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The nasal cavity structures

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B. THE NASAL CAVITY STRUCTURES

G. Bjuggren* and G. Fant

In connection with the processing of the data underlying the chapter on nasal sounds and nasalization of ref. (1) a few anatomical investigations of the dimensions of nasal cavities were made by G. Bjuggren. It is the purpose of the present report to present some of these original data and to discuss its implications for the theory of nasal transmission.

Fig. I-B-1, also reproduced in ref. (2), shows cross-sectional cuts through a plastic mold of the nasal cavity system prepared from a male corpus. These sections have been arranged so as to show separately the left and the right part of the nasal system. Because of the finite width of the sawblade, used for cutting the mold, it has been considered appropriate to display both surfaces of a cut.

The left and right parts of the nasal cavity structures join in the common epipharynx about 7-8 cm from the termination of the nostrils. The area at the far end in the epipharynx is of course highly dependent of the particular position of the soft velum. The total length of the combined system along an axial coordinate running through the center of gravity was close to 11 cm for this particular subject. Of interest is the complex outline of the sections in the middle of the nose where the bottom, middle and upper passages are apparent**. Readers are referred to the excellent atlas of Daves and Loechel (6) for orientation with respect to anatomical details.

From an acoustical point of view and in the first approximation it is the total cross-sectional areas including the sum of the right and the left parts of the nose as a function of the axial coordinate which determines the characteristics of nasal sound transmission. This area function and a measure of circumference are given in Fig. I-B-2. Because of the intricate shape of the air cavities

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** These data organized in a more apparent anatomical sequence appeared in the recent Season's Greetings Card from the Speech Transmission Laboratory.

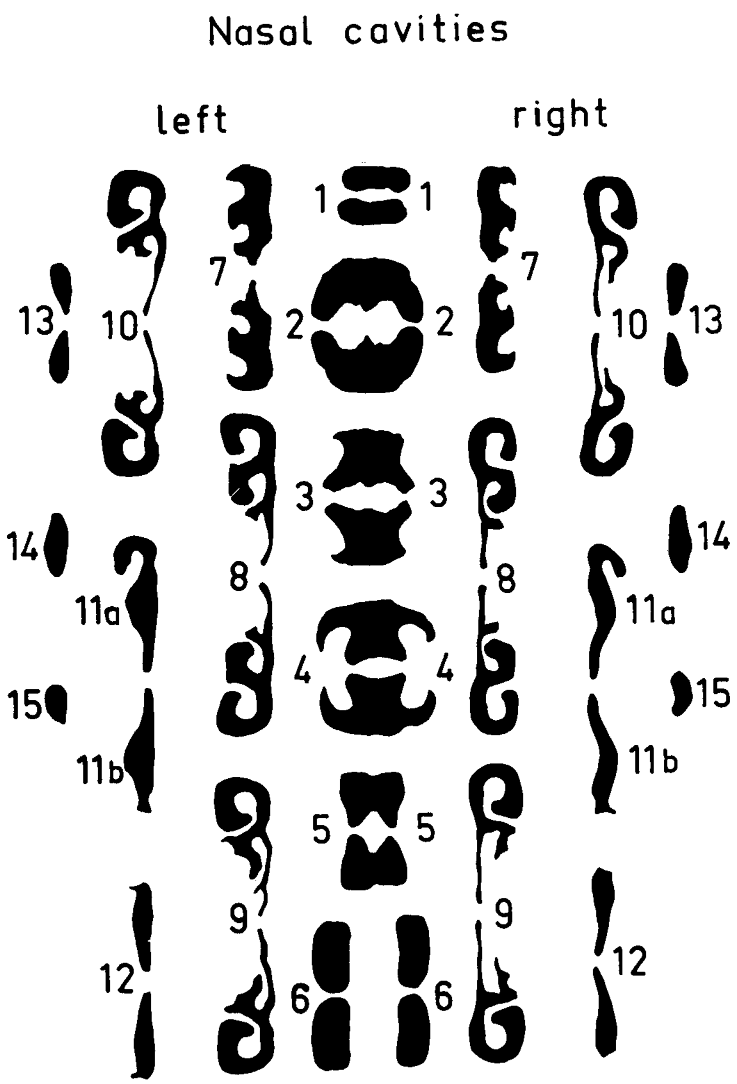

Fig. I-B-1. Cross sections of a nasal mold from a male prepared by G. Bjuggren. Sections are numbered from the epipharynx to the nostrils as in Fig. I-B-2. Each section, except 14 and 15, is represented by two contours, those of each side of the saw-blade.

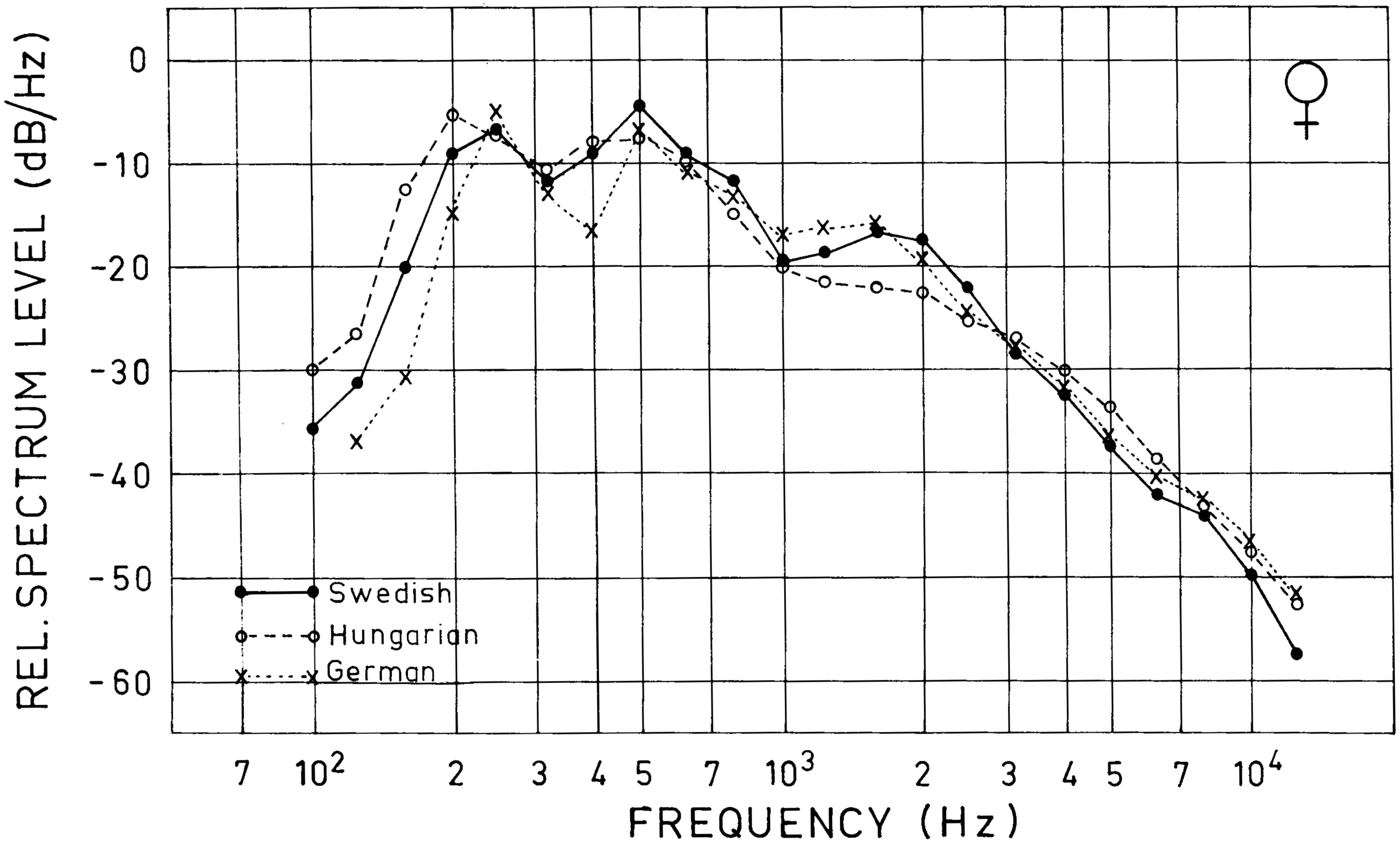

Fig. II-B-2. Average speech spectra of Swedish, Hungarian and German female subjects determined by the chorus method.

the length of the bounding line of a section is about 3.5 times as large as the circumference of a circular section of the same cross-sectional area. The dissipative energy losses within the cavity system are proportional to this "shape factor", see ref. (1), p. 305. This is one of the determinants of the relatively high formant bandwidths of nasal sounds. However, in practice any formant will be associated with reactive energy distributed over other places of the vocal and nasal tract system and the total bandwidth is a weighted average of terms proportional to the ratio of dissipative to reactive energy along the entire tract. It is not the scope of this article to review the complete theory.

The relations between nasal tract geometry and the pole-zero patterns of nasal consonants and nasalized vowels have not yet been fully established. Recently Fujimura (4)(5) discovered that the pole-zero pattern of nasal transmission was considerably more complex than was previously conceived of in the earlier studies of Fant (2) and Fujimura (3). This is ascribed to the general lack of symmetry between the right and left nasal passages which can be shown to introduce extra pole-zero pairs in addition to those of the complete symmetry.

Area functions of the left and right passages are reproduced separately in Fig. I-B-3 which pertains to molds from two female noses. The asymmetry of nose No. 2 is apparent. Fig. I-B-3 also demonstrates that the size of the epipharynx may vary considerably.

Of acoustic significance is the tendency of a fixed place of narrowing at the place where the nasal system branches off in the two side-passages about 3 cm from the termination at the uvular outlet. This narrowing and the nostril openings bound the fixed part of the nasal cavity system. The lowest natural frequency of this system in an uncoupled state may be calculated with a fair degree of accuracy by means of a Helmholtz resonator model. In case of a narrow velar passage as in slight degrees of nasalization the epipharynx constitutes a separate part of the nasal system. The system in Fig. I-B-2 from coordinate 0 to 9 thus has the natural frequency of approx. 1000 c/s and with the epipharyngeal end completely closed approx. 500 c/s. These figures, however, might perhaps be somewhat lower due

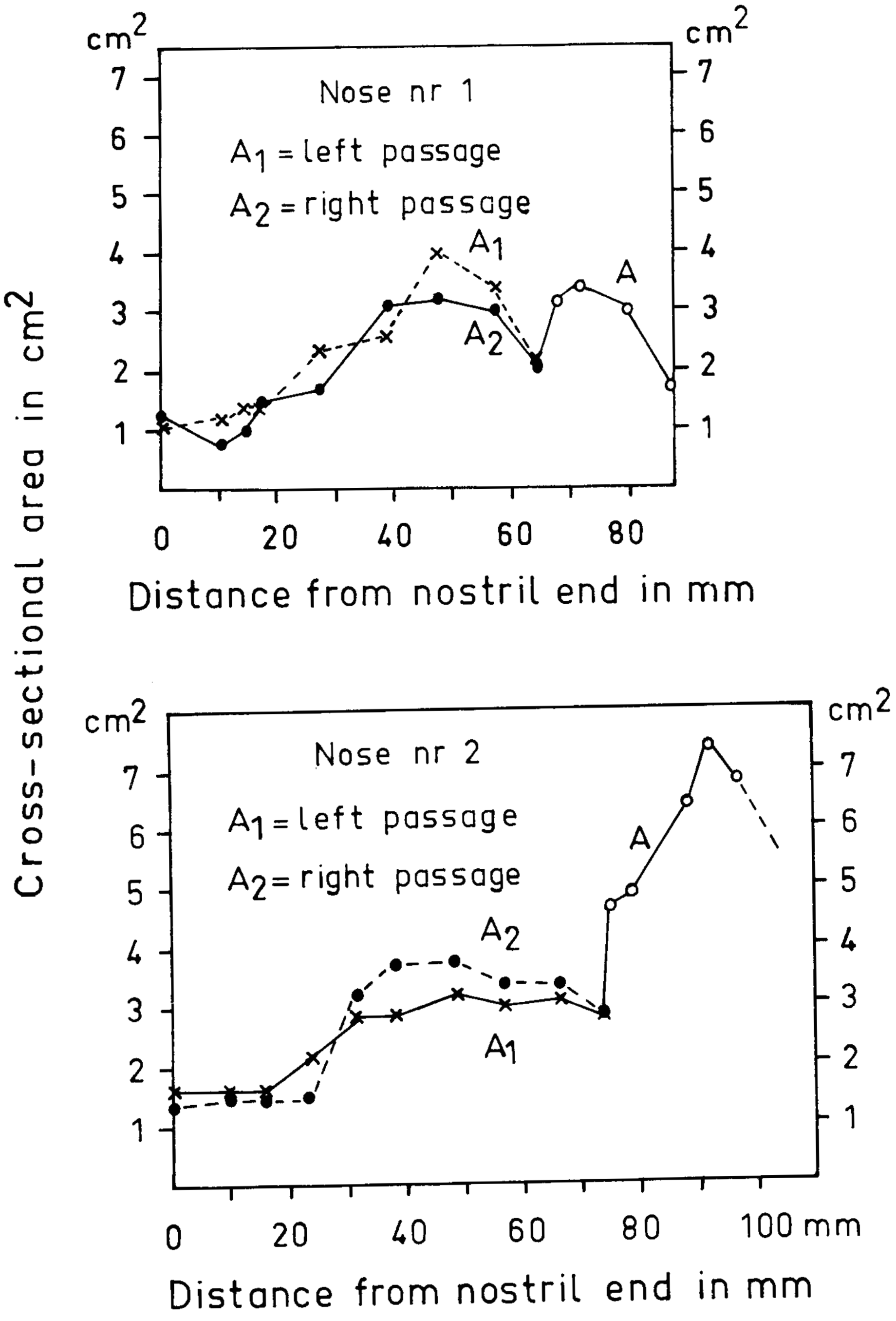

Fig. I-B-3. Area functions of two female noses. The left and right nasal pathways are represented separately.

to additional mass elements at bends and at the internal orifice related to radiation terms of the wave equation.

The anatomical variation of nasal cavity dimensions is appreciable and it is highly probable that thin-nosed individuals would have even lower natural frequencies of the nasal cavity system than indicated above. A physiological requirement for the base formant of a nasalized vowel to be low in frequency and fairly independent of the speaker's F_1 is that the fundamental resonance of the nasal system is indeed low.

It is interesting to note that the effect of nasal asymmetry on the spectrum of the orally closed nasal consonant is similar in principle to the effect of nasalization on a vowel, i.e. to introduce additional poles and zeros.

More data of the type already collected by Fujimura [5] and direct impedance measurements of the nasal cavities should provide a much clearer picture of individual spread in relevant nasal transmission characteristics.

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