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STOP DURATION AND VOICING IN ENGLISH

A good deal of what is known about the acoustic cues to the voiced-voiceless contrast in English stop consonants is due to the work of Pierre Delattre and his colleagues of the Haskins Laboratories (Delattre, 1958; Liberman, Delattre and Cooper, 1958: Liberman *et al.*, 1959). A recent summary statement of Delattre's (1965) emphasizes the multiplicity of acoustic features to which the listener attends in deciding whether a stop belongs to the /bdg/ or the /ptk/ set. This multiplicity is not hopeless diversity, however; some, and perhaps all, of the acoustic cues to the voicing contrast are certainly interconnected as consequences of a much simpler articulatory difference between the two categories of stops. Thus, Arthur Abramson and I have for some time been trying to understand many of these features as the acoustic consequences of a difference in the size of glottal aperture (Lisker and Abramson, 1964, 1965, 1967, 1968; Abramson and Lisker, 1965, 1968a, 1968b). Two features, very likely not independent of one another, are less plausibly considered to be related directly to glottal aperture; these are the durations of stop closure and of an immediately preceding syllabic. In the present discussion attention will be limited to the feature of closure duration.

In a paper (Lisker, 1957) published some years ago I reported finding that the voiced-voiceless contrast of English stops may have, as one of its phonetic manifestations, a difference in the duration of closure. The evidence was a set of spectrographic measurements showing that in intervocalic position within trochaic words /p/ is regularly longer than /b/. Moreover, there were data from a series of tape-cutting experiments to indicate that this difference is of some perceptual significance. Since these findings are consistent with certain current views which relate the /ptk/ : /bdg/ contrasts to a '*fortis-lenis*' difference[1], and this in turn to a long-short difference, it is perhaps worth emphasizing the fact that medial /p/ and /b/ were found NOT to differ significantly EXCEPT when preceded by a stressed syllabic and followed by an unstressed one.[2] Moreover, it was also pointed out in my paper of 1957 that the

[1] Thus Roman Jakobson, C. Gunnar Fant and Morris Halle state that "in consonants tenseness is manifested primarily by the length of their sounding period, and in stops, in addition, by the greater strength of the explosion".

[2] Perhaps because this point was made in a footnote in my paper (1957, footnote 6, p. 43), A. Malécot (1961) interpreted my data as lending strong support for the Jakobson, Fant and Halle statement cited in footnote 1.

measure of closure duration is further limited in usefulness because, in the nature of things, an acoustical measure of closure duration cannot be applied to stops either in initial position or finally when there is no acoustic indication of a release. The purpose of the present discussion is to present some additional measurements of stop closure duration, this time derived not from acoustic records at all, but taken instead from records of the intraoral air pressure developed during stop productions in various positions within isolated words.[3] These new data corroborate the earlier acoustic measurements of medial stop durations, and also enable us to define a measure of closure duration for stops in utterance-initial position.

Pressure traces of the kind shown in Figure 1 were obtained by introducing a pressure transducer (Statham Pressure Transducer Model P 23-BB) into the hypopharynx

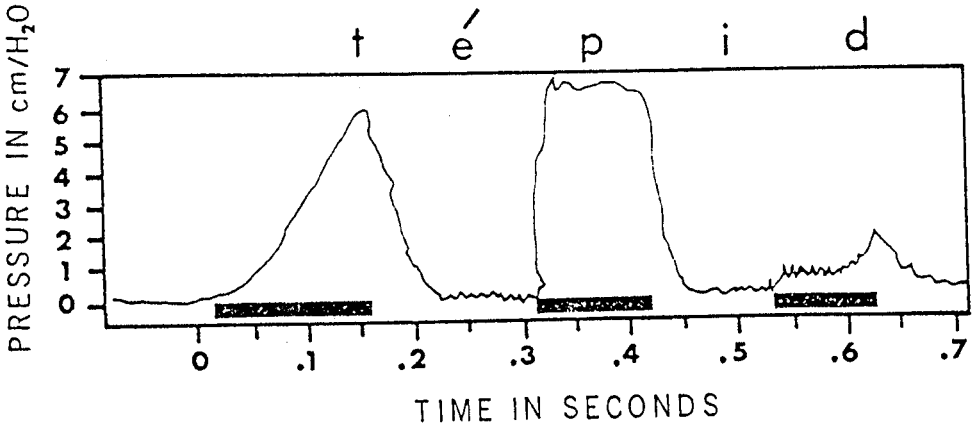

Fig. 1

by way of the nose and recording its output on one channel of a penwriter. Simultaneous recordings of the speech waveform and glottal signal on other channels of the penwriter made it a fairly simple matter to correlate aspects of the intraoral pressure profile for a given utterance with features of the acoustic signal, and hence indirectly with the sequence of articulatory events performed by the subject. If we suppose that when oral closure occurs there is a rise in the intraoral pressure,[4] and that the point in time at which the pressure drops sharply corresponds to the release of the occlusion, then we have in the interval between these two points of pressure change a measure of the duration of the stop closure. In the representative pressure trace of the word 'tepid' (Figure 1) such intervals, indicated by the horizontal bars, have durations of 150, 105 and 95 msecs. for the initial, medial and final stops respectively. There is reason to be cautious about accepting the value determined for the

[3] This experiment is described in Lisker, 1965.

[4] More precisely, to be sure, we must suppose that the air pressure begins to rise before the mouth is completely closed.

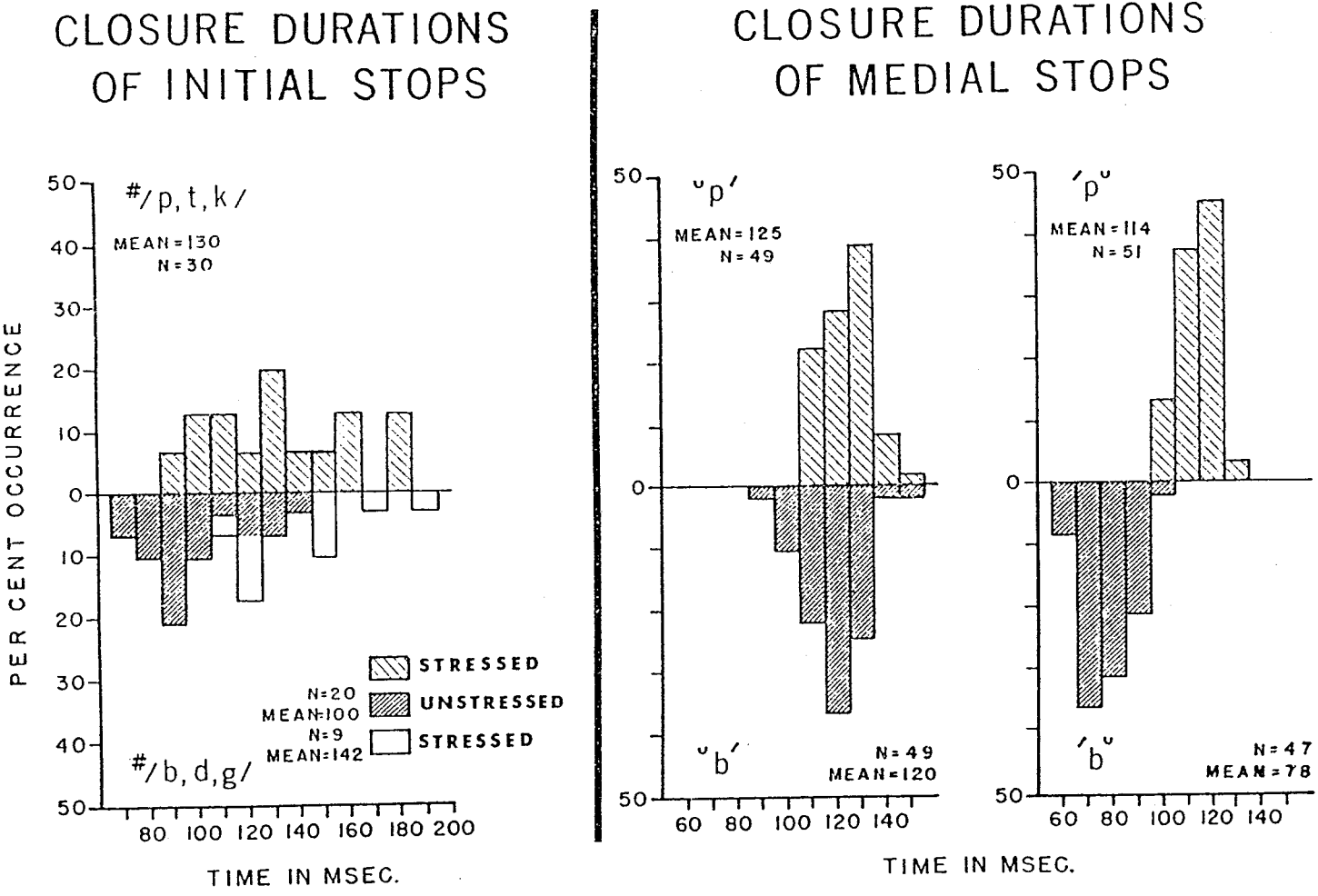
CLOSURE DURATIONS OF INITIAL STOPS
#/p, t, k/
MEAN=130
N=30
#/b, d, g/
N=20
MEAN=100
N=9
MEAN=142
STRESSED
UNSTRESSED
STRESSED
PER CENT OCCURRENCE
50
40
30
20
10
0
10
20
30
40
50
80 100 120 140 160 180 200
TIME IN MSEC.
CLOSURE DURATIONS OF MEDIAL STOPS
ˇp´
MEAN=125
N=49
ˇb´
N=49
MEAN=120
´pˇ
MEAN=114
N=51
´bˇ
N=47
MEAN=78
50
0
50
60 80 100 120 140
TIME IN MSEC.

Fig. 2

final stop as a true measure of its closure duration,[5] but the duration of 105 msecs. for the medial /p/ is in very close agreement with the value obtained by measuring the length of the formantless interval in the spectrogram for the same utterance token. This agreement argues for the reasonableness of the measurement convention adopted.

The data to be reported are derived from pressure profiles recorded from ten productions of a set of twenty disyllabic utterances, all by a single talker. The items were pronounced in isolation in a 'normal conversational' manner at a fairly uniform rate and loudness level. Each utterance was produced with unemphatic declarative sentence intonation. Values obtained for the initial and medial stops included in the test utterances are given as frequency distributions in Figure 2. From these displays it is very clear that, if these values represent durations of stop closure, then the two categories of stops differ dramatically in this feature only in medial post-stress position, where mean values and ranges are remarkably similar to those determined spectrographically.[6] It is in just this position that a durational difference in the syllables preceding the stops is most apparent. Initially and in medial position after unstressed syllabics the voiced and voiceless categories differ only negligibly in duration. There is, to be sure, a difference between the two categories in respect to closure duration, in that stress conditions the duration of the voiced stops, but plays essentially no role in the case of the voiceless category. The durational differences between voiced stops preceding stressed and unstressed syllabics are certainly as much to be remarked as the difference between voiced and voiceless categories in the one position where a serious difference is found.

From the above it appears that a difference in closure duration is far from being a regular feature of the contrast between English /ptk/ and /bdg/. It thus becomes impossible to assert both that a durational difference is the regular mark of a *fortis-lenis* contrast and that /ptk/ are everywhere *fortes* as contrasted with *lenes* /bdg/. If the vitality of the *fortis-lenis* view of the contrast is maintained, then the durational feature is no more serviceable as an index of force of articulation than other proposed measures have proved to be. If, on the other hand, it is supposed that the two stop categories differ in force of articulation only where they differ in duration, then the *fortis-lenis* difference no longer can be said to fulfill the distinctive feature role as this is usually understood.

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[5] Articulatory changes other than release of the stop occlusion may play major roles in effecting a drop in the intraoral air pressure.

[6] "Closure durations for *p* fall in the 90–140 msec. range, with an average value of about 120 msecs., while values for *b* vary from 65 to 90 msecs., with an average of 75 msecs." (Lisker, 1957, 43). However, a more recent study by Sharf (1962) reports mean values of 92 and 60 msecs. for *p* and *b* respectively. Whether the differences in the values given in the two reports are substantive or merely due to different measuring conventions is not clear, but it should be noted that the ratios of *b* to *p* closure durations are almost identical.

REFERENCES

Abramson, Arthur S. and Leigh Lisker,

1965 "Voice Onset Time in Stop Consonants: Acoustic Analysis and Synthesis", *Rapports du 5e Cong. Intl. d'acoustique* (Vol. Ia, Conf A51).

1968a "Laryngeal Behavior, the Speech Signal and Phonological Simplicity", *Proc. 10th Intl. Cong. of Linguistics*, Bucharest 1967.

1968b "Discriminability Along the Voicing Continuum: Cross-Language Tests", *Proc. 6th Intl. Cong. Phon. Sci.*, Prague 1967.

Delattre, Pierre,

1958 "Les indices acoustiques de la parole", *Phonetica* 2: 108–18, 226–51.

Jakobson, Roman, C. Gunnar Fant and Morris Halle,

1963 *Preliminaries to Speech Analysis* (Cambridge, Mass., MIT Press).

Liberman, Alvin M., Pierre C. Delattre and Franklin S. Cooper,

1958 "Some Cues for the Distinction Between Voiced and Voiceless Stops in Initial Position", *Language and Speech* 1: 153–67.

Liberman, Alvin M., Frances Ingemann, Leigh Lisker, Pierre C. Delattre and Franklin S. Cooper,

1959 "Minimal Rules for Synthesizing Speech", *J. Acoust. Soc. Am.* 31: 1490–99.

Lisker, Leigh,

1965 "Supraglottal Air Pressure in the Production of English Stops", *Haskins Laboratories Status Report on Speech Research* 4.

Lisker, Leigh and Arthur S. Abramson,

1964 "A Cross-Language Study of Voicing in Initial Stops: Acoustical Measurements", *Word* 20: 3. 384–422.

1965 *Proc. 5th Intl. Cong. of Phon. Sci., Munster*, 1964 (Basel, S. Karger), pp. 389–91.

1967 "Some Effects of Context on Voice Onset Time in English Stops", *Language and Speech* 10: 1–28.

1968 "The Voicing Dimension: Some Experiments in Comparative Phonetics", *Proc. 6th Intl. Cong. Phon. Sci., Prague*, 1967.

Malécot, André,

1961 The Effectiveness of Inter-Oral Air-Pressure-Pulse Parameters in Distinguishing Between Stop Consonants", *Phonetica* 14: 65–81.

Sharf, D.J.,

1962 "Duration of Post-Stress Intervocalic Stops and Preceding Vowels", *Language and Speech* 5: 26–30.