ELECTRICAL GLOTTOGRAPHY

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Our study was concerned with a glottograph of the Fabre type belonging to the Laboratory of Phonetics in Prague. The principle of the Fabre glottograph is that the movements of the vocal folds are picked up as an electrical resistance change between two electrodes placed on each side of the thyroid cartilage.

Fig. 1 shows the signal response of the Fabre glottogram when a relay suddenly increases a resistance in parallel with the electrodes. This temporary resistance increase is associated with an upward deflection of the glottogram curve. Two different lower limiting frequencies are used in the glottograph depending on which purpose it is used for. The direct output of the glottograph with a time constant of 4 sec, displays a rather clean rectangular response. The built-in amplifier curve shows a waveform distortion typical of the 25 msec time constant. As seen from B this distortion is not serious in studies of stationary phonation, providing the duration of the pitch cycle is not excessively long.

Once the vocal cords have opened in their full length a further separation does not affect the resistance much. Thus the flat top of the cycle. On the other hand, once the vocal cords, when closing, have made contact at some point there will follow a further rapid resistance decrease because of the contact progressing horizontally and vertically, thus offering an increased area of conductance for the glottograph current. The following phase from maximum closure to opening is generally more gradual at a low voice pitch. This is to be expected in view of the axial component of the vocal cord movement which during the closed period displaces the area of contact upwards whilst this area is decreasing. One can often identify a point of contact break as indicated by a sudden change of the slope of the glottogram curve.

The outstanding feature of the Fabre glottogram is the extremely rapid resistance fall when the cords reach contact in the closing phase. It is therefore well suited for measuring the fundamental frequency in speech.

The Sonesson photo-electrical glottography provides a measure of the cross-sectional area at the level of maximum narrowing in the glottis. To a first order of

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approximation this area as a function of time is proportional to the flow of air through the glottis, as theoretically predicted by van den Berg et al (1957). It is also known that inverse filtering of the current from a pressure microphone with extended low frequency response provides a measure of this glottal flow. We can in Fig. 2 compare these two methods with the Fabre glottogram.

In order to bring out the synchrony with the acoustic flow in C and D, we have corrected for a 1 msec latency in the inverse filter, as indicated by the displacement of the time scales. We can now observe that when the electrical glottogramm in the ascending opening phase has reached the saturated flat level, the glottal pulse flow has already reached one-half of its peak value. This should be the instant when the glottal slit has reached a state of maximal length while the cords continue to separate. At the instant when the electrical glottogram signals the first contact of the cords, the air pulse is almost but not quite terminated.

In Fig. 3 there is displayed the oscillogram of three sentences and the direct output of the Fabre glottograph below. The time scale is compressed in this figure. Well ahead of the phonation the resistance keeps falling by a magnitude greater than the amplitude of periodic excursions within the voiced portion. To what extent this is a result of overall changes in the spatial distribution of muscle mass and to what extent it reflects the successive closing of the arythenoids is hard to say.

In A of Fig. 3 we see the typical excursion of the base line upward during the voiced occlusion of /*b*/ whilst the voicing ripple successively decays in amplitude. In less stressed articulations of voiced stops the glottograph oscilations retain rather constant amplitude during the voiced occlusion. In the unvoiced stop gap of /*k*/ there is a similar but more pronounced increase of the resistance signifying a corresponding opening movement. The extent of this never reaches the value of rest before the sentence.

C finally shows that a glottal stop inserted to function as a boundary marker between two morphemes, one ending with a vowel and the other starting with a vowel. The resistance retains a value even lower than in the preceding and following voiced segments. This is natural in view of the cords being tightly pressed together.

Preliminary studies of the glottogram mean resistance as a correlate of the distinctions between stressed and unstressed syllables and as a factor influenced by the Swedish word accent 1 (acute) and accent 2 (grave) have been undertaken but these are not conclusive enough to deserve a detailed discussion. There is some indication that a stressed vowel has a lower resistance than an unstressed vowel but this is not quite consistent.

The Fabre glottograph, when adjusted to have a long time constant, is a valuable instrument for indirect studies of the voice mechanism as well as of laryngeal articulations. It is recommended as a supplement to inverse filtering or optical glottography. The typical feature of an extremely well developed discontinuity in the closing phase could be made use of in speech analysis as a reference for time domain voice frequency analysis.

REFERENCES

van den Berg, Jw., Zantema, J. T., and Doornenbal, Jr., P.: "On the Air Resistance and the Bernoulli Effect of the Human Larynx", *J. Acoust. Soc. Am.* 29 (1957), 626—631.

Sonesson, B.: *On the Anatomy and Vibratory Pattern of the Human Vocal Folds, Acta Oto-Laryngologica*, Suppl. 156 (Lund 1960).

Further references see in *STL-QPSR* 4/1966 (Fant, G., Ondráčková, J., Lindqvist, J. and Sonesson, B.)

DISCUSSION

Fischer-Jørgensen:

Thanks to a visit by dr. Ondráčková to Copenhagen we have also had the opportunity to work with Fabre's glottograph and we got very similar results for consonants. Difference according to vowel quality intonation and stress seem, however, to indicate that the curves may be influenced by other factors than the degree of opening of the glottis, e.g. the gross movements of the larynx. We should suggest experiments with smaller electrodes having a well defined placement (see Annual Report of the Phonetic Institute of Copenhagen 1967).

Gsell:

I would be interested in technical data about the device of the glottograph you built. In Grenoble we tried to construct the classical glottograph as described by Fabre. The results we obtained with this basic device were close to those obtained with an intensity-meter on voiced and unvoiced parts of speech.

Ondráčková, Lindqvist, Fant:

Ad Gsell: The technical design is not much different from that used by Fabre and Husson, see also STL-QPSR 4/1966. In our experience the glottograph trace differs substantially from that of an intensity record. The amplitude of the glottal periods are almost constant as long as the phonatory mode is constant. The characteristic feature of the glottographic wave shape is the rapid step signalling the instant when the cords make contact which can be adopted as a pitch period marker.

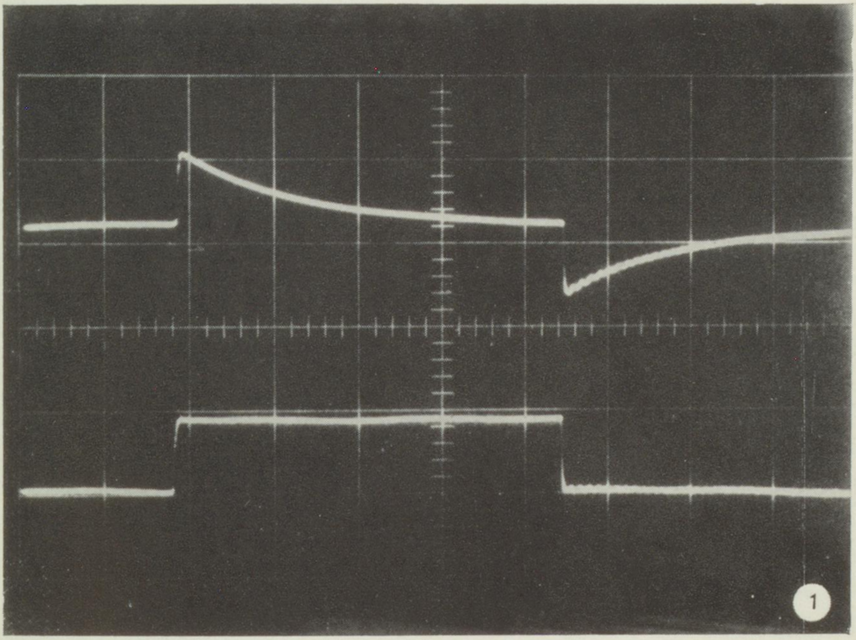
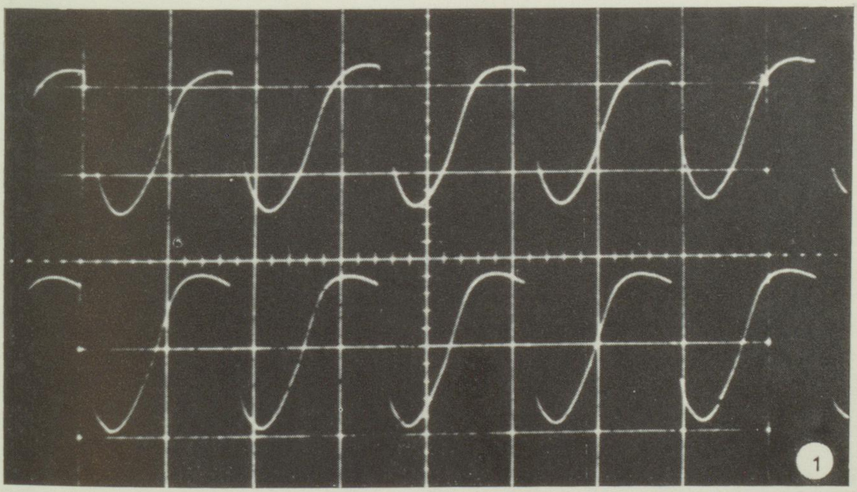


Fig. 1. A. Response of the glottograph to a rectangularly shaped resistance increase. The direct output with a long time constant preserves the waveform.



1. B. Typical glottogram, male subject, long time constant above, short time constant below synchronously recorded. ($\tau = 4$ sec; $\tau = 0{,}025$ sec)

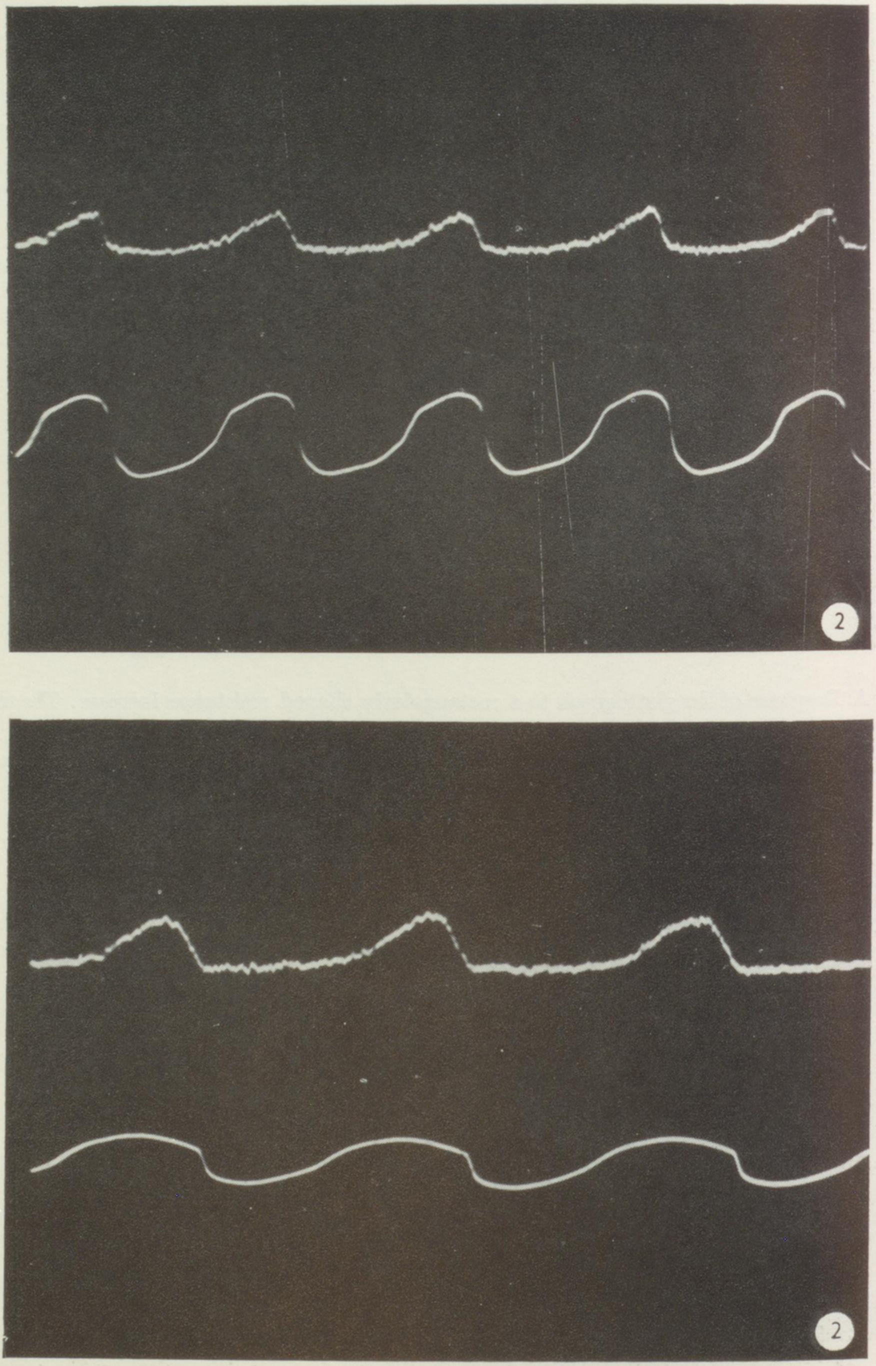


Fig. 2. A, B. Synchronous recordings of optical (above) and electrical glottogram (below), speaker (GF).

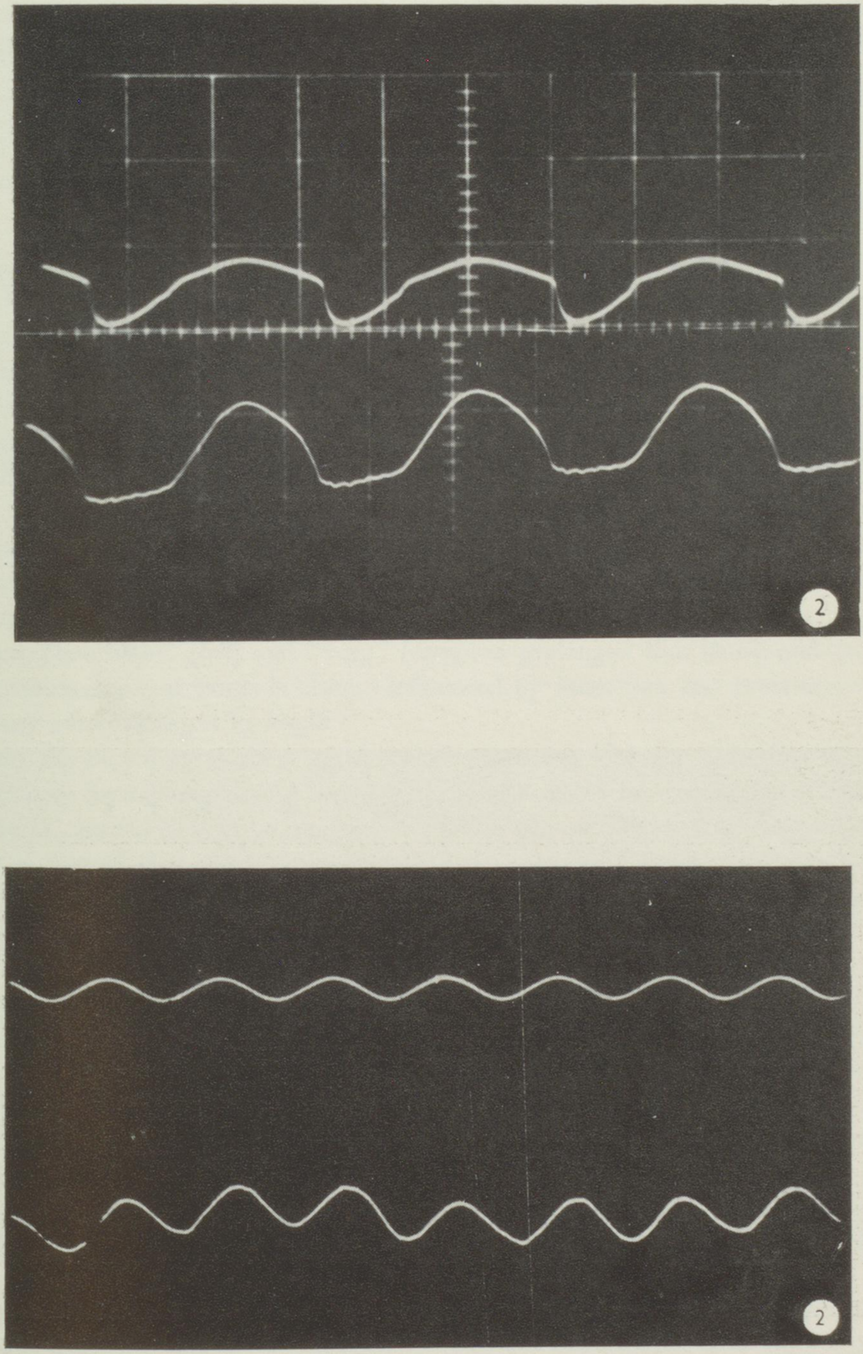


Fig. 2. C, D. Electrical (above) and inverse filter glottal flow (below), subject (JS).

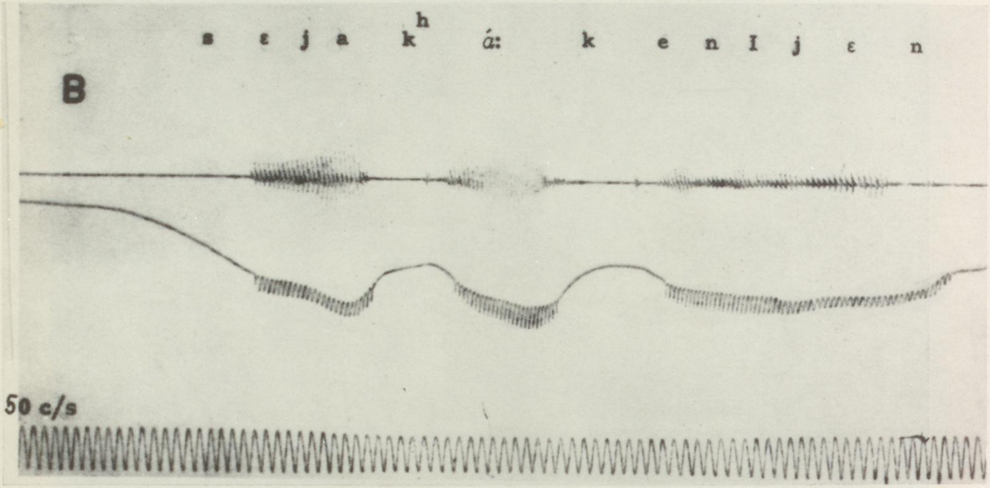
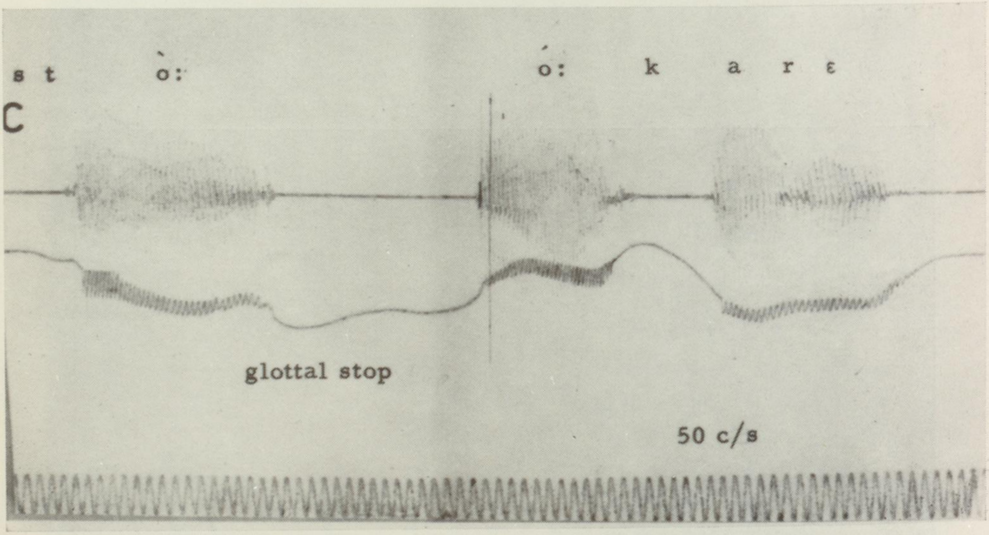


Fig. 3. B illustrating the accent 1 nonsense word [*ká:ken*] within a carrier phrase.



3. C. Glottal stop marking a word boundary shows up as an extreme low resistance in the electrical glottogram. The Mingograph channel displaying the output of the electrical glottograph lags the speech oscillogram trace by 15 msec as indicated by the vertical line. This instrumental factor affects (A), (B), and (C).