Proceedings of The Institute of Acoustics 3A18

AERODYNAMIC AND ACOUSTIC ASPECTS OF NASALITY

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INTRODUCTION

Nasality is an aspect of speech structure which appears to be both very simple and very complicated. As with other features of speech, the use of a single term taken to include all stages of the speech chain is to be avoided. Nasality defined as a lowered velum is not the same as nasality defined by nasal airflow. Acoustic nasality is different from both of these. Perhaps the perceptual end of the chain is the best starting point. What the listener receives is, presumably, a wide range of acoustic effects associated with the presence of the speaker's nasal cavity. Acoustic theory shows that the acoustic output for acoustically linked tubes in parallel varies with change in shape of one branch, the oral cavity, even though the other branch, the nasal cavity, is of fixed shape. In this sense, the relationships between perceived nasality and acoustic structure must be very complex. Nevertheless, it is tempting to speculate that listeners may be able to extract from the total signal a phonetic feature of 'nasality' which tells them that the speech comes from one particular, fixed, nasal cavity. It seems possible that such a feature would appear more strongly in the nasal output than in the oral output; the listener might be able to decompose the total, mixed, output into these two components, by heuristic methods. Separated acoustic recordings may give insight into this question.

EXPERIMENTAL METHODS

The 'nose trumpet' method of Hyde (1968) has been taken as a starting point. Two adjacent, similar rooms have been linked by a nose-shaped hole in a chipboard baffle partition. The rooms have been treated similarly acoustically. Two matched, high quality microphones (AKG D202 dynamic) with cardioid characteristics are positioned at equal distances from the speaker's mouth and nostrils. The microphones are, inevitably, off axis; a cardioid response was chosen for this reason and in preference to omnidirectional microphones which would record more of the room characteristics. The transmission loss across the baffle is better than 24 dB for nearly all frequencies of interest. Nose outlines are based on anaesthetic masks made to fit each individual's face. The speaker first makes a studio recording with one of the baffle microphones, placed at the same angle as for the baffle. Prerecorded material with gaps are repeated by the speaker. In this way, tempo and prosodic features are fairly closely controlled. The speaker then records at the baffle, following his or her own studio recording. Volume flow rate of air from nose and mouth separately or nose alone are obtained, using masks constructed from anaesthetic masks and incorporating a pneumotachograph device (Mercury flow-heads and Gaeltecpressure transducers). The airflow signal from the nose is shown both low-pass filterd at 50 Hz and as recorded on a Revox tape recorder. Thus, d-c (aerodynamic) and low frequency (acoustic) aspects of nasal airflow may be compared on mingograph traces.

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RESULTS

Fig. 1 shows nasal airflow for [i], [u] and [a] for one adult, male speaker. The low-pass filtered traces are on the baseline. There is thus no positive evidence for an air passage linking the oral and nasal cavities, though the traces do not exclude that possibility. The nasal acoustic signal is consistently greater for [i] and [u] than for [a]. The differences may simply reflect the different spectral distributions for the different vowels, combined with the frequency characteristics of the flowhead-pressure transducer system. This needs further investigation.

Fig. 2 shows the onset for nasal consonants for the same speaker. The d-c component of nasal airflow and the low-frequency acoustic component increase in similar fashion in each case. In many examples of sentences containing nasal consonants, these and the adjacent vowels show similar effects: as nasal airflow increases the nasal acoustic component increases also,

Fig. 3 shows the nasal acoustic output as recorded at the baffle, for [ʌm], [ʌn] and [ʌŋ], for the same speaker. Some formants are hardly altered when the closure is made in the oral cavity. Relative constancy of formants seen in the nasal output is a feature of the sentences, also. In "mean", for example, the oral output for the same speaker, DB, shows a transition for the second formant from a low frequency up to about 2.4 kHz, for [mi]. This 'place' information is not visible in the nasal output, but a formant essentially constant at 2.3 to 2.5 kHz is seen. This may perhaps be a candidate for a speaker-specific 'nasal' feature.

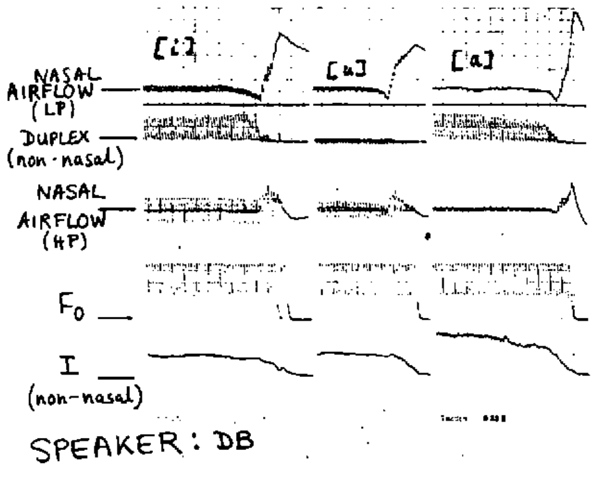

Fig. 1 Aerodynamic and acoustic nasal outputs for three vowels.

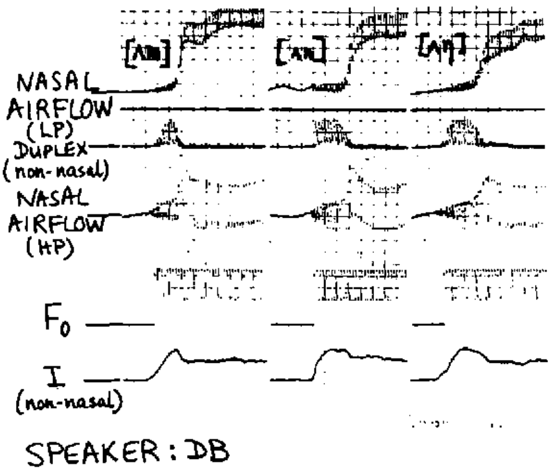

Fig. 2 Aerodynamic and acoustic nasal outputs for three nasal consonants and adjacent vowels.

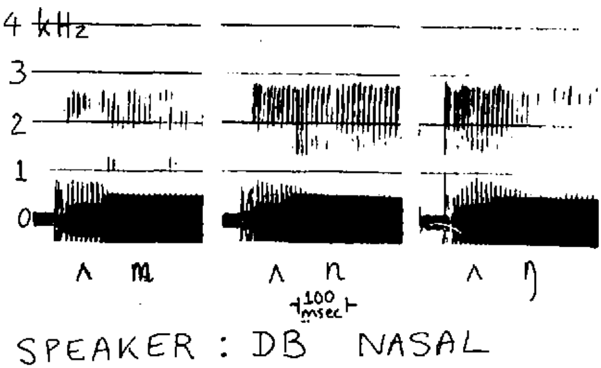

Fig. 3 Acoustic structure of the nasal outputs for three nasal consonants and adjacent vowels.

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RELATIONSHIPS BETWEEN ACOUSTIC AND AERODYNAMIC ASPECTS

Considering the oral and nasal cavities in parallel and assuming that each contains one major narrowing of the tube – in the oral branch the tongue constriction for the vowel, of cross-section area AM; in the nasal branch the velopharyngeal port, of cross-section area AN, then:

$$\frac{UN}{UN + UM} = \frac{AN}{AN + AM}$$ where UN and UM are the volume flow

ratesof air through nose and mouth constrictions respectively.

Acoustically, the fraction of wave propogation through the nasal branch is:

$$\frac{LM}{LN + LM}$$ if resistive elements are disregarded, where LN and LM

are the effective inductances of the nose and mouth passages respectively, as seen from the uvula (Fant, 1960, p. 43). If the inductances are associated mainly with two constrictions of similar lengths l, then, approximately:

$$\frac{LM}{LN + LM} = \frac{\rho l/AM}{\rho l/AN + \rho l/AM} = \frac{AN}{AN + AM}$$ (ρ is the density of air)

In this case the two parallel branches may be expected to behave similarly from the aerodynamic and acoustic point of view, each with respect to the other.

Hyde interpreted his nasal output data as cases where the velum does not require to be closed. The airflow data reported here, particularly for vowels between two plosive or fricative consonants, suggest that a significant amount of sound is transmitted across a closed velum, to appear as a nasal output. Direct observation of velum movement is needed to answer this question. If the nasal acoustic output is, indeed, closely related to the nasal airflow output in this way, then when there is an air passage linking the two cavities, the ratio of nasal to oral airflow should give an indication of the strength of acoustic nasality. If, however, much of the nasal acoustic output arises through acoustic transmission across a closed velum, then distribution of energy in standing waves for each resonance of the pharyngeal-oral tube would need to be considered.

REFERENCES

1. S.R. Hyde 1968 Nature 219, 763-765. Nose trumpet: apparatus for separating the oral and nasal outputs in speech.
2. G. Fant 1960 Acoustic Theory of Speech Production. Mouton, The Hague.