LARYNGEAL ARTICULATION IN SWEDISH

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The laryngeal articulation in Swedish has been studied by means of a special fiber scope inserted through the nasal passage. Registrations were made on film and with optical glottography.

1. SWEDISH CONSONANTS

The Swedish consonant system can be divided into 18 phonemes.

	voiced(lax)	unvoiced(tense)
stops	b d g	p t k
fricatives	v j	f s ç ɧ
nasals	m n ŋ	
liquids	r l	
aspirated segment	h	

The voiceless consonants are produced with a glottal abduction gesture, while the voiced consonants are produced with the glottis in voicing position. The [h] is also produced with a glottal abduction gesture, but to a much smaller degree than the stops and fricatives.

2. GLOTTAL CONDITION FOR LAX CONSONANTS

For the lax (voiced) stops it is sometimes possible to observe a small separation of the vocal folds towards the end of the occlusion. Supported by observations made on English subjects, it has been suggested in the literature that this could be the result of an active adjustment of the vocal folds in order to facilitate voicing.

In order to investigate this question further, two experiments were performed with Swedish subjects. In both experiments a valve was inserted in the subject's mouth so that the vocal tract could be closed off by the experimentor. When the valve was closed to simulate a /b/-occlusion, similar glottograms as those for voiced stops in connected speech could be registered. If the subject tried to have the muscles in his neck relaxed, it was possible to observe a vocal fold separation on the glottogram slightly above the peak of the vibration amplitude prior to the closure of the valve.

In a second experiment the pressure drop across the glottis was recorded simultaneously with the voicing picked up with a throat microphone. It was then found that the vocal folds could continue to vibrate down to nearly 1 cm H_2O, at low and normal fundamental frequency both for the artificial [b]-sound and for voiced stops in speech. According to the results obtained by the cited experiments, we assume that Swedish lax stops are produced with the vocal folds in voicing (neutral) position, without any adjustments of the vocal folds in order to maintain voicing.

The main factor determining the degree of voicing for voiced stops is the yielding walls of the vocal tract and perhaps also the movement of the tongue. It is not yet known if the yielding of the walls is active in the sense that the muscles are relaxed or activated for that purpose. However, it is quite clear that there must be a fundamental difference in this respect regarding the articulation of Swedish voiced stops and more audible voiced stops, like those used in French and Russian.

3. TENSE CONSONANTS

Tense consonants in Swedish are produced with a glottal abduction gesture with only one exception. After [s] the tense stops may be produced without any visible opening gesture. The magnitude of the glottal opening may vary widely depending on the degree of stress. For the stops, the glottal opening is about four times the vibration amplitude of the vocal folds in the surrounding sounds as measured on the optical glottogram. In unstressed position this may be reduced to about one or one and a half times the vibration amplitude. The fricatives have in general a slightly larger glottal opening gesture.

For the stops, the degree of stress will affect the length of the aspiration, which may disappear in unstressed position. After a stressed vowel the aspiration is also lost even if the syllable has a secondary stress. The duration of the oral occlusion is in that position about 1.8 times the occlusion-time for the lax stops. In other positions the lax and tense stops have about equal duration of the occlusion. There are some variations in the timing of the glottal opening gesture, but the maximum of the opening generally appears in the first half of the occlusion and before the middle of the acoustical segment for the fricatives. For the stops this implies that the glottal opening starts in the preceding vowel and pre-aspiration is often found, especially in the position after a stressed vowel.

4. PRE-SPEECH ARTICULATION

When the larynx is not used for speech the glottis is generally opened for breathing. When speech is to start, the vocal fold has to move from an open position to that required for the speech. If the speaker hesitates before starting to speak, the speech will generally be preceded by a glottal stop gesture so that the sub-glottal pressure is allowed to rise before the speech is initiated. If this is not the case there must be a careful synchronization of the closing movement and the activity of the respiratory muscles. If the sub-glottic pressure is increased too late, the voicing will be delayed and if it is increased too early, the speech will start with an /h/-like aspiration. The latter is the case for a Swedish dialect, where words with an initial vowel will start with an /h/. Initial /h/ will instead be substituted by a glottal stop. London 'cockney' is a familiar example of this phenomenon.

5. POST-SPEECH ARTICULATION

An utterance is normally always actively terminated. Because the intention is to stop the voicing at the end of the phrase this can be done by one of the two devoicing gestures of the larynx. These are the glottal stop gesture and the glottal abduction gesture. For Swedish speakers, the most common terminator is the glottal abduction gesture. In the Eskilstuna dialect of Swedish, where a creaky voice is used, the glottal stop gesture is also common as a terminator of speech as it is in certain other languages, such as Japanese.

The terminating abduction gesture is very similar to the one used for voiceless consonants, except that the vocal folds do not close again if speech is not continued. Instead they stay half opened for about 50-100 msec and then are opened completely for breathing.

6. CONSONANT IN UTTERANCE-INITIAL POSITION

When a lax stop is put in utterance initial position it will in most cases be produced unvoiced and the intraoral pressure at the release is approximately the same as for the tense stops. The acoustic results will then be about the same as for an unaspirated tense stop with the same place of articulation. In Swedish, the opposition is maintained by the fact that [p], [t], and [k] are much aspirated in that position.

From what has been said here, one could draw the conclusion that the state of the glottis is without importance DURING the occlusion of the utterance initial lax stops. However the fiber-optic data show that the lax stops are always produced with the glottis in voicing position and the absence of voicing is accidental. The voicing itself is in Swedish not very important and no extra effort is made to start the voicing before the release of the stop closure.

A similar position-invariance in glottal articulation can also be shown for the tense consonants. Even in utterance-initial position the glottal abduction gesture is always present, superimposed on the pre-speech closing movement. The data suggest that these two movements are added to each other.

The addition of the glottal movements may be explained by the fact that the proprioceptive feed-back for glottal abduction is poor and by the fact that the acoustic output is not affected.

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DISCUSSION

ABRAMSON (Storrs, Conn.)
I have four comments: (1) Your finding of a considerably decreased glottal area during [p]-closure of [spik] should be aligned with Kim's findings on degree of aspiration and size of glottal opening. It would probably be better here to think of a single glottal gesture for the cluster rather than one for the [p]. (2) It is refreshing to find that your observations on involvement of the walls of the vocal tract do not lead you automatically to conclude that the movement is either active or passive. (3) Your data clearly show the primacy of laryngeal control. (4) In the light of the foregoing, I do not understand why you use the terms 'tense' and 'lax' so casually. Even if laryngeal pulsing is not always audible during the occlusions of 'voiced' stops in Swedish, certainly voicing as a feature is relevant in the sense of the relative timing of laryngeal and supraglottal events proposed by Lisker and me.

LINDQVIST
The glottal gesture for [s] followed by [p, t, k] is often quite different from shown. In many cases it is possible to see a glottal opening gesture associated with the stop sound even after [s]. I therefore think that it is a simplification to speak about one glottal gesture for clusters instead of speaking of a glottal gesture composed of the gestures associated with each phoneme in the cluster.

As regards the use of 'tense' and 'lax' ,I could of course use 'voiceless' and 'voiced'. What I wanted to point out was that the audibility of the voicing for Swedish voiced stops is not as important as it seems to be in some other languages.

MACNEILAGE (Austin, Tex.)
In observing electromyography recordings made by Dr. Thomas Shipp in San Francisco, I have often, although not always, observed activity at the posterior cricoarytenoid muscle, and inhibition at the interarytenoid and thyroarytenoid muscles during voiced intervocalic stops and fricatives in English. This suggests that the accompanying glottal adjustment is often an active and not a passive effect. Secondly, I have observed that in voiceless final stop consonants in English, there was a very consistent tendency in two subjects for thyroarytenoid activity to begin rather early in the preceding vowel, much earlier than the beginning of posterior cricoanytenoid

activity. This suggests that in this environment vocal cord tensing may participate in the offset of voicing.

This was not accompanied by interarytenoid activity and so is probably not associated with a glottal stop.

LINDQVIST
What I tried to show was that an adjustment of the vocal folds during voiced consonants is, at normal pitch, on the one hand not necessary in order to maintain voicing. On the other hand, if it has any effect, this effect is very small, probably too small to play any role in language learning as compared with other mechanisms to maintain voicing.
In my descriptive model of the larynx I would like to regard the 'voicing position' to be the positioning of the vocal folds where voicing is most easily maintained. This is different from Halle's and Stevens' assumption. As pitch in speech is regulated by the length and, to some extent, by the tension of the vocal folds, my assumption may be correct only for normal pitch. Our measurements have shown that in order to maintain vocal fold vibration at increased pitch (about one octave above the normal) there has to be two to three times as much minimum pressure drop across the glottis as compared with normal pitch. It is therefore to be expected that in some languages a lowering of the pitch may be used to facilitate voicing. In a tone language, for instance, the combination of high tone and a voiced stop should be very unfavorable for vocal fold vibrations.

Your observation on EMG-data is very interesting. I cannot make any comments on this because too little EMG-data has been published and I have mainly studied Swedish consonants which are different from the English ones. However, if your observations of the adjustment of the glottis for voiced fricatives and stops are correct, this does not necessarily mean that the adjustment is made to facilitate vocal fold vibrations.

In English it seems to be common in many dialects to use a glottal stop for a final voiceless stop. I think that in a reduced glottal stop gesture (which in that position is sufficient to stop voicing) you do not necessarily find an increased activity in the interarytenoid muscle, because this muscle has already quite a high degree of activity during phonation. In a glottal stop gesture ALL abductor muscles are active, not only vocalis. I therefore think it is misleading to speak about stiffened vocal folds as a means of stopping vibrations. The mechanism is much more complicated and it is physiologically related to the protective closure of the larynx.