

Transillumination of the Larynx in Running Speech*

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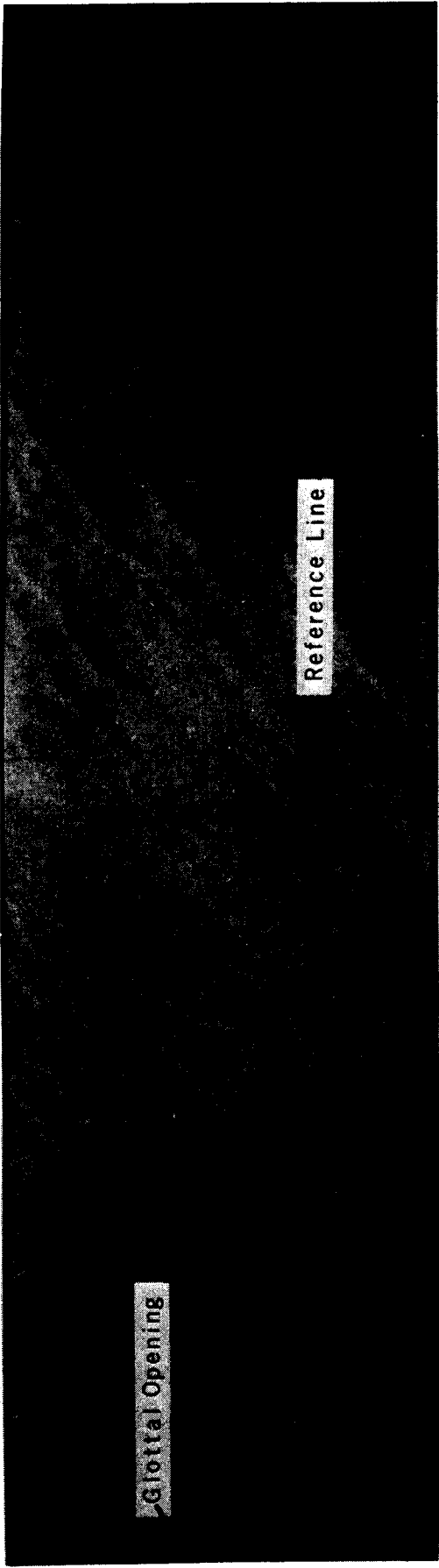
It has become increasingly clear to us that if we are to account in any simple way for all the acoustic features and physiological measures associated with the voiced-voiceless contrast in English, we must refer them back to events involving the larynx and to the timing of those events in relation to supraglottal gestures. The work on transillumination of the larynx reported by Sonesson in 1960 suggested that this technique might be appropriate for getting the most direct kind of data on the dynamics of laryngeal behavior during production of those sounds, the stop and fricative consonants, for which voicing is distinctive.

In brief, the technique we use involves directing a beam of light down on the glottis and placing a photocell against the throat below the thyroid so as to pick up the light transmitted through the open glottis and the tissues of the neck. Careful positioning of light and photocell pickup permitted satisfactory light level registration when the subject breathed quietly (glottis open); virtually zero light was transmitted when the breath was held (glottis closed). Variations in light intensity recorded during speech activity showed great consistency for repetitions of the same utterances. For the most part those variations could be reasonably ascribed to variations in the area of glottal aperture. To be sure, there were occasional

random fluctuations, even after the purely instrumental troubles were under control. We suppose that they reflect some sort of articulatory "noise" such as jostling of the light by the epiglottis or changes in the position of the larynx.

In the first trials, the light source was a high-intensity Xenon arc whose output was conducted through a fiber optics bundle. This was later replaced by a sub-miniature incandescent bulb introduced directly into the pharynx. In both cases it was possible to achieve good placement of the light beam with minimal disturbance of articulation by going in through the nose. The transmitted light was picked up by a red-sensitive photomultiplier tube with a light cone. The output was stored on magnetic tape for later display in the form of oscillograms such as the one shown in Slide 1. The upper trace, labelled "glottal opening," shows the variation in light registered by the photocell as the subject pronounced the sentence, "Don't put a dirty tape around the tube." Gross opening of the glottis is indicated for the four voiceless stops in the sentence. The intervals of small aperture are seen on the "glottogram" as low amplitude modulation at the frequency of the voice fundamental. We can also see how the glottis shifts from the open position of quiet breathing to a closed one just before the onset of speech, and how it returns to an open position after the cessation of speech activity. In addition to the glottogram and the acoustic waveform, marked "speech wave" on the display, we also recorded simultaneously the outputs of a throat microphone and a pressure transducer placed so as to measure the intraoral air pressure. Though these records have not yet been completely analyzed, they have been useful in enabling us to correlate features of the glottogram with other articulatory events.

The preliminary data now to be described represent the first crude analysis of recordings from a single subject reading



Glottal Opening

Reference Line

D o n't—p u t—a—d i r t y—t a p e—a r o u n d—the—t u b e.

a set of sentences selected to include all the English stop and fricative consonants in a variety of positions. In analyzing the glottograms and other records, we have begun by classifying these sounds simply on the basis of 1) whether or not there was an indication of gross opening of the glottis, and 2) whether or not there was any observable interruption of pulsing. In making this rough classification we limited attention, for the time being, to the stops and fricatives in utterance-medial position between vowels and other characteristically voiced sounds. Moreover, we excluded from consideration items of doubtful linguistic status. Slide 2 gives the distributions of stop and fricative phonemes with respect to these two articulatory distinctions, considered separately. We found it advisable, in the case of the voiceless stops and the voiced fricatives, to distinguish between items on the basis of whether they precede stressed or unstressed syllabics. From the display we see that, in the case of the stops, the voiced and voiceless categories are almost perfectly sorted on the basis of presence versus absence of either glottal opening or interruption of pulsing. For /ptk/, especially in unstressed position, there are several items whose glottograms fail to show any opening of the glottis, and others for which there is no apparent break in pulsing. For the fricatives the picture is slightly more complicated. Here the voiceless set shows glottal opening and interruption of pulsing for virtually all items, independently of stress condition, but the voiced set also includes items produced with open glottis, as well as a few with interruption of pulsing. In comparison with the stops, the fricatives appear to differ a bit more sharply with respect to pulsing interruption than to glottal opening. That our records should show such a high incidence of glottal opening for the voiced fricatives as compared with the voiced stops is not unreasonable if we suppose that a well-formed

fricative requires audible turbulence, and that the airflow needed for this is most easily supplied when the glottis is partially open. In this connection, it is interesting to note that there are differences within the class of voiced fricatives: it is almost exclusively the fricatives with higher levels of noise intensity, primarily /z/ and /ʒ/, that show opening of the glottis as the normal accompaniment of the oral constriction.

If, instead of considering the two features of glottal aperture and pulsing continuity separately, we take their four possible combinations of conditions together, then we find the consonants distributed as shown in Slide 3. It would seem that this represents some slight improvement in the resolution of voiced and voiceless categories. For example, two of thirteen cases of /ptk/ with unbroken pulsing were produced with the glottis in an open position. For 98% of a total of 312 consonant tokens recorded, the situation can be summarized as follows: 1) the voiceless stops were produced with either opening of the glottis or interruption of pulsing, or both; 2) the voiced consonants, both stop and fricative, were produced without interruption of pulsing; and 3) the voiced fricatives were produced with either an open or a closed glottis, and this distinction generally matched the difference between fricatives of high and low intensity. From our classification on the basis of glottal aperture and pulsing features we should then put fricatives of the second kind together with the voiced stops.

By and large, the preliminary analysis of our transillumination records is encouraging. To be sure, there are certain questions raised by the data that can only be resolved after the observational technique has been much further developed. Thus, for the moment, we can do little more than make an educated guess as to just how the opening of the glottis is performed under each of the conditions of pulsing in running speech.

GLOTTIS + PULSING

| | OPEN | | CLOSED | |
|------------|-------------------|------------|----------|------------|
| | % Broken | % Unbroken | % Broken | % Unbroken |
| STOPS | 3 | 3 | 2 | <u>92</u> |
| | <u>79</u> | <u>10</u> | <u>8</u> | 2 |
| FRICATIVES | 3 | <u>72</u> | 0 | <u>25</u> |
| | <u>97</u> | 1 | 1 | 0 |
| | /bdg/ (N=66) | | | |
| | /ptk/ (N=106) | | | |
| | /vǝzz̥/ (N=68) | | | |
| | /fθss̥/ (N=72) | | | |

Nevertheless, much information is promised by the records as they stand, and awaits only the completion of a detailed quantitative study of the durations, magnitudes and relative timing of the laryngeal gestures of opening and interruption of pulsing. But even on the basis of our first crude analysis it appears that much of the complexity encountered in studying the voiced-voiceless differences of English in its auditory, acoustic and physiological aspects is obviated by referring to the relatively simple differences in laryngeal behavior.

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