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GLOTTAL MODES IN CONSONANT DISTINCTIONS*

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Our most direct knowledge of how the larynx operates derives from observations by means of a laryngeal mirror inserted through the open mouth, from which we know that voicing involves adduction of the arytenoids so that the vibrating vocal folds are closely, but not tightly approximated, that quiet respiration is accomplished with the glottis well opened, and that whisper, creaky voice, falsetto, murmur, 'glottal stop' and 'aitch' involve still other more or less easily distinguished modes of laryngeal adjustment. The observational method is, of course, not applicable to speech, and up till fairly recently whatever was said about the functioning of the larynx during speech was by inference, and subject in part to controversy. It was supposed, very plausibly, that during voiced intervals in which the mouth is open the larynx operates just as observed during the phonation of prolonged vowel-like sounds. There was less agreement, and sometimes less certainty, as to laryngeal functioning during voiceless intervals in running speech, which typically coincide more or less with constriction of the supraglottal airway. Given the structure of the vocal tract and the myoelastic-aerodynamic theory of phonation, and assuming the larynx fixed in the voicing mode, we should expect a more or less rapid extinction of voicing to be inevitable when there is severe constriction. Conversely, we should expect the suppression of voicing only in that circumstance. Compatible with this is the observation sometimes made that sounds with little constriction are 'normally' voiced, and its less often stated corollary that obstruents, particularly stops, are 'normally' voiceless. If a language is 'normal' in this way, then it seems reasonable to suppose that in fact a single glottal mode, that of voicing, is maintained without significant change in utterances of that language, with shifts in mode reserved for para-linguistic effects. The absence of a distinctive voicing feature is then matched by the absence of differential control of the larynx during speech. But while such languages are reported, they are not very common. The literature of phonetic description suggests rather a special affinity between voicing as a distinctive feature and stop consonants, so that voiced stops are by no means rare. If we suppose

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that the voicelessness of certain stops is compatible with the glottal mode appropriate to voicing, then the presence of voicing in others implies some other mode and/or some other way of maintaining the necessary trans-glottal airflow during occlusion. Theoretical arguments have been advanced by Halle and Stevens for a shift in glottal mode as a necessary condition for stop voicing, a shift which effects a reduction in the resistance to airflow through the glottis (Halle and Stevens 1967:267-271). Moreover, if voicelessness persists after the stop release, as in the case of voiceless aspirates, then still another mode of glottal adjustment would seem to be implicated.

It has been further asserted that, in addition to mode of glottal adjustment, a dimension of articulatory force plays a strong role in determining whether or not vocal fold vibration accompanies a supra-glottal constriction (Chomsky and Halle 1968:325) .This fortis-lenis dimension has been variously understood; currently it is the fashion to say that it determines the extent to which the pharynx is free to expand in response to an increase in air pressure such as occurs during obstruent production. Obviously, a trans-glottal airflow can be better maintained during an occlusion if the pharyngeal cavity volume is increasing, and Rothenberg has reported experiments measuring the compliance of the cavity walls which yield values compatible with the durations of voiced closure observed in speech (Rothenberg 1968:92-94). In the case of aspiration, moreover, still another parameter, sub-glottal air pressure, has been enlisted by Chomsky and Halle as a significant factor by way of explaining the relatively high rates of airflow observed (Chomsky and Halle 1968:326).

By and large, much of what is said to be known about the management of stop voicing and aspiration is more hypothetical than data-based, and where there are data, they are more often than not derived from nonsense exercises of the speech mechanism whose relation to running speech is not clear. With recent developments in instrumentation new techniques have come into use which yield more direct information on the glottis in consonant production. Studies in transillumination, electroglottography, electromyography, and fiberoptics and X-ray cinephotography have already provided some findings that fail to confirm some of the recently stated theories of glottal behavior as it relates to distinctive voicing. From transillumination and fiberoptics studies carried on at Haskins Laboratories, for example, it appears that voiceless unaspirated stops, in English at least, most often involve some opening movement of the arytenoids, while on the other hand there is no detectable movement of these cartilages in a large majority of voiced stops observed (Sawashima *et al* 1971:). If a shift in glottal mode is in theory required for stop voicing, and if it is superfluous for the voiceless unaspirated stops, then it is puzzling that evidence of a special glottal adjustment in the first case is so elusive and that in the second case it seems so clear. If there is, in fact, a gesture of devoicing rather than to ensure voiced occlusion, it might be inferred that a fortis-lenis difference is of less than crucial importance, at any rate for fluent American English. Nor has there been any demonstration that higher sub-glottal pressures are required for aspiration (Kim 1970: 111-112), while there is clear evidence from Kim's work that the area of glottal aperture at the time of stop release is directly related to the prominence of this feature (Kim 1970:109-111). The mechanism by which aspiration, or something much akin to it, is produced during the release of voiced stops is not well studied. It seems possible, though, that this variety of aspiration is voiced, unlike the more commonly found aspiration, simply because the glottal aperture does not become large enough for vocal fold vibration to cease in the absence of an articulatory constriction.

In summary, it seems to us that theories of stop voicing and aspiration that stress the importance of extra-laryngeal factors can claim less basis in observed fact than does one which stresses the paramount role of the larynx, specifically the positioning of the arytenoid cartilages as it determines glottal aperture. It is difficult to deny that extra-laryngeal factors may affect voicing significantly, but it is one thing to argue that they have the capability, another to demonstrate that they do in fact regularly operate in a manner consistent with that capability. Glottal adjustment alone does not determine the voicing state of a stop consonant, but no other factor seems to be nearly as important.

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New Haven, Connecticut
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REFERENCES

Chomsky, N. and M. Halle
1968 *The Sound Pattern of English* (New York, Harper and Row).

Halle, M. and K.N. Stevens
1967 "On the Mechanism of Glottal Vibration for Vowels and Consonants", *Quarterly Progress Report of the Research Laboratory of Electronics, M.I.T.* 85:267-271.

Kim, C-W.
1970 "A Theory of Aspiration", *Phonetica* 21:107-116.

Rothenberg, M.
1968 "The Breath-Stream Dynamics of Simple-Released-Plosive Production", *Bibliotheca Phonetica* 6 (Basel, S. Karger).

Sawashima, M., A.S. Abramson, F.S. Cooper, and L. Lisker
1971 "Observing Laryngeal Adjustments During Running Speech by Use of a Fiberoptics System", *Phonetica* 22:193-201.

DISCUSSION

ROTHENBERG (Syracuse, N.Y.)

Though I believe your paper to be generally quite accurate, I believe that you did not mention that glottal airflow during the articulatory closure of a voiced stop can also be absorbed by a slight nasalization, that is, a small velopharyngeal opening. I have previously shown indirect evidence that such nasalization occurs in at least some languages in India (Rothenberg 1968). Lately we have obtained more direct evidence. Using air flow records taken with a pneumotachograph mask having a response time small enough to resolve individual glottal pulses (see my paper presented at this Congress), we have noted a consistent nasalization of voiced stops for a native speaker of Hindi.

Relating to your comments about the glottal adjustment during a voiced closure, records taken with this same pneumotachograph, with the (bilabial) articulatory closure bypassed with a short tube, have shown waveforms for voiced plosives and neighboring vowels to be very similar. This was for speakers of at least two languages. Of course there may be some languages for which this is not true.

REFERENCES

Rothenberg, M.
1968 "The Breath-Stream Dynamics of Simple-Released Plosive Production", *Bibliotheca Phonetica* VI (Karger, Basel).
See also Rothenberg's paper presented at this Congress, to be found on pp. 380-388 of this volume.

LISKER

In our thinking about mechanisms for maintaining glottal airflow during oral occlusion, we have long been aware of the possibility of nasal leakage, and of observational data presented by you and by Yanagihara and Hyde showing cases in which this possibility is realized. Of course the fact that a native speaker of Hindi consistently nasalized his voiced stops says little about the voicing habits of speakers generally in the production of voiced stops, though it might just as well be argued that, until there are data showing voiced stops during which NO nasal airflow was recorded, we may suppose such stops to be regularly nasalized. If this were in fact true, it would render redundant a good deal of speculation about pharyngeal adjustments as necessary for voiced occlusion.

SCULLY (Leeds)

In connection with the problem of maintaining trans-glottal air flow during voiced stops, I should like to make the following comments; aerodynamic data and the pressure data presented by R. McGlone at this Congress (see pp. 375-379 of this volume) both indicate that the blade of the tongue is in constant movement during the production of /d/ in English. Oral airflow is not reduced to zero except for a short time in the middle of the occlusion period. Indeed some of my aerodynamic data indicates incomplete oral closure even during the central part of the occlusion. Aerodynamic and acoustic measurements which I am currently making using metal constriction models indicate that incomplete oral closure may well result effectively in silence. I offer this as another possible air flow escape mechanism. Enlargement of the oral cavity may arise from active tongue movements during the occlusion as well as from the passive expansion of the vocal tract walls. This and other air flow absorbing mechanisms may well prove to be the same for voiced as for voiceless stops; these would not in that case necessarily differ in the feature tense-lax.

LISKER

In our discussion of stop consonant voicing we have taken the term STOP CONSONANT in its usual meaning, so that any evidence indicating non-interruption of airflow during an articulatory constriction means that, by definition, we are dealing with some event other than a stop, whether or not effective silence is achieved. At the same time it is very interesting that you find cases in which airflow through the mouth is not completely interrupted where a stop consonant is usually said to occur. If such cases involve English /d/ exclusively the observation may perhaps be less interesting; in American English, at least, post-tonic /d/ is regularly 'realized' as a voiced flap, and incomplete occlusion is hardly surprising. I am not sure as to the facts of British English in this regard, but possibly they are not very different. As to the possibility that active movements of the tongue have the effect of enlarging the oral cavity behind an occlusion, this seems quite possibly to be true. At the same time, however, I would wonder whether this effect of tongue movement might not depend significantly on the particular vowels preceding and following the stop.

GREGG (Vancouver)

Has any experimental work been done on the voiceless /h/ glottalized plosives and affricates of some of the Amerindian languages?

LISKER

To my knowledge no serious work on Amerindian languages has been done in which advanced techniques of phonetic observation have been applied.