

A Radiographic Study of Nasality

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It is generally accepted that the degree of perceived hypernasal voice quality is related to the configuration of the entire oral-pharyngeal-nasal tract resonance system and not just to the degree of velopharyngeal aperture. Subtelny (4) found relationships between degree of nasality and a number of vocal tract measures. She noted that, for the vowel /i/, the tongue was placed in a more anterior position in cleft palate subjects than in normal subjects and that the anterior oral cavity tended to be shorter and the posterior oral cavity longer in the cleft palate group than in normals. Warren and Ryon (5), in an analog study, concluded that in the presence of a velopharyngeal aperture, air pressure and airflow characteristics are determined by oral opening, nasal resistance, and respiratory effort rather than the degree of velopharyngeal aperture. Lubker and Moll (3) reported that "nasal air flow is dependent not only upon the amount of velopharyngeal opening but also upon the amount of oral constriction" (p. 271). In addition, Fant (2) and various other authors have stressed the variability of acoustic output of the vocal system from subject to subject and from vowel to vowel probably due to individual differences in the physical properties of vocal tracts.

In an earlier report (1), the results of an acoustic study of nasality were presented. The present study serves as an extension of this and was designed to investigate certain physical correlates of nasality and their relationships to the acoustic results reported earlier.

Procedures

Three groups of subjects were selected for study. The groups consisted of twenty normal speakers, twenty speakers classified as having functional nasality, and twenty speakers with cleft palate and nasality. All subjects were adult males. Lateral head X rays were taken of each subject during the center portion of the vowel /i/ in plosive consonant environment by means of an Angrabrite stereocephalostat triggered by a voice-operated relay. Spectrographic analysis of recordings made during

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the filming process were used to determine whether the X ray coincided with the center portion of the vowel. The head of each subject was oriented in the Frankfort horizontal with a head-holding device. Immediately after the films were taken, the speech samples were repeated in a sound-treated environment and analyzed spectrographically. The results of the spectrographic analysis were reported earlier (1).

The following measures were taken from the X rays in one-hundredths of an inch: velopharyngeal aperture, defined as the least distance between the soft palate and the posterior pharyngeal wall; tongue-palate aperture, defined as the least distance between the tongue and the hard palate; tongue-pharynx aperture, defined as the least distance between the tongue and the posterior pharyngeal wall; lip aperture, defined as the least distance between the upper and lower lips; front oral length, defined as the distance from the point of tongue-palate constriction to the point of lip constriction on a line parallel to the hard palate; back oral length defined as the distance from the posterior pharyngeal wall to the point of tongue-palate constriction on a line parallel to the hard palate; and pharyngeal length, defined as the distance on the posterior pharyngeal wall from the plane of the hyoid body to the plane of velopharyngeal constriction.

Median ratings of nasality for each subject were obtained by the method reported earlier (1). The x-ray data were analyzed in two ways. First, the relationship between the physical measures and the degree of perceived nasality was investigated. Second, the relationship between physical characteristics which seemed associated with hypernasality and the acoustic correlates of nasality previously obtained was investigated. For reference, these acoustic correlates were related to loss of power, increased damping, and the addition of resonances and anti-resonances to the vowel spectrum.

Twenty-three per cent of the x-ray dimensions were measured twice to provide an estimate of measurement error. Ninety-three per cent of the repeated measures were within .05 inches of the original measures. The average error for any one dimension was .05 inches or less.

Spearman rank-order correlation coefficients corrected for ties were computed between degree of perceived nasality and each of the physical measurements. In addition, combinations of some of the measures were compared to degree of nasality. Some of these combinations were percentage of back and front oral cavity length to total length, and differences between and ratios of various of the aperture measures.

Results

Only two of the physical measures were highly correlated with the degree of perceived nasality. These were velopharyngeal aperture, and the ratio of velopharyngeal aperture to tongue-pharynx aperture. Lower correlations were found between the degree of perceived nasality and

TABLE 1. Spearman rank order correlation coefficients between degree of perceived nasality and selected vocal tract measurements.

	<i>correlation coefficient</i>	
	<i>all subjects</i>	<i>subjects with velopharyngeal apertures</i>
velopharyngeal aperture.....	.78	.74
ratio of velopharyngeal aperture to tongue-pharynx aperture.....	.78	.80
tongue-palate aperture.....		.56
tongue-pharynx aperture.....		.60
ratio of velopharyngeal aperture to tongue-palate aperture.....		.59

tongue-palate aperture, tongue-pharynx aperture, and the ratio of velopharyngeal aperture to tongue-palate aperture. All of these correlations, presented in Table 1, were significant beyond the .01 level of confidence.

The correlations between increased tongue-pharynx and tongue-palate distance and increased nasality indicate a lower, more forward position of the tongue for the more nasal subjects. The cavity length measurements did not reveal any relationship to the degree of perceived nasality.

Another way of looking at the data was to see how many of the most nasal subjects (those with median nasality ratings of 5.0 to 7.0 on the seven-point scale) had physical measurements which fell outside of the range of any of the less nasal subjects. Table 2 presents the medians, semi-interquartile ranges and ranges for all subjects divided into least, mid and most nasal speakers on the basis of the perceptual judgements.

Table 3 presents the percentage of most nasal subjects with extreme physical measurements. Once again the trend for the more nasal subjects to have the tongue placed in a low anterior position is indicated.

Reference to Table 2 suggests another trend in the physical measurements. On all measures except pharynx length and front-oral length, there was a tendency toward increased variability with increasing nasality. This was particularly apparent for the tongue-palate and tongue-pharynx apertures and for the measure of back-oral length.

In a previous study of the acoustic correlates of nasality (1), using the same data, the following acoustic measures were found to be related, inconsistently, to the degree of perceived nasality: a) frequency of the fundamental and of formant three, b) relative intensity of the third harmonic and of formants two and three, c) bandwidth of formants one and two, and d) the appearance of extra resonance peaks and acoustic fill between regular vowel formants. An attempt was made to discover any relationships which existed between the occurrence of acoustic and

TABLE 2. Measures of central tendency and variability of physical measurements for subjects grouped by degree of perceived nasality. Categories are least nasal: median ratings 1.0-2.0; mid group: median ratings 2.5-4.0; most nasal: median ratings 5.0-7.0.

	<i>degree of nasality</i>		
	<i>least</i>	<i>mid</i>	<i>most</i>
velopharyngeal aperture			
median	0	0	.29
Q	0	.02	.28
range	.00-.07	.00-.05	.02-.78
N	19	15	6
tongue-palate aperture			
median	.13	.12	.24
Q	.03	.03	.16
range	.07-.22	.05-.21	.05-.47
N	19	14	9
tongue-pharynx aperture			
median	.81	.88	.98
Q	.09	.10	.24
range	.51-.93	.48-1.07	.28-1.18
N	18	15	15
lip aperture			
median	.38	.38	.37
Q	.06	.04	.09
range	.20-.46	.25-.57	.20-.61
N	17	15	14
back-oral length			
median	1.81	1.88	1.75
Q	.11	.12	.16
range	1.35-2.09	1.17-2.80	1.25-2.30
N	19	15	9
front-oral length			
median	2.22	2.14	1.95
Q	.09	.15	.11
range	1.80-2.83	.72-2.48	1.67-2.22
N	18	15	9
pharyngeal length			
median	3.12	3.22	3.26
Q	.16	.22	.15
range	2.83-3.30	2.90-3.70	2.83-3.89
N	19	15	13

physical measures which seemed related to the degree of perceived nasality. No consistent relationships were found.

Conclusions

The results of this study were not surprising for several reasons. First, several sources of error in the study should be noted. As many investiga-

TABLE 3. Percentage of subjects in most-nasal group who evidenced more extreme physical measures than any subjects in the least-nasal group.

<i>measure</i>	<i>percentage</i>
tongue-palate apertures larger than least-nasal subjects.....	60
tongue-pharynx apertures larger than least-nasal subjects.....	56
tongue-palate and/or tongue-pharynx aperture larger than least-nasal subjects.....	83
lip apertures larger than least nasal subjects.....	21

tors have noted, the oral structures are in constant motion during speech and so the value of the single exposure X ray is limited and may not reflect the parameters of importance. In addition, some variability was undoubtedly added by the procedure of basing the physical measurements and the acoustic measurements on different utterances. However, the similarity of the acoustic results, reported previously, and the physical results cannot be overlooked. In the acoustic study, the same pattern of inconsistency of relationship was obtained as in the present study. It is hypothesized that, in part, this individual variability may reflect the fact that, particularly in the case of the cleft palate subjects, gross differences in the size and shaping of the nasal chambers could be expected. In any of the subjects, the presence of a slightly deviated septum, or any other structural variation, could account for the differences in acoustic output of the system.

Summary

The present study tended to support the results of previous research which has attempted to define the physical correlates of nasality. In addition, the findings reported here emphasize the high degree of variability from person to person in terms of the measurements which seemed related to the degree of nasality. In addition to the expected high correlation between size of the velopharyngeal aperture and degree of perceived nasality, the most nasal subjects tended to have a lower, more anteriorly placed tongue and to be more variable on most of the physical measures obtained than the least nasal subjects.

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