AIR PRESSURE SENSITIVITY OF SOFT PALATE IN CLOSED POSITION

SVEND SMITH

It is a well-known fact that the soft palate in its closed position varies its height of closure against the back pharyngeal wall.

During the nineteenth century, it was demonstrated that the soft palate becomes higher when the vowel [i:] is pronounced, whereas it stays relatively low on the vowel [a:]. It is natural to assume that muscular function is responsible for this difference (higher activity of levator velum palatinae on [i:]).

As a consequence of this, one might assume that a flow of air might be evoked in the closed-off nasal cavities when the series [a — i — a — i — a] are pronounced orally. In the transition from [a] to [i] the nasal flow would be egressive, and in the transition from [i] to [a], ingressive. This phenomenon was in fact consistently demonstrated in our experiments, thus being a consequence of muscular activity (see Figure 1).

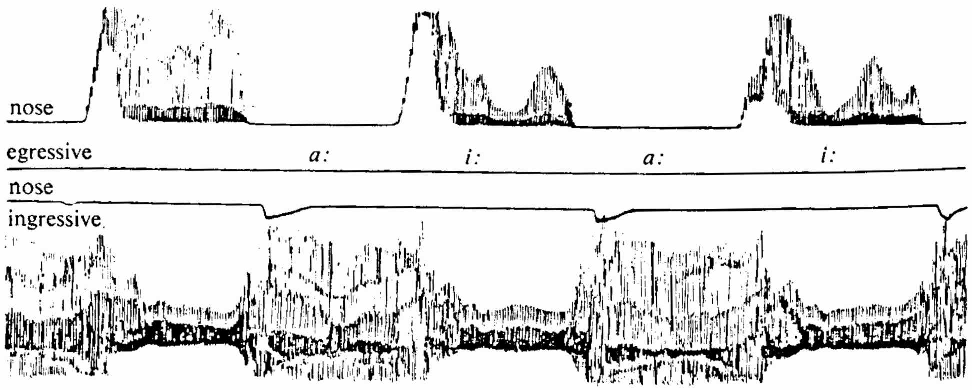

Fig. 1.

The subtle movements of the velum during oral consonant articulation were shown for the first time by E.L. Ackermann in 1935 (Ackermann 1935:2-9). Ackermann points out that movements of the soft palate can be observed as a consequence of the articulation of oral stop consonants. In her experiments, the individual who was

used as a subject was a patient with a hole in his cheek, which allowed a view from above of the soft palate. The equipment used for the investigation was an ordinary movie-camera, which photographed the undamaged velum from above. An exact measurement of the variations during oral stop consonant articulation was achieved.

The assumption recently developed by James F. Lubker and Kenneth L. Moll (Lubker and Moll 1965), that positive or negative flow may exist when the velopharyngeal port is closed, was unfortunately — because of their insufficient equipment — not proved for oral vowels combined with single oral consonants.

This paper will deal with the flow variation resulting from the movements of the closed velum.

1. THE INSTRUMENT

It is necessary to apply an air-flow transducer which can receive the slightest slow d-c changes of both the ingressive and the egressive air stream of nasal and oral cavities, and which is able to record vibrations of sound simultaneously. Also the instrument will have to be constructed in such a way that atmospheric pressure shows a fixed base-line.

Furthermore, the system must register the whole amount of nasal inspiratory (ingressive) and expiratory (egressive) air-flow; if not, the very small but important changes of air-flow cannot be observed. Thus, a tightly fitting mask must be used.

The registration must be able to follow the small variations with a minimum of delay. Compared with the electronic registration of sound, a mechanic transducer should have no more than five milliseconds delay-time in recording, i.e., a hardly noticeable delay for usual recording speeds of 10-20 cm/sec. In a registration system which is working properly, the recording of (e.g., the burst of) a [d]-consonant should present an almost 90° deviation from the base-line, the speed of the recording paper being 10 cm/sec.

The double valve type of air-flow meter (Svend Smith) consists of a tube open at both ends. The intake of air takes place at one end and the outlet of air at the other end (see Figure 2). In the middle of the tube an opening is placed. The mouth or the nose of the subject (in this case only the nose) is brought into close contact with this opening.

At the moment of inhalation, one of the two specially constructed valves opens and the other closes; at the moment of expiration the first-mentioned valve closes and the latter opens.

An electric light source is directed through the variable sizes of the slit-openings of the valve, and the variations of the slit-openings are eventually recorded on an oscillograph as variations of light on a photocell.

By use of a throat microphone a comparison of the electro-acoustic transducing

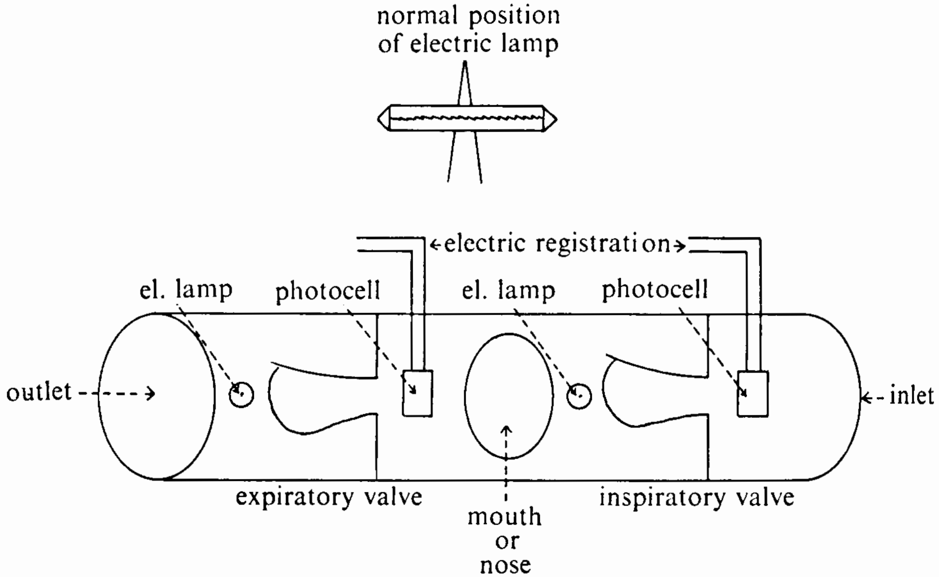

Fig. 2.

system and the electro-mechanically transduced signal can be achieved. The recording on a four channel Mingograph (ink-beam writer) was employed for our experiments.

Trace 1 on all figures shows nasal expiration (egressive air-flow); trace 2 shows nasal inhalation (ingressive air-flow). Trace 3 shows a fifty cycle sine-wave (mains), and trace 4 shows the oscillographic picture — linear up to about 600 H. The aerometer was then adapted for signals of slightest flow variations. This is possible when the lamp filament, which is one single glowing thread, is orientated against the slit opening of the valve in approximately the same way as the two lines of the letter *X*, instead of in normal perpendicular position (see Figure 3).

Because of this, the registration of strong air-flow from the pharynx through the nose — as in nasal consonants *m*, *n*, *ŋ* — was suppressed. The strong air-flow would have led to a damage of the Mingograph. Care was therefore taken that no nasal sound occurred in the sound material used for the experiments.

2. EXPERIMENTS

The curves presented here are representative of a greater number of registrations with similar results. All curves are taken from one subject (myself).

An absolutely air-tight system is a prerequisite for the experiments. The least leakage of air results in a failure of registration, and thus the usual mask with soft edges cannot be used. After some experiments we came to the conclusion that a sharply edged mask had to be fitted to the surroundings of the nose. The upper part of

plastic bottles were cut with a pair of scissors so that they would fit to the individual face. The stiffness of the mask prevents artefacts arising from head-movements and adds to the chance of registering sudden changes in small amounts of air-flow.

All tracings are tracings of air-flow. This means that a descending curve on the expiratory trace (Trace 1) does not necessarily mean a lowering of the velum but only that — following a pronounced ascending movement — a less pronounced ascending movement of the soft palate takes place. Only steep falls can be interpreted as a lowering, usually continued on the inspiratory curve.

3. PROGRAM

Three points will be discussed in my comments on selected curves which are typical for the phenomena found: (1) The influence of oral pressure during consonant articulation on the soft palate in closed position (labial versus dental stop consonants); (2) The influence of the on-glide and off-glide phases of these consonants; and (3) The rôle of vowel articulation on the above findings.

4. CURVES

Recordings were made of VCV groups: [a:ba: — a:da: — i:bi: — i:di:].

Observations of the curves (see Figures 3 and 4) lead to the conclusion that in all cases ingressive air flow at the moment of explosion is stronger at dental articulation than at labial articulation. It is also stronger on [a] than on [i] surroundings. The moment of explosion can be defined with the highest possible exactitude (1-2 milliseconds).

The moment of implosion is also clearly definable (around 10 milliseconds). This moment of final contact lies at the peak of the nasal fremitus, as in many cases may be deduced from the oscillographic curve. Especially the last example [i:di:] shows the on-glide of the stop-consonant, i.e., the rising time of fremitus until the peak (final closure) is reached.

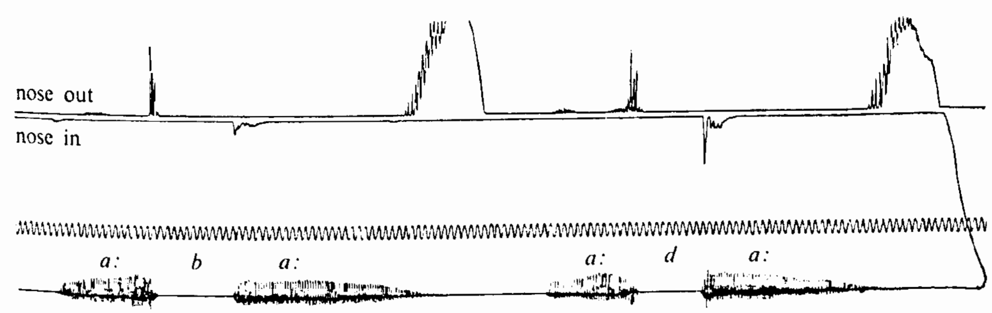

Fig. 3.

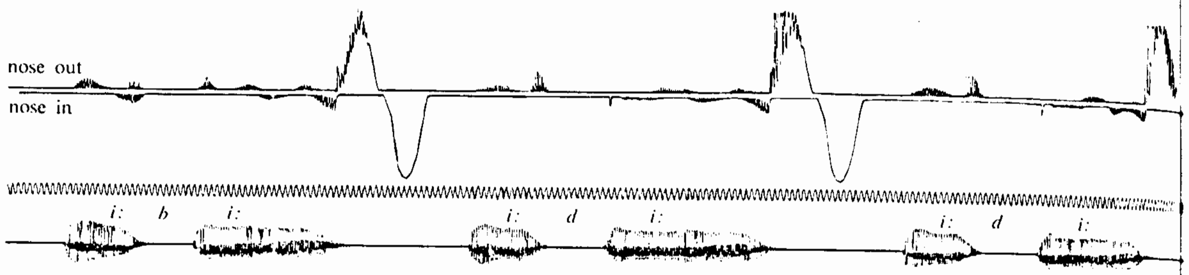

Fig. 4.

5. DISCUSSION

The reasons for these events are the following.

(1) The oral pressure is higher in the closure phase on dentals than on labials. The reason for this is that the walls of a labial closure cavity are not as stiff as the walls of a dental closure cavity.

(2) The [a] surroundings of the stop consonants cause a more pronounced inflation and deflation of the soft palate, i.e., the musculature is less tense and/or the closure is situated rather low.

(3) The closure length can be estimated with an exactitude of around 10 m/s, the beginning being indicated by the peak of the '*Blählaut*', and the end by indication of ingressive air.

(4) An on-glide phase can in many cases be observed. When the tongue and lips are carrying out a movement towards closure, the pressure in the oral cavity rises slowly.

Towards the end of vocalization of the last [i:] in the VCV group, the inspiratory curve is in most cases slightly lowered. The reason for this is a down-sliding of the contact zone of velum, giving rise to the observed ingressive air in the nasal cavities. The final opening-moment can by means of this technique be defined far better than by using X-ray film.

This study was carried out not only with the aim of showing the sensibility of the soft palate to d-c air-pressure variations in the mouth, but also to show the possibilities of an instrument which is capable of a continuous registration of even the smallest nasal egressive and ingressive air-streams, all of them indicating subtle and immediate changes in soft palate positioning in closed position on different vowels in combination with different stop consonants.

This technique is in a way comparable to the well-known technique of swallowing a rubberballoon in order that differences in tracheal pressure — transduced to the oesophagus — be registrated (cf. experiments carried out by Ladefoged a.o.). Our technique has the advantage that the oral passage is not impeded by any transducer at all.

6. SUMMARY

Two factors influence the passive movements of the soft palate at the articulation of stop consonants: (1) variable degrees of tenseness of the soft palate in producing different vowels (i:a); and (2) the place of oral consonant articulation.

Dental articulation has a higher effect than labial. Pressure variations in the mouth during on-glide and off-glide phases of stop consonants can be observed as a respectively slower rise during on-glide phase and a sudden fall at off-glide phase.

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DISCUSSION

SCULLY (Leeds)
Although nasal airflow traces alone show very interesting features, the amount of information can be increased by measuring oral pressure at the same time. Quantitative measures of the cross-section area of the velopharyngeal port may then be extracted from the data.

SMITH
I agree.