productions of words, whereas the other utilized complete sentence productions — one might suspect that a speaker's production in reciting isolated words would be somewhat different than when producing a sentence. However, whatever the reasons for this apparent discrepancy, the relationship between intraoral air pressure variations associated with consonants appearing in different phonetic positions is unclear. Consequently, the present study was initiated in an attempt to specify more clearly the affect of phonetic environment on intraoral air pressure associated with certain

stop consonants. Sentential material was utilized since it more nearly approximates the normal speech production process.

Figure 1 is a summary of the factors under test. The bilabial voice-voiceless stops /p/ — /b/ and the lingua-dental voice-voiceless stops /t/ — /d/ were the consonants of interest. These consonants were arranged in words which were placed in sentences in such a way as to represent six distinct phonetic environments. Figure 2 demonstrates the bilabial stop /p/ in each of the phonetic environments under test. Similar sentences containing the /b/, /t/ and /d/ stops in the six distinct phonetic environments were also represented in the speech sample.

FACTOR I: CONSONANT TYPE
Levels: (a) Bilabial stops
(b) Lingua-dental stops

FACTOR II: VOICING
Levels: (a) Voiced
(b) Unvoiced

FACTOR III: PHONETIC ENVIRONMENT
Levels: (a) Initial position (initiates sentence)
(b) Medial position-zero juncture (within word)
(c) Medial position-open juncture (consonant ends one word and begins the next)
(d) Medial position-sustained juncture (between clause environment)
(e) Final position-falling juncture (consonant ends a declarative sentence)
(f) Final position-rising juncture (consonant ends a question)

FACTOR IV: SUBJECT SEX
Levels: (a) Male
(b) Female

Fig. 1. Phonetic factors affecting intraoral air pressure associated with stop consonants

PHONETIC ENVIRONMENT (Consonant of interest is in italics)

1. Initial position (initiates sentence)
   *P*ete missed the boat.
2. Medial position-zero juncture (within word)
   This is the to*p*ic for today's discussion.
3. Medial position-open juncture (consonant ends one word and begins the next)
   This is the to*p* *p*ick for today's race.
4. Medial position-sustained juncture (between clause environment)
   When you reach the to*p*, *p*ick up the rock samples and send them down.
5. Final position-falling juncture (consonant ends a declarative sentence)
   Talk is chea*p*.
6. Final position-rising juncture (consonant ends a question)
   You think this is chea*p*?

Fig. 2. Phonetic factors affecting intraoral air pressure associated with stop consonants

Five young adult males and five young adult females repeated the experimental sentences. Intraoral air pressure was sensed by a tube constructed to fit around the premaxillary arch, around and perpendicular to the last molar as shown in Figure 3.

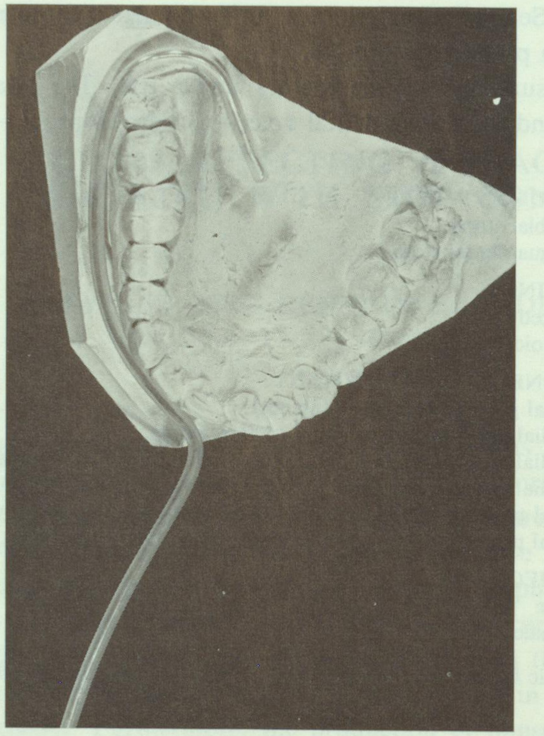

Fig. 3.

Outside the mouth this tube was attached to a differential pressure transducer and in turn to one channel of an oscillographic writer. The speakers' vocalizations were recorded on tape and also displayed on another channel of the oscillograph. Each speaker was instructed to read each experimental sentence three times in an identical manner at a comfortable vocal intensity level. The peak intraoral air pressures for each consonant of interest were measured from the oscillographic traces for each of the three utterances and a mean calculated — the mean air pressures are reported in cmH_2O.

All the factors in this study were subjected to an analysis of variance. For the sake of time, the results of this analysis are summarized for the six phonetic environments only, and are presented in Figure 4. Figure 5 shows tracings of actual air pressure waveforms from one speaker demonstrating these findings. The consonant /p/ is used as the example — the /p/ of interest is underlined as well as its associated pressure pulse. As can be seen, the highest peak pressure occurred for the open juncture environment shown for 'to*p* *p*ick' in the third trace. Note that although the consonant /p/ ends one word and begins another, there is only one pressure pulse associated with its production. Contrast this with the production of the same words in the sustained juncture environment in the fourth trace — a double pressure pulse is associated with this production. Notice that the peak pressure for the word '*p*ick' is

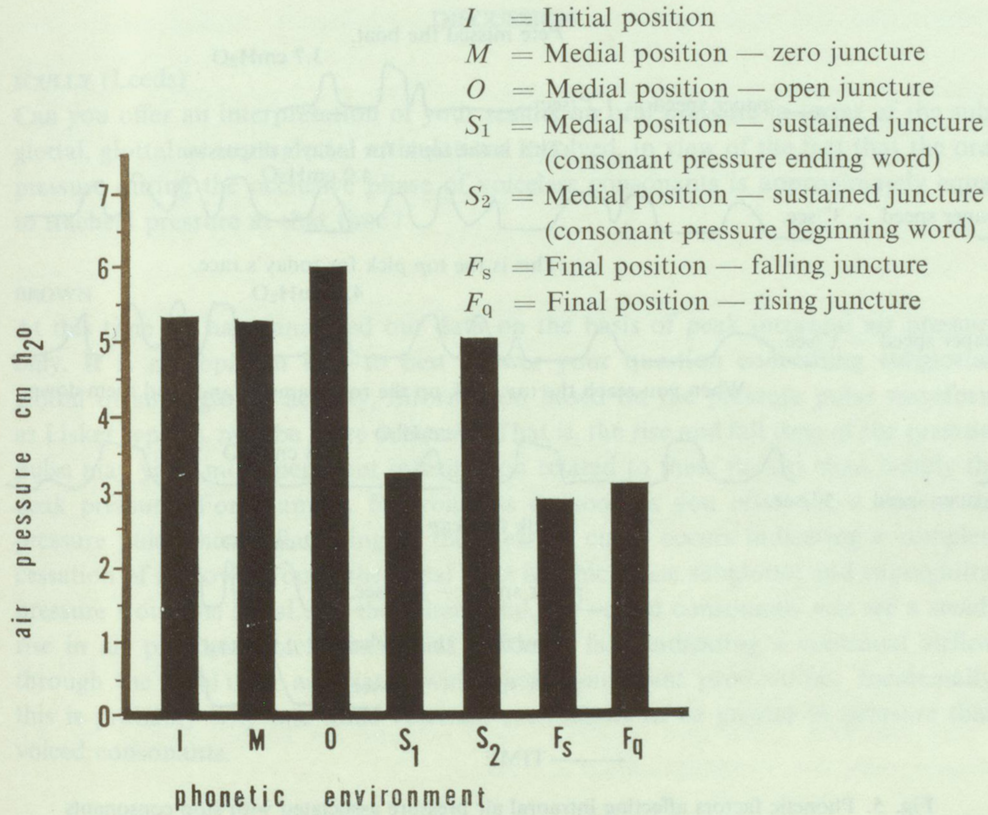

Fig. 4.

similar to the initial /p/ consonant in trace one, while the peak pressure for the /p/ in 'to*p*' is similar to the final /p/ in 'chea*p*' shown in the fifth and sixth traces. The first trace represents the /p/ initial position in '*P*ete', while the second trace represents the medial position-zero juncture in 'to*p*ic'. Notice that for this initial and medial position the peak air pressure is nearly the same. Also, note that the peak pressure for the /p/ in 'chea*p*' occurring at the end of a declarative sentence is identical to the peak pressure for the /p/ in 'chea*p*' ending a question.

In conclusion, these results for phonetic position of consonants support the previous results of Brown *et al.* (1970), while they disagree with Lisker's (1971) findings. However, it should be stressed that the present study and Brown *et al.* included a considerably larger speaker sample than previous reports along with more diversified and representative speech samples. Furthermore, we offer the suggestion that 'medial' position from a 'production' aspect should be better defined. Indeed, it would appear from our results that a medial position per se, does not functionally exist during connected discourse. Except for the medial position — open juncture, the other medial positions were similar to initial or final productions, at least as demonstrated by peak intraoral air pressure. Consequently, it may be more accurate to classify

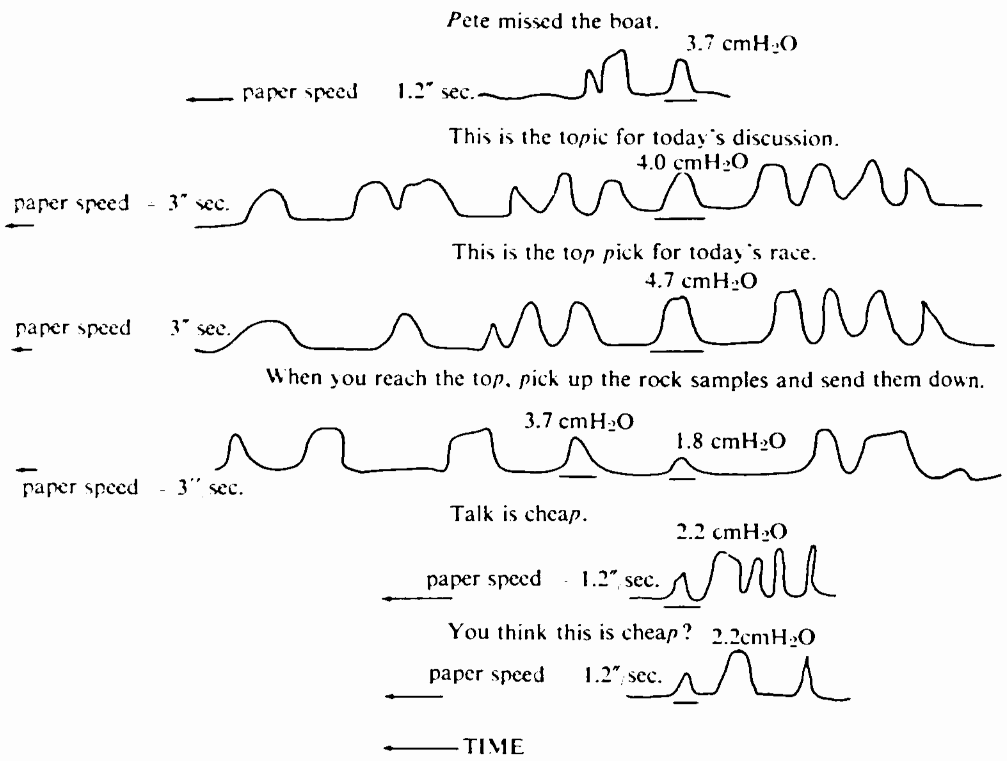

Fig. 5. Phonetic factors affecting intraoral air pressure associated with stop consonants

consonants appearing in medial environments as was done in this study — zero juncture, open juncture, or sustained juncture, as the case may be.

Finally, this study has concerned itself primarily with peak intraoral air pressure. The earlier study by Lisker discussed the importance of the characteristic waveform shape of the air pressure pulse, i.e., rise time and decay time of the pressure pulse. We agree with Lisker that such characteristics of the pressure pulse yields significant information concerning consonant articulation during connected speech and further experimentation along these lines has been initiated.

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1971 *Language and Speech* 13:215-230.

DISCUSSION

SCULLY (Leeds)
Can you offer an interpretation of your results on oral pressure in terms of the subglottal, glottal or supraglottal articulations involved, in view of the fact that the oral pressure during the occlusive phase of voiceless consonants is approximately equal to tracheal pressure at that time?

BROWN
At this time we have analyzed our data on the basis of peak intraoral air pressure only. It is my opinion that to best answer your question concerning subglottal, glottal or supraglottal activity, information based on the pressure pulse waveform as Lisker reports, may be more adequate. That is, the rise and fall time of the pressure pulse may yield more pertinent information related to these factors than merely the peak pressure. For example, for voiceless consonants you often see a rise in the pressure pulse then a flattening of the pressure curve occurs indicating a complete cessation of airflow through the vocal tract in which case subglottal and supraglottal pressure would be equal. On the other hand, for voiced consonants you see a steady rise in air pressure which peaks and suddenly falls indicating a continual airflow through the vocal tract associated with voiced consonant productions. Incidentally, this is probably why one finds voiceless consonants to be greater in pressure than voiced consonants.