An Investigation of the Relationship between Oral Panendoscopic Evaluations of Velopharyngeal Physiology and Perceived Listener Judgments of Hypernasality

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AN INVESTIGATION OF THE RELATIONSHIP
BETWEEN ORAL PANENDOSCOPIC EVALUATIONS OF VELOPHARYNGEAL PHYSIOLOGY
AND PERCEIVED LISTENER JUDGMENTS OF HYPERNASALITY

by

Earl J. Seaver, III

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Earl J. Seaver, III
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## TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>THE PROBLEM AND ITS BACKGROUND</td>
</tr>
<tr>
<td></td>
<td>Assessment Techniques</td>
</tr>
<tr>
<td></td>
<td>Purpose of Study</td>
</tr>
<tr>
<td>II</td>
<td>THE RESEARCH DESIGN</td>
</tr>
<tr>
<td></td>
<td>Apparatus</td>
</tr>
<tr>
<td></td>
<td>Testing</td>
</tr>
<tr>
<td></td>
<td>Judges</td>
</tr>
<tr>
<td></td>
<td>Judgment Procedures</td>
</tr>
<tr>
<td></td>
<td>Subjects</td>
</tr>
<tr>
<td>III</td>
<td>RESULTS</td>
</tr>
<tr>
<td></td>
<td>Judgment Tasks</td>
</tr>
<tr>
<td></td>
<td>Correlation Results</td>
</tr>
<tr>
<td></td>
<td>Analysis of Variance</td>
</tr>
<tr>
<td>IV</td>
<td>DISCUSSION</td>
</tr>
<tr>
<td>V</td>
<td>SUMMARY AND IMPLICATIONS</td>
</tr>
<tr>
<td></td>
<td>APPENDICES</td>
</tr>
<tr>
<td></td>
<td>BIBLIOGRAPHY</td>
</tr>
</tbody>
</table>
## LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Frequency of usage of phonemes in test stimuli</td>
<td>28</td>
</tr>
<tr>
<td>2</td>
<td>Intra-judge reliability as determined by correlation coefficients (r) for test retest ratings of listener judgments (LJ) and panendoscopic judgments (PJ)</td>
<td>35</td>
</tr>
<tr>
<td>3</td>
<td>Inter-judge reliability as demonstrated by percentage of agreement for listener judgments (LJ) and panendoscopic judgments (PJ)</td>
<td>36</td>
</tr>
<tr>
<td>4</td>
<td>Subject data</td>
<td>39</td>
</tr>
<tr>
<td>5</td>
<td>Median score values of judged severity of nasality and velopharyngeal closure</td>
<td>40</td>
</tr>
<tr>
<td>6</td>
<td>Results of the ten by two by two analysis of variance for the variables of judges, types of surgery and types of judgment procedures</td>
<td>45</td>
</tr>
<tr>
<td>7</td>
<td>Comparisons of mean rating values for the significant differences found in the analysis of variance</td>
<td>46</td>
</tr>
<tr>
<td>8</td>
<td>Percentages of agreement of the judges on the experimental panendoscopic (PJ) and listener judgment (LJ) tasks</td>
<td>51</td>
</tr>
<tr>
<td>9</td>
<td>Relative frequency of usage of vowels in the test stimuli. Percentages are figured relative to the vowel usage only</td>
<td>53</td>
</tr>
<tr>
<td>FIGURE</td>
<td>DESCRIPTION</td>
<td>PAGE</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
<td>------</td>
</tr>
<tr>
<td>1</td>
<td>Block diagram of videotape panendoscopy equipment</td>
<td>26</td>
</tr>
<tr>
<td>2</td>
<td>Frequency distribution of median score values of judgments of severity of nasality</td>
<td>42</td>
</tr>
<tr>
<td>3</td>
<td>Frequency distribution of median score values of panendoscopic judgments of velopharyngeal closure</td>
<td>43</td>
</tr>
</tbody>
</table>

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CHAPTER I

THE PROBLEM AND ITS BACKGROUND

Assessment Techniques

The concomitant problems associated with oral clefts include hypernasality (Buck, 1954; McWilliams, 1954; Van Hattum, 1958; Van Riper and Irwin, 1958; Spriestersbach and Powers, 1959b; Spriestersbach, 1965; Moll, 1968; Morris, 1968; Takagi et al., 1970). An understanding of this phenomenon requires an appreciation of both the normal physiology, and the disruption of that physiology caused by the cleft.

Normally, during exhalation, the air stream passes through the laryngeal structures and is vibrated by the vocal cords or passes unobstructed through an abducted glottis. The air stream continues into the pharyngeal system and the oral or nasal cavities where resonances and antiresonances are created. In normal English speech all but three phonemes are resonated primarily in the pharyngeal-oral cavities. The three nasal phonemes, /n/, /m/, and /ŋ/, differ in their resonance characteristics in that the nasal cavity is the primary resonating source. The coupling of the nasal cavity to the rest of the vocal tract is accomplished by the velopharyngeal valve. During non-nasalized phonations, the velum makes a posterior-superior movement towards the posterior wall of the pharynx, closing off the nasal cavity. During nasalized phonation the velopharyngeal valve does not seal, the oropharyngeal and nasal cavities are coupled, and
the resonances and antiresonances of the nasal cavity create a perceptual event that is subsequently described as nasality.

A number of techniques, instruments, and procedures have been developed to study normal velopharyngeal physiology. These procedures can be classified as either direct or indirect, depending upon the procedures incorporated. Direct methods typically involve visual observations of the velopharyngeal physiology.

The most widely used direct measure of velopharyngeal activity is radiography. Lateral head X-rays are taken of the lateral portion of the head during normal respiration, swallowing, or while the subject is sustaining individual phonemes (Buck, 1954; Subtelny, 1957; Graber et al., 1959; Blackfield et al., 1961; Wildman, 1961; Bzoch, 1964; Moll, 1965). The examiner evaluates and assesses the anterior-posterior relationships of the velum and posterior pharynx.

A number of difficulties and limitations are present with the use of lateral X-ray (Bzoch, 1970). Certain of these difficulties or limitations arise from the inability to view velopharyngeal valving in its physiological entirety. During the analysis, the examiner is provided with a two-dimensional, static representation of a three-dimensional, dynamic process. Therefore, only guarded inferences can be made regarding cephalometric observations of running speech. Also, because of the lateral positioning of the equipment, the examiner's view of the mesial-lateral plane is restricted.

Another radiographic technique which better illuminates the velopharyngeal structures is laminagraphy (Hagerty et al., 1958a;
Hagerty and Hill, 1960; Moll, 1965). This procedure involves rotating the X-ray equipment along an arc equidistant from the structures in question. Consequently, the structures acting as the loci of the arc are distinct, while the other structures are blurred because of their variable distance from the equipment.

Most popular of the radiographic techniques is cinefluoroscopy (Carrell, 1952; Calnan, 1956; Moll, 1960; Bjork, 1961; Moll, 1962; Powers, 1962; Bjork and Nylen, 1963; Shelton et al., 1963; Shelton et al., 1964; Moll, 1965; Harrington, 1970; Hooper et al., 1970). X-ray motion pictures are made of the velopharyngeal activity during continuous activity. The pictures are taken at speeds varying from 24 to 200 frames per second (Shelton et al., 1963; Moll, 1965), and displayed on the fluoroscope screen of an image intensifier tube. The primary advantage of this procedure is that the examiner is able to view the dynamic phenomena of continuous speech. Also, sound can be synchronized with the films so that the examiner may relate a specific image with a specific instant of the output signal.

Skolnick (1970) has developed and reported a radiographic technique that allows for the observation of the mesial-lateral plane of the velopharyngeal port area. Base cinefluorographic pictures are taken from a position perpendicular to the velopharyngeal port area of the subject who has been placed in a sphinx position with the head and neck lifted.

While this procedure utilizes the advantages of cinefluorography and observations of the mesial-lateral plane, certain limitations are apparent. Because of the necessity for the velopharyngeal port plane
to be perpendicular to the X-ray beam, it is necessary to take simultaneous lateral and base cinefluorography. Therefore, the subject is forced to undergo radiation exposure of two radiographic procedures rather than one. Also the author discusses the difficulty in obtaining pictures of those subjects who are not able, because of a relatively short neck, to place the velopharyngeal port area in the proper position for examination. Mention is also made to the difficulty in examining individuals with large adenoidal tissue. One must also question the effects the abnormal head and neck positions have on the normal velopharyngeal valving.

Certain of the limitations of radiography in general relate directly to the subject (Bzoch, 1970). Because of X-ray, the subject is exposed to radiation. Although the dosage can be controlled by various methods (Moll, 1965), it remains a variable that must be closely monitored. If the samples are inadequate, the subject must return later, undergo immediate re-examination, or undergo larger doses of radiation while the equipment is being positioned to facilitate better pictures.

The most widely used clinical observation of velopharyngeal valving is the peroral examination.

A detailed description of the use of the peroral examination is given by Manson and Grandstaff (1970).

The examiner observes the posterior-superior movement of the palate while depressing the dorsal portion of the tongue. During the production of the vowel /a/, the examiner observes the extent of palatal movement and the symmetry, as well as subjective evaluations
of palatal length and adequacy. Some investigators have stated that lateral pharyngeal movements can be detected from this examination procedure (Johnson et al., 1963; Manson and Grandstaff, 1970) but they do not agree as to the validity of this observation, nor its significance.

The examiner is limited in his observations when using this procedure. He observes the velum from an anterior-inferior position, and subjectively evaluates its movement characteristics. Because the mouth must be open and the tongue restricted, the evaluation is administered while the subject is sustaining /a/, thereby eliminating observation of connected speech and other phonemic variations.

A technique using motion picture analysis has been described by Harrington (1944), Bloomer (1953), and Calnan (1953). In these studies, velopharyngeal activity was observed through surgically-created orifices in the skull. This provided a view and record of the velopharyngeal activity during connected speech. Although these procedures provided unobstructed observations of valving, the effect of absences of large portions of the face on the intricate physiology of velopharyngeal valving must be considered before comprehensive statements regarding normal physiology can be made. Obviously this procedure has no clinical value as an evaluation technique.

Two procedures that have been used to observe the velopharyngeal physiology involve modifications of endoscopic equipment and procedures.
Pigott (1969) has used the nasendoscope to observe the velopharyngeal physiology from a superior position in the nasal pharynx. A novel view of velopharyngeal structures that includes observations of not only the anterior-posterior plane, but the mesial-lateral plane from a position most immediate to the velopharyngeal port is obtained. While valving can be observed either optically or by recording equipment, difficulty with the insertion of the instrument through the nares should be recognized. Nasendoscopy does not seem to lend itself to a clinical evaluation of velopharyngeal valving due to the patient's routine reluctance and biological irritation to the insertion. This results in major limitations when considering its clinical merit.

A second technique using endoscopic instrumentation is the oral panendoscope (Taub, 1966). The oral panendoscope is inserted per-orally allowing observation of the velopharyngeal valving from an inferior position in the oral pharynx. Like nasendoscopy, oral panendoscopy provides the examiner with a view of the anterior-posterior relationships, and the mesial-lateral dimensions. Willis and Stutz (1969a and 1970), in their observations of normals, have reported on the movements in velopharyngeal valving during connected speech. They have described not only the velar and posterior pharyngeal tissue movements, but the importance of lateral pharyngeal tissue movements. Six distinct patterns of velopharyngeal movement in normals, appearing consistently in all forms of physiological activity requiring velopharyngeal valving, were described.
Coupled to video tape equipment, the technique remains relatively inexpensive and portable. Panendoscopy poses no potential health risk to the subject, and can be administered even to a child with a minimum of discomfort when proper rapport has been established.

Again, three-dimensional velopharyngeal activities are observed in a two-dimensional plane. Also, although the examiner is able to observe velopharyngeal activity during connected speech, the speech sample is limited to a specific number of phonemes because of the restriction of the tongue by the panendoscope. Because of the initial fear of the gag reflex, the clinician frequently must spend time establishing rapport during the pre-examination period. Another possible limitation involves the control of the gag and swallow reflexes. A mild topical anesthetic such as Cetecaine can be used to reduce these reflexes.

The final two direct techniques do not involve direct visual observation of the velopharyngeal structures. The first of these two procedures is electromyography. A number of investigators (Broadbent and Swinyard, 1959; Basmajian and Dutta, 1961; Cooper, 1965; Fritzell, 1969; Harris, 1970) have reported the use of EMG techniques to study the activity of the musculature involved in velopharyngeal valving. EMG provides a graphic representation of the electrical activity which accompanies muscle contraction. The potentials or activity are reported through needle or suction electrodes attached to specific muscles. Although this procedure provides a measure of the forcefulness of the velopharyngeal structures, and a more
objective analysis of the anatomy directly involved, certain difficulties are present with the methodology. EMG measures the activity of the muscles, but does not measure the direction or resulting distance displacement. The direction of the movement must be ascertained through observation of musculature origin-insertion. Often this is ambiguous as with the debate over the insertion and functioning of the tensor muscle in velopharyngeal valving (Fritzell, 1969; Harris, 1970).

Electrode placement often provides difficulty for the investigator. The complex muscle structure of the pharynx makes it difficult to be certain of the actual muscle segments that are being measured (Fritzell, 1969; Harris, 1970). EMG can be a very valuable research tool, but has little clinical value.

Recently the use of ultrasonic principles has gained significant impetus in speech research (Kelsey et al., 1969; Lubker, 1970; Minifie et al., 1970). Its use in velopharyngeal activity investigations needs further exploration.

The indirect observation techniques involve measuring velopharyngeal activity from related or resulting phenomena. The basic principle underlying these procedures is that velopharyngeal activity is either consistent during various activities or systematically affects various overt phenomena and therefore can be thought to be indirectly measured or evaluated by these phenomena. As stated earlier, the velopharyngeal mechanism is needed to separate the nasal and oral cavities during speech for the oral sounds. When this is achieved, a normal voice quality is perceived. Furthermore, various
speech sounds require the establishment of intraoral breath pressure (Black, 1950). This pressure is established by blocking the oral cavity at some point, along with velopharyngeal valving, to prevent the nasal escape of the impounded air. The indirect techniques can be further subdivided into either the measurement and analysis of speech or speech-related activities.

A common clinical technique for observing speech related phenomena is the use of manometrics. Manometrics require the subject to blow into a mouth piece connected to some form of read-out system, first with the nostrils open, then occluded. The pressure scores are inserted into a ratio with the 'open' score placed over the 'occluded' score. In blowing activities, normal speakers achieve velopharyngeal valving to prevent the air stream from leaking out of the nasal cavity. To check this physiological response, the non-occluded score is compared to the score the subject obtains with a pseudo-valve of nasal occlusion. If the ratio obtained is 1.0 or near, the subject is performing equally well on both tasks. A score of less than 1.00 would indicate that the subject is performing better with the nares occluded and therefore the subject is presumed to have difficulty in providing adequate velopharyngeal valving. A score of greater than 1.0 would indicate that the subject is performing better with the nares open. This score most usually represents an invalid assessment.

Numerous reports on manometric and spirometric techniques are to be found in the literature (Spriestersbach and Powers, 1959a; Morris et al., 1961; Spriestersbach et al., 1961; Hanson, 1964; Hardy,
1965; Morris, 1966; Pitzner and Morris, 1966; Lubker, 1970). All of these techniques involve basically the same techniques of blowing into a mouth piece with a maximum expiratory effort in order to obtain some type of pressure measurement. The measurement involves the number of ounces per square inch in a chamber, or the distance a column of mercury or water is moved in a calibrated tube.

The manometric device which has received the most wide usage, because of its size and portability, is the Hunter Oral Manometer (Hardy, 1965; Morris, 1966; Shelton et al., 1968).

Although manometrics provide a measure of the effectiveness of the velopharyngeal mechanism to valve in order to maintain oral breath pressure, they do not represent the adequacy of the mechanism during speech. Because this can only be inferred from the ratios obtained, they can often be misleading. A score of 1.0 or near may not always represent an ability to achieve total velopharyngeal valving. Quite obviously, if a subject obtained a score of 1.0 with significantly low scores, he could not be said to be performing identical to another individual who obtained a ratio of 1.0 with significantly higher scores. Spriestersbach and Powers (1959a) have stated that pressure scores of at least 8.0 ounces per square inch should be obtained before the resulting ratios can be thought to represent an adequate test. If some type of bleed or escape valve is not present, caution must be taken to assure that the subject is not using some form of lingual or buccal valving to create oral breath pressure. With the bleed on, the subject is forced to maintain a continuous breath stream which counteracts atypical valving.
Other indirect measuring techniques are used to assess oral air flow and pressure. While air flow and pressure techniques not requiring maximum expiratory efforts are based on the same principles as manometrics, these techniques are separated from manometrics because of the differences in the sophistication of equipment and their objectivity.

Oral air pressure instrumentation consists of a pressure transducer, a read-out system, and a tube connecting the two (Warren and Dubois, 1964; Subtelny et al., 1966; Arkebauer et al., 1967; Isshiki et al., 1968; Warren and Mackler, 1968; Lubker, 1970; Machidi and Nagi, 1970; Subtelny et al., 1970). The pressure transducer is placed either in the oral cavity or in an anesthetist's mask and is sensitive to the presence and variation in the pressure of the oral breath stream. The sensings of the transducer are conveyed by the connecting tube to a read-out system which prints a frequency representation of the pressure. The transducer system allows the examiner to make assessments of the intricate fluctuations of the pressure during connected speech.

As with manometrics, the results of oral breath pressure studies are only an indirect measure of the velopharyngeal valving. Statements about the velopharyngeal mechanism represent an inference based on normative data.

Air flow instrumentation is essentially the same as that used in air pressure study, except, instead of a pressure transducer, one of two types of flowmeter is used (Kelleher et al., 1960; Isshiki and Ringel, 1964; Quigley et al., 1964; Lubker and Moll, 1965; Machida,
Van Hattum and Worth, 1967; Emanuel and Counihan, 1970; Lubker, 1970; Machida and Nagi, 1970). The hot-wire anemometer consists of wire that is heated and placed in line with the oral breath stream. As the breath stream passes over the wire, it is cooled and the temperature reduction of the wire is recorded in some manner on the read-out system. The amount of air flow is directly related to the amount of reduction in the heat of the wire. The other type of flowmeter, the pneumotachograph, is constructed so that the air flow meets a specified resistance. A pressure transducer then measures the pressure change and provides for a calibrated read-out that represents the flow change in the oral cavity.

Nasal air flow and pressure studies have incorporated basically the same apparatus and procedures as oral air flow and pressure studies (Hess and McDonald, 1960; Kelleher et al., 1960; Lubker and Moll, 1965; Emanuel and Counihan, 1970; Lubker, 1970; Machida and Nagi, 1970). The pressure transducers and flowmeters are placed in or near the nares or nasal cavity to measure and record the breath stream present in the nasal cavity. Most of the investigations using this instrumentation have involved hypernasal speakers.

Also, the area of the velopharyngeal port can be measured, using nasal flow readings, by using hydrodynamic principles (Warren, 1967; Warren and Mackler, 1968; Machida and Nagi, 1970).

The final group of assessment techniques involves the observation of pathological speech. Because hypernasality is associated with a deficiency in velopharyngeal valving, an indirect measure of its adequacy can be made by analyzing its output characteristics.
These assessments concern either the electrical analysis of the acoustical phenomena associated with hypernasality, or the perceptual assessment of the hypernasality.

The electrical analysis of the acoustical phenomena associated with hypernasality involves two basic procedures. The first is the creation of artificial hypernasality. The simulated nasality is created by using electrical analogs. Electrical analogs involve the representation of the speech mechanisms by electrical circuitry (House and Stevens, 1956; House, 1957; House and Stevens, 1958; House, 1960; Warren and Devereaux, 1966; Warren and Ryon, 1967).

Noise is generated by a complex noise generator and is passed through a series of transmission lines which represent the resonances of the vocal tract. A variable coupler is connected between the transmission channel and a highly damped resonating channel which simulates the velopharyngeal port and nasal cavity respectively. House and Stevens (1956), utilizing electrical analogs of vowels, found a broadening and flattening of the spectral peaks particularly in the first formant region. They also reported a reduction in the overall intensity when the oral and nasal cavities were coupled. In House's (1957) analog studies of nasalized consonants, the following data were reported:

"...synthetic nasal consonants are characterized by low frequency spectral prominence in the vicinity of 200-300 Hz, by a second prominence near 1000 Hz, by an antiresonance or 'zero' that varies according to articulation; by high frequency attenuation greater than that found in vowel sounds; and by an over-all level lower than vowels." p. 198
While analogs allow for a systematic study of simulated nasality, caution must be used when making comparisons to hypernasality resulting from cleft palate. Curtis (1968) points out this factor when he states:

"... the data were derived from models which simulate the normal vocal tract structure, whereas the cleft palate problem is complicated by an abnormal vocal tract structure with a range of variety and severity of deviations." p. 52

Jakobson et al. (1967) have reported data on the nasalization of phonemes similar to that discussed above. They have shown that the nasalized phonemes in English demonstrate spectra with an overall increase in energy when compared to the oral phonemes. On nasalized vowels they discovered a reduction in the first two formant intensities accompanied by an additional formant located between the two. With the front vowels, this formant was located below the first formant. The nasalized consonants were also observed to have two distinct additional formants around 200 and 2500 Hz.

Fant (1960) has theorized that the reduction of formants is due to a zero of the nasal cavity coinciding with a formant of the vocal tract. If the zero does not coincide with the formant then there will be a reduction in the intensity of the harmonics surrounding the formants. Similarly, if a pole of the nasal cavity coincides with a formant of the vocal tract, there will be a resulting increase in the intensity of the formant. If a pole does not coincide with a formant, then an increase in energy will be observed between the formants.
The spectral analysis of hypernasality represents a subjective evaluation of frequency-time-intensity graphs. While the underlying assumption for using spectral analysis of hypernasality is that an increase in oral-nasal coupling results in an increase in the spectral changes in the acoustical output (Bloomer and Peterson, 1955; House and Stevens, 1956; Dickson, 1962), more systematic experimentation utilizing acoustic analyses concomitant with direct physiological analyses in order to assess the effect of small differences of velopharyngeal valving on the acoustical output signal (Bjork, 1961; Bjork and Nylen, 1963) is needed.

Fletcher (1970) has reported on the development of instrumentation (TONAR) which derives a ratio between the measured acoustical outputs from the nose and mouth. He feels that this instrument provides not only an objective measure of hypernasality, but a means for approaching therapy (Fletcher and Peterson, 1970).

Perceptual observation of the speech output can be made either on the resonance phenomena or the articulatory characteristics related to velopharyngeal valving. It is known that various speech sounds, in particular the plosives, fricatives and affricates, require the establishment of intra-oral breath pressure for the normal production of speech (Black, 1950). If this pressure build-up is prohibited, these sounds will be, understandably, weak or distorted. Because of the velopharyngeal insufficiency often associated with oral clefts, these phonemes often account for much difficulty in articulation (Spriestersbach et al., 1956; McWilliams, 1958; Counihan, 1960; Byrne et al., 1961; Spriestersbach et al., 1961;
Van Demark, 1964; Pitzner and Morris, 1965; Moll, 1968; Morris, 1968; Prins and Bloomer, 1968; Subtelny et al., 1970).

Based on the above assumption, Morris, Spriestersbach and Darley (1961) developed the Iowa Pressure Articulation Test. They divided twenty-five subjects into either a good closure group or an inadequate closure group based on X-rays and spirometer measurements. After administering a 150-item diagnostic test (Templin and Darley, 1960) to all of the subjects, they selected those sounds that yielded significant between-group differences. Of the seventy-four items, forty-three were selected as discriminators between speakers with adequate and inadequate velopharyngeal valving. It is assumed that the results of the test are indicative of oral breath pressure, and that a poor performance reflects an inadequate velopharyngeal valving for speech. This method is limited in that the examiner can only infer about the velopharyngeal mechanism's operation. The examiner must judge if the misarticulations truly represent inadequate valving or some other form of etiology.

The final indirect assessment technique involves perceptual listener judgments of a speaker's resonance quality. This procedure is based on the recognition that when the phonated air stream is allowed into the nasal cavity, certain resonances and antiresonances produce a change in the acoustic properties and they are perceived as hypernasality. Again, because the velopharyngeal mechanism is the regulator for the oral-nasal coupling, it is assumed that a judgment of the speech output represents an evaluation of that mechanism's efficiency. Controlled listener judgment studies involve...
a number of listeners evaluating a recording of a speaker's productions according to some type of rating or ranking scale (McWilliams, 1954; Spriestersbach and Powers, 1959b; Lintz and Sherman, 1961; Moll, 1962; Bradford et al., 1964; Counihan and Cullinan, 1970; Subtelny et al., 1970).

Considerable debate has taken place over the method of presentation of the speech samples.

Sherman (1954) and Spriestersbach and Powers (1959b) have argued that the forward playing of a recorded sample does not truly represent a judgment of the resonance characteristics. They substantiate this with the fact that other language parameters as articulation difficulties and the audible emission of nasal air affect the listener's evaluation. The backward playing of the recordings eliminates these cues, thereby forcing the judges to depend solely on the resonance cues. Other investigators (Counihan and Cullinan, 1970; Fletcher and Bishop, 1970) have stated that the converse is true. Their investigations suggest that the forward playing of recordings is the most valid and reliable method for judging hypernasality.

A large portion of the measuring techniques discussed here also have been used in attempting to measure hypernasality. Hypernasality has been defined (Kanter, 1948; Van Riper and Irwin, 1958; Moll, 1968) as a voice quality characterized by excessive resonance of the output signal in the nasal cavity. Moll (1968) has stated that if a perceptual definition of hypernasality is used, then the only
technique which possesses face validity in measuring it is perceptual listener judgments. Realizing the subjectiveness of listener judgments, more sophisticated and objective procedures have been used to measure hypernasality. Before these techniques can be thought of as a measure or index of hypernasality, their results must be correlated with perceptual listener judgments.

While the assessment of the pressure consonants represents a perceptual listener judgment, it does not involve an assessment of the deviant voice quality. One must assume that the weaker or greater the distortion of the consonants, the more inadequate the velopharyngeal activity, and the more severe the hypernasality.

Lintz and Sherman (1961) investigated the effects of phonetic elements upon the perception of nasality. They found in regards to the severity, that the hypernasal population differed from the non-nasal population in the relationships between consonant environment and vowels. They found that voiced syllables and the fricatives were judged more nasal. Caution must be taken when drawing conclusions from this investigation because non-cleft nasal subjects were used (Moll, 1968).

McWilliams (1954) investigated the relationships between articulation, intelligibility, and nasality in 48 hypernasal adults. A significant correlation coefficient of .821 was reported between consonant articulation and nasality ratings on a five-point scale. The judgments of both articulation and nasality were made of utterances contained in words, sentence phrases, and short passages by two different groups of judges.
Significant relationships were found between consonant articulation errors and nasality by Subtelny et al. (1970). Nasality and articulation were judged in sentences containing articulation test items. Nasality was judged according to a seven-point scale, with three representing normal resonance, for 96 (48 pre- and post-operative pharyngeal flaps) subjects. Relationships between nasality and total articulation errors, voiced and voiceless plosives, and voiced and voiceless fricatives of .50, .41, .40, .55, and .54, respectively, were reported.

Subtelny et al. (1961), using an N of 70, reported a significant relationship of .42 between intelligibility and nasality ratings on a four-point scale. The intelligibility of twenty-seven of the speakers was judged according to 48 nonsense syllables, while the other 43 cleft palate speakers were judged according to their performance on eight PB word lists. Nasality was judged for all speakers according to their performance on a continuous reading passage. The reported relationships must be viewed cautiously because of the two different, non-continuous intelligibility stimuli passages that were compared to the uniform and continuous reading passage.

Van Hattum (1958) reported relationships between articulation performance and nasality judgments of 20 cleft palate subjects. He observed that subjects judged to be more superior in articulation abilities were judged to be less nasal based on the data. Nasality was judged on a scale of six points and articulation was evaluated in sentences.
Oral air flow and pressure, both manometric and non-maximum expiratory efforts, are utilized for assessing velopharyngeal activity under the assumption that hypernasality and, subsequently, velopharyngeal valving are inversely related to the amount of oral air flow and/or pressure.

Investigations of the relationships between air flow and pressure have centered primarily around their relationship to velopharyngeal inadequacy as measured by radiographic techniques (Spriestersbach and Powers, 1959a; Morris et al., 1961; Powers, 1962; Brooks et al., 1965; Massengill et al., 1970) or to articulation proficiency (Morris et al., 1961; Spriestersbach et al., 1961; Fitzner and Morris, 1965; Barnes and Morris, 1967).

Shelton et al. (1967) found correlation coefficients ranging from .008 to .47 between various measures of oral and nasal sound pressure levels and nasality judgments on a nine-point scale. It must be also pointed out that the speech samples used varied from individual to individual, and they were presented backward to the judges.

Subtelny et al. (1970) correlated nasality ratings of 46 pre- and post-operative cleft palate subjects with intra-oral pressure measurements taken while producing /p/ and /s/. They reported correlations of -.56 for /p/ and -.48 for /s/, both of which were significant above the .01 level.

More investigation is needed before statements regarding the validity of pressure-flow measurements as an index of hypernasality can be made.
As with oral air flow/pressure studies, nasal air flow/pressure studies have primarily involved the relationships between these measures and articulatory measures (Hess and McDonald, 1960; Emanuel and Counihan, 1970; Lubker et al., 1970; Machida and Nagi, 1970).

Subtelny et al. (1970) correlated nasality ratings with nasal flow on /p/ and /s/. Correlation coefficients significant above the .01 level (.51 for /p/ and .55 for /s/) were reported. It also must be noted that the flow measures were made in a free field. When a "nasal ratio" was established in order to eliminate possible contamination due to vocal effort and respiratory capacity, they reported coefficients of .68 for /p/ and .72 for /s/.

In an attempt to validate the use of TONAR as a valid assessment of hypernasality, Fletcher and Bishop (1970) correlated acoustical ratios and the direct magnitude scores of nasality. Among their results they reported significant correlations between rank-order listener judgments and acoustic TONAR measurements, and TONAR measurements and absolute ratings of speech during the forward play of tape recordings. Their results led them to the conclusion that, "TONAR has promising clinical possibilities."

As with the other indirect assessment techniques, the relationship between TONAR results and physiological movements is both relative and inferential.

Radiography has been used to assess the amount of anterior-posterior distance between the velum and posterior pharynx. It is expected that the greater the distance, the more the escape of air
into the nasal cavity, and the greater the severity of the hypernasality.

Hagerty and Hoffmeister (1954) correlated listener judgments of hypernasality on a four-point scale and velum-to-pharyngeal wall distance as seen by lateral X-ray while the subjects were producing /a/ and hissing. For the 44 subjects, correlation coefficients of .60 for /a/ and .78 for hissing were reported.

Subtelny et al. (1961) correlated the nasality ratings of 70 subjects on a four-point scale and the amount of velopharyngeal distance during the production of /u/ as depicted from later x-rays. A significant correlation coefficient of .53 was reported.

Subtelny et al. (1970) divided the cephalometric data for 48 pre- and post-operative cleft palate subjects into sub-groups of speech adequacy. They reported that the area of the nasopharyngeal space was significantly larger in the poor talking group. They also reported measures of nasopharyngeal depth, velar mobility and velopharyngeal constriction site and degree, as discriminating the two speech groups.

While the above is not a comprehensive or exhaustive report, more systematic investigation is needed into the relationships between speech production and radiographic analyses of velopharyngeal physiology on both isolated phonemes and connected speech.

EMG tracings provide a much more difficult problem in assessing velopharyngeal adequacy and, therefore, hypernasality. Because of the problems with electrode placement and knowing the direction of movement, it becomes difficult to know exactly what effect the muscle...
activity has on velopharyngeal valving. The results of EMG study would need to be compared to normative data and then to hypernasality judgments before valid statements could be made about the use of EMG for assessing hypernasality.

Oral panendoscopy and nasendoscopy are used to observe the velopharyngeal activity during speech. Before they could be used to measure hypernasality, their measurement of velopharyngeal openings during speech would have to be correlated with listener judgments. Nasendoscopy has not been used in this manner.

The oral panendoscope has been used for both the experimental and clinical assessment of velopharyngeal activity. Clinically, the speech pathologist observes the velopharyngeal activity and makes assessments of the adequacy of the mechanism for speech, under the assumption that the greater the velopharyngeal opening or port during speech the more hypernasal the speaker. Because of the lack of objective measuring instrumentation, the clinician is forced to make subjective judgments relative to his experience in the normative study of panendoscopic findings.

Purpose of Study

It is the purpose of this study to investigate the validity of the subjective and clinical panendoscopic assessments of velopharyngeal activity as an index of hypernasal voice quality. Because panendoscopy has been used primarily as a clinical tool, certain variables have not been controlled. First, the examiner must rely on his study of normative physiology to base his judgments of
velopharyngeal mechanism. Because the velopharyngeal mechanism has been observed to not occlude entirely during normal speech production, the examiner must have some internalized scale upon which to assess the degree of closure.

Secondly, the assessment of pathological closure has been used primarily to aid the plastic surgeon and cleft palate team in selecting the best procedure or procedures to aid the individual. After corrective procedures have been carried out, panendoscopy is used to assess the success of the procedures in aiding the velopharyngeal mechanism in valving. Because the assessment of velopharyngeal activity being aided by a pharyngeal flap represents and requires a more discriminative judgment than do panendoscopic assessments of unaided velopharyngeal inadequacies, subjects having undergone this procedure were selected.
CHAPTER II

THE RESEARCH DESIGN

Apparatus

Panendoscopy

The panendoscopic samples were obtained using the apparatus described by Willis and Stutz (1969a). The apparatus is diagramed in Figure 1.

Video recordings were stored on Sony one-half-inch video tape. The visual image of the velopharyngeal mechanism was transmitted through a Taub Oral Panendoscope inserted perorally into the oral-pharynx. The image was received and transmitted by a Sony VCK-2100A video camera to either a Sony CV-220 or AV-3600 video tape recorder. The image was monitored on a Panasonic model TH-9001M television. A synchronized audio sample was obtained using a neck suspended Sony F-98 laveliere microphone coupled to the video recorder. The light intensity of the panendoscope was controlled by a National model A8232 light controller rheostat.

Listener tapes

Two microphones (Altec 633A and Electro-Voice 635A dynamic omni-directional) were used with an Ampex 602 tape deck to record the speech samples. This assured high quality recordings of each subject's speech. The samples were stored on type 125 Formula 10 - All Purpose Audio Tape. The microphone was held lateral to the
Figure 1: Block diagram of videotape panendoscopy equipment.
corner of the subject's mouth, approximately five inches away. The tape speed was 7.5 inches per second.

Testing

Panendoscopy

The subject was seated on an adjustable swivel stool and the examiner began attempting to establish a relaxed atmosphere. When the examiner felt that an atmosphere conducive to panendoscopy had been established, a peroral examination was administered. This provided the examiner with the opportunity to observe the oral cavity structures, and the shape of the oral pharynx where the panendoscope would be placed. The examiner was also able to observe the subject's gag reflex by inserting a tongue depressor into the oral pharynx approximating the examination position. If the subject was not able to initially tolerate the tongue depressor, this procedure was repeated until the subject was sufficiently conditioned. When these procedures were completed, the light of the panendoscope was turned on to heat the lens, and the subject was fitted with the microphone.

The subject was given the cards containing the test stimuli (see Appendix I). The test stimuli included those phonemes found in two preliminary investigations to be the easiest to produce with the panendoscope inserted in the oral cavity. The test stimuli are not phonetically balanced (see Table 1).

The subject practiced the test stimuli in order to become familiar with the list and to provide the examiner with an
<table>
<thead>
<tr>
<th>Phonemes</th>
<th>Words</th>
<th>Sentences</th>
<th>Words</th>
<th>Sentences</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>p</td>
<td>7</td>
<td>21</td>
<td>16.7</td>
<td>25.9</td>
<td>22.8</td>
</tr>
<tr>
<td>l</td>
<td>7</td>
<td>12</td>
<td>16.7</td>
<td>14.8</td>
<td>15.4</td>
</tr>
<tr>
<td>f</td>
<td>6</td>
<td>11</td>
<td>14.3</td>
<td>13.6</td>
<td>13.8</td>
</tr>
<tr>
<td>h</td>
<td>3</td>
<td>6</td>
<td>7.1</td>
<td>7.4</td>
<td>7.3</td>
</tr>
<tr>
<td>b</td>
<td>2</td>
<td>2</td>
<td>4.8</td>
<td>2.5</td>
<td>3.2</td>
</tr>
<tr>
<td>v</td>
<td>1</td>
<td>-</td>
<td>2.4</td>
<td>-</td>
<td>.8</td>
</tr>
<tr>
<td>w</td>
<td>1</td>
<td>-</td>
<td>2.4</td>
<td>-</td>
<td>.8</td>
</tr>
<tr>
<td>ae</td>
<td>6</td>
<td>7</td>
<td>14.3</td>
<td>8.6</td>
<td>10.6</td>
</tr>
<tr>
<td>a</td>
<td>3</td>
<td>10</td>
<td>7.1</td>
<td>12.4</td>
<td>10.6</td>
</tr>
<tr>
<td>A</td>
<td>3</td>
<td>8</td>
<td>7.1</td>
<td>9.9</td>
<td>8.9</td>
</tr>
<tr>
<td>u</td>
<td>2</td>
<td>4</td>
<td>4.8</td>
<td>4.9</td>
<td>4.9</td>
</tr>
<tr>
<td>u</td>
<td>1</td>
<td>-</td>
<td>2.4</td>
<td>-</td>
<td>.8</td>
</tr>
</tbody>
</table>

Table 1: Frequency of usage of phonemes in test stimuli.

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opportunity to evaluate the subject's reading abilities.

After the practice reading, the following directions were given to the subject:

"Now we are going to make some television pictures of the inside of your mouth. There are some things that you are going to have to do to help me take the pictures. First, you will have to keep your tongue on the bottom of the instrument. After I put the instrument in your mouth, I want you to move slowly forward toward the camera until I tell you to stop. I am going to hold onto your chin so that you will move slowly forward, and so you will not move your head to the side.

After the instrument is back far enough so that I am filming what I want to, I will have you close your mouth and just breathe. When you are relaxed, then I will have you say some sounds like /a/, /pa/, /ba/, and so forth. After you have said these, I will ask you to read the words and sentences on the card. While reading try to hold your head as still as possible so that the instrument can take pictures of the inside of your mouth. If you move too much, I will have you stop and I will have you move forward again and repeat what you are reading.

If you should have to cough or swallow then just pull your head away from the camera.

After you have the cards, I will have you rest with the instrument out of your mouth before we start again on the other side of your mouth.

Do you have any questions?"

Next the camera was positioned. The subject was asked to sit up straight on the stool, but in a relaxed position. The camera and panendoscope were positioned closer to the subject, and the height adjusted so that the panendoscope was at a height equal to that of the lower lip. The camera and panendoscope were rotated to the side and the tripod was moved closer to the subject. Optimum placement of the camera is when the camera and panendoscope are moved close enough to the subject so that the panendoscope is in the examination position in the oral pharynx when the subject is seated upright with his mouth around the instrument.
After the equipment was adjusted, the video tape recorder was turned on and the subject was asked to give his name, age and address. This served two purposes. First, it identified the tape sample, and second, it allowed the examiner to adjust the audio and video levels of the recorder. The subject was then asked to place his mouth around the panendoscope.

While the panendoscope was being inserted, the examiner observed, perorally, the passage until the lens passed the faucial pillars. The subject was then instructed to close his mouth and the examiner shifted his attention to the television monitor. The subject was instructed to move slowly forward until the left lateral velopharyngeal port was observed. At this point, the subject was told to stop, remain still and to breathe deeply. The light intensity was increased to provide for the best quality picture. When the subject appeared relaxed, and the left lateral port was in an at-rest position, he was asked to phonate /a/. The monitor was observed to make sure the panendoscope was positioned to afford recording of the entire velopharyngeal mechanism. When the subject was again relaxed, he was again asked to phonate /a/, and the monosyllables /pa/ and /ba/.

When the subject appeared relaxed, he was asked to read the test words and sentences at a normal or comfortable rate and loudness. The subject was cautioned to remain as still as possible while reading. If the subject moved so that the velum, posterior and lateral pharyngeal tissues, and pharyngeal flap were not observable, he was
asked to stop, reposition the panendoscope, and to reread the specific stimulus on which he was stopped.

After adequate pictures had been obtained for the left lateral port, the panendoscope was removed, the light allowed to cool, and the subject to rest. The light was rotated to the opposite side of the lens and the examination was duplicated, this time observing the right lateral port.

When possible, the two lateral ports were recorded separately because of a mechanical limitation of the panendoscope. Because the lens of the instrument is ground with a fifty degree image field, most often, both ports cannot be adequately viewed simultaneously. In order to provide for a consistency in judgments, and to follow a clinical routine, the procedure of photographing each port separately was selected. For two of the subjects only one port was available for observation due to the size and placement of the pharyngeal flap.

The tapes were edited for the best samples and randomized for presentation. The best samples were those which displayed the valving mechanism structures that are felt critical for evaluating movement during phonation. These structures include the border of the velum, the pharyngeal flap, and the lateral and posterior pharynx. The randomization was checked against the speech samples to assure that no subject appeared in the same position. The sound tracks of the tapes were erased to prevent possible identification by the judges. The tapes were numbered for presentation.
Speech

Each subject read the panendoscopic test stimuli. These stimuli were used to keep the output consistent in both the panendoscopic and listener judgments.

The subjects were instructed to read the individual words and sentences at a rate of approximately one per second. The sentences were read at a normal and comfortable intensity. The recorder was turned on, and each subject identified himself and gave his address.

Judges

Selection

Ten graduate students from the Department of Speech Pathology and Audiology at Western Michigan University served as judges. These students were selected because they were all enrolled in a cleft palate seminar which included instruction and practicum in panendoscopic examinations and evaluations. The students had individually participated in approximately 32 hours of panendoscopic evaluations. All of the students had participated in hyponasality judgments in other graduate classes and seminars.

Training

All of the judges had been trained previously in recognizing and observing velopharyngeal physiology as seen panendoscopically. A basic evaluation procedure involving the observation of the individual structures involved in velopharyngeal valving, along with the
parameters of symmetry, patterning, and the amount of opening after maximum movement has occurred were stressed in the instructional periods.

Because the judges had been trained in observing and evaluating normal valving, some training was needed in evaluating valving aided by pharyngeal flaps. During a two-hour session, the judges were trained to observe and evaluate velopharyngeal valving aided by this procedure. Subjects from the video tape files at Western Michigan University were used as training samples. The amount of closure, symmetry, lateral tissue movement, posterior pharyngeal wall movement, and velar movement were emphasized during this session.

Inter- and intra-judge reliability were tested for both judgment procedures.

A sample of four hypernasal speakers and one normal speaker was played to each of the judges utilizing the experimental listener judgment procedures.

The tape samples were later presented to three faculty members of Western Michigan University's Department of Speech Pathology and Audiology under identical conditions in order to check the validity of the experimental judges' ratings. A rank order coefficient of .875 was computed.

The judgment procedure was duplicated one week later, and Spearman rank order correlation coefficients were computed between the two presentations to assess the intra-judge reliability. Interjudge reliability was assessed using the percent of agreement on the
first judgment procedure. The data from these procedures are presented in Tables 2 and 3.

All samples were rated according to the experimental five-point rating scale (Appendix II).

The panendoscopic reliability and validity were tested using films of pharyngeal flaps. Five samples from the video tape collection at Western Michigan University were selected by the examiner. The judges were asked to rate each subject according to the five-point scale in Appendix II.

The judgments were correlated with a second trial judgment of the same subjects one week later, to test the intra-judge reliability. Again inter-judge reliability was tested using percent of agreement scores obtained from the initial testing procedure.

The validity of the panendoscopic judgments was tested by correlating mean score rankings of two individuals who had participated in panendoscopic evaluations over the last two years, with the mean score rankings of the judges. A rank order correlation coefficient of .900 was established.

Data from the panendoscopic judgment procedures are presented in Tables 2 and 3.

The judgment check procedures of the panendoscopic procedures differed from the experimental procedures in that they were not panendoscopic samples of connected speech, and they were taken of both ports simultaneously.
<table>
<thead>
<tr>
<th>Judge</th>
<th>r(LJ)</th>
<th>r(PJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR</td>
<td>.975</td>
<td>.925</td>
</tr>
<tr>
<td>PW</td>
<td>.975</td>
<td>.928</td>
</tr>
<tr>
<td>RM</td>
<td>.950</td>
<td>.950</td>
</tr>
<tr>
<td>LG</td>
<td>.875</td>
<td>.800</td>
</tr>
<tr>
<td>CH</td>
<td>.675</td>
<td>.575</td>
</tr>
<tr>
<td>JF</td>
<td>.950</td>
<td>.975</td>
</tr>
<tr>
<td>MH</td>
<td>.725</td>
<td>.775</td>
</tr>
<tr>
<td>TL</td>
<td>.975</td>
<td>1.000</td>
</tr>
<tr>
<td>TC</td>
<td>.928</td>
<td>.975</td>
</tr>
<tr>
<td>JM</td>
<td>.800</td>
<td>.900</td>
</tr>
<tr>
<td>Median</td>
<td>.928</td>
<td>.925</td>
</tr>
</tbody>
</table>

Table 2: Intra-judge reliability as determined by correlation coefficients (r) for test retest ratings of listener judgments (LJ) and panendoscopic judgments (PJ).
<table>
<thead>
<tr>
<th>Subject</th>
<th>Percent Agreement (LJ)</th>
<th>Percent Agreement (PJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>80</td>
<td>90</td>
</tr>
<tr>
<td>2</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>3</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>4</td>
<td>90</td>
<td>40</td>
</tr>
<tr>
<td>5</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>Mean</td>
<td>72</td>
<td>74</td>
</tr>
</tbody>
</table>

Table 3: Inter-judge reliability as demonstrated by percentage of agreement for listener judgments (LJ) and panendoscopic judgments (PJ).
Judgment Procedures

Panendoscopic

The panendoscopic samples were shown first to the judges. The judges were seated at a distance of approximately ten feet from the television monitor, and the lights were turned off in the room.

The tapes were presented using a Sony television monitor coupled to either a Sony CV-220 or a Sony AV 3600 video tape recorder. The judges were read the directions listed in Appendix III.

The judges were asked to rate the panendoscopic tapes according to the five-point rating scale (Appendix II).

Before the start of the judgment session, the judges were reminded to observe the entire tape segment of each subject, and then to circle only one of the numbers on the rating scale which they felt best represented the velopharyngeal activity. A sample score sheet is provided in Appendix II.

Listener judgments

The original speech samples had been transferred through an Ampex A6350 Professional tape recorder to Scotch 175 Magnetic recording tape. A 700 Hz calibration tone had been placed at the beginning of the final tape.

The listener judgments were administered in an I.A.C. 1203-A Sound proof audiometric testing room. The subject samples were played from a Sony TC-5600 tape deck, through a Grason-Stadler Model 162 speech audiometer.
The audiometer's V.U. Meter was calibrated to the recorded 700 Hz tone. The speech samples were played to the judges at a normal conversational level of 46 dB hearing level.

The judges were asked to rate the productions of each subject according to the rating scale of hypernasality in Appendix IV.

After the directions (Appendix III) had been administered the judges were again asked to listen to the entire sample before selecting their rating.

Subjects

The experimental population consisted of eight subjects, six females and two males, who all had undergone pharyngeal flap procedures to aid deficient velopharyngeal valving.

Four of the subjects possessed superiorly based flaps and four inferiorly based pharyngeal flaps. As indicated earlier, two of the subjects (L.R. and L.B.) possessed only one port lateral to the pharyngeal flap.

The subjects ranged in age from 9.8 to 32.9 years with a mean age of 15.84 at the time of examination.

No attempt was made to control the variables of the type of cleft, the amount and type of speech therapy and sex in this study.

Subject data are given in Table 4.
<table>
<thead>
<tr>
<th>Subject</th>
<th>Sex</th>
<th>Exam. Date</th>
<th>Birthdate</th>
<th>Surgery Date</th>
<th>Type of Flap</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM</td>
<td>M</td>
<td>7-21-70</td>
<td>1-20-57</td>
<td>7-31-63</td>
<td>Inferior</td>
</tr>
<tr>
<td>CM</td>
<td>F</td>
<td>3-19-70</td>
<td>7-8-52</td>
<td>3-21-67</td>
<td>Superior</td>
</tr>
<tr>
<td>AS</td>
<td>M</td>
<td>7-21-70</td>
<td>7-1-57</td>
<td>3-12-69</td>
<td>Inferior</td>
</tr>
<tr>
<td>AH</td>
<td>F</td>
<td>4-18-70</td>
<td>7-11-37</td>
<td>2-28-69</td>
<td>Superior</td>
</tr>
<tr>
<td>LR</td>
<td>F</td>
<td>7-21-70</td>
<td>3-18-58</td>
<td>6-2-69</td>
<td>Inferior</td>
</tr>
<tr>
<td>LB</td>
<td>F</td>
<td>6-4-70</td>
<td>10-20-60</td>
<td>11-11-68</td>
<td>Superior</td>
</tr>
<tr>
<td>JB</td>
<td>F</td>
<td>7-21-70</td>
<td>12-5-56</td>
<td>6-27-68</td>
<td>Inferior</td>
</tr>
<tr>
<td>KL</td>
<td>F</td>
<td>8-6-70</td>
<td>4-12-57</td>
<td>3-2-68</td>
<td>Superior</td>
</tr>
</tbody>
</table>

Table 4: Subject data.
CHAPTER III

RESULTS

Judgment Tasks

**Nasality judgments**

The results of the perceptual listener judgments of hypernasality are summarized in Table 5. Median score values ranged from 1.0 to 3.33 with a mean of 1.63. The frequency distribution of the median score values (Figure 2) is unimodal and positively skewed. The median score values for five of the eight subjects were distributed at or very near 1.0 on the hypernasality scale.

**Panendoscopic judgments**

The results of the ratings of velopharyngeal closure are summarized in Table 5. The median score values ranged from 1.125 to 4.25 with a mean score value of 2.31. The frequency distribution for the closure ratings is bimodal and is skewed slightly positively (Figure 3). Five of the eight median score values are located below the midpoint of the rating scale.

**Correlation Results**

A nonparametric Spearman rank correlation coefficient was computed to investigate the relationship between video tape oral panendoscopic evaluations of velopharyngeal closure and listener judgments of hypernasality. A rho ($r_s$) of .542 was computed. This
<table>
<thead>
<tr>
<th>Subject</th>
<th>Panendoscopic Scale Value</th>
<th>Listener Judgment Scale Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.17</td>
<td>1.125</td>
</tr>
<tr>
<td>2</td>
<td>1.93</td>
<td>2.50</td>
</tr>
<tr>
<td>3</td>
<td>3.50</td>
<td>1.70</td>
</tr>
<tr>
<td>4</td>
<td>1.125</td>
<td>1.21</td>
</tr>
<tr>
<td>5</td>
<td>1.25</td>
<td>3.33</td>
</tr>
<tr>
<td>6</td>
<td>1.21</td>
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</tr>
<tr>
<td>7</td>
<td>1.79</td>
<td>1.00</td>
</tr>
<tr>
<td>8</td>
<td>2.50</td>
<td>1.125</td>
</tr>
</tbody>
</table>

Table 5: Median score values of judged severity of nasal- sality and velopharyngeal closure.
Figure 2: Frequency distribution of median score values of judgments of severity of nasality.
Figure 3: Frequency distribution of median score values of panendoscopic judgments of velopharyngeal closure.
rho was found to be significant above the ten percent level of confidence. Significance was not attained at the five percent level.

**Analysis of Variance**

A ten by two by two analysis of variance was computed to test the interactions between and within the variables of the judges, types of judgment procedures and types of surgery.

Significant differences at or above the one percent level were found between the types of surgery, types of judgment procedures and the types of judgment procedures by types of surgery interactions (Table 6).

Investigation of the mean rating scores for the significant interactions (Table 7) reveals that those subjects having inferiorly based pharyngeal flaps were rated higher numerically on both the panendoscopic scale (i.e., judged to be demonstrating less closure) and the hypernasality scale (judged to be demonstrating more hypernasality) than those subjects having superiorly based pharyngeal flaps. Mean rating score values for both judgment procedures combined were 2.39 for the inferiorly based pharyngeal flap subjects and 1.66 for the superiorly based pharyngeal flap subjects.

For the panendoscopic judgment task the mean rating was 2.90 for the inferiorly based flap group and 1.70 for the superiorly based flap group.

For the listener judgments of hypernasality the inferiorly based flap group had a mean rating of 1.88 as compared to 1.62 for the superiorly based flap group.
<table>
<thead>
<tr>
<th>Source</th>
<th>M.S.</th>
<th>d.f.</th>
<th>F-Ratio</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Judges (JDG)</td>
<td>1.642</td>
<td>9</td>
<td>1.2351</td>
<td>.28</td>
</tr>
<tr>
<td>Surgery (SRG)</td>
<td>21.025</td>
<td>1</td>
<td>15.8182</td>
<td>.00*</td>
</tr>
<tr>
<td>Judgment Procedure (JP)</td>
<td>12.100</td>
<td>1</td>
<td>9.1034</td>
<td>.00*</td>
</tr>
<tr>
<td>JDG x SRG</td>
<td>.206</td>
<td>9</td>
<td>.1546</td>
<td>1.00</td>
</tr>
<tr>
<td>JDG x JP</td>
<td>.364</td>
<td>9</td>
<td>.2738</td>
<td>.98</td>
</tr>
<tr>
<td>SRG x JP</td>
<td>9.025</td>
<td>1</td>
<td>6.7900</td>
<td>.01**</td>
</tr>
<tr>
<td>JDG x SRG x JP</td>
<td>.483</td>
<td>9</td>
<td>.3636</td>
<td>.95</td>
</tr>
<tr>
<td>Within</td>
<td>1.329</td>
<td>120</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1.421</td>
<td>120</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* - Significant above the 1% level

** - Significant at the 1% level

Table 6: Results of the ten by two by two analysis of variance for the variables of judges, types of surgery and types of judgment procedures.
<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean Rating Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Types of Surgery (SURG):</strong></td>
<td></td>
</tr>
<tr>
<td>Inferiorly Based Flap Ss</td>
<td>2.39</td>
</tr>
<tr>
<td>Superiorly Based Flap Ss</td>
<td>1.66</td>
</tr>
<tr>
<td><strong>Types of Judgment Procedures (JP):</strong></td>
<td></td>
</tr>
<tr>
<td>Panendoscopic Scale</td>
<td>2.30</td>
</tr>
<tr>
<td>Listener Judgment Scale</td>
<td>1.75</td>
</tr>
<tr>
<td><strong>SURG x JP:</strong></td>
<td></td>
</tr>
<tr>
<td>Inferiorly Based Flap Ss</td>
<td></td>
</tr>
<tr>
<td>Panendoscopic Scale</td>
<td>2.90</td>
</tr>
<tr>
<td>Listener Judgment Scale</td>
<td>1.88</td>
</tr>
<tr>
<td>Superiorly Based Flap Ss</td>
<td></td>
</tr>
<tr>
<td>Panendoscopic Scale</td>
<td>1.70</td>
</tr>
<tr>
<td>Listener Judgment Scale</td>
<td>1.62</td>
</tr>
</tbody>
</table>

Table 7: Comparisons of mean rating values for the significant differences found in the analysis of variance.
The analysis of variance also revealed a significant difference between the two types of judgment procedures. The analysis of the means revealed that all subjects were rated higher numerically on the panendoscopic scale than on the nasality scale, 2.30 and 1.75 respectively.
CHAPTER IV

DISCUSSION

Because the Spearman rho reported in this study failed to reach significance at the more accepted five percent level of confidence, it must be concluded that the results of this study support the hypothesis that a relationship between the two variables in question does not exist in the population from which the sample was drawn. Regardless of what the magnitude of the correlation might have been with this sample, it would had to have been viewed cautiously because of the small sample size and therefore the relatively low power of the statistical test. Because of the low power imposed by the small sample size and other factors discussed below, there can be a case made in defense of rejecting the hypothesis of no relationship at the ten percent level in favor of the alternative hypothesis that a relationship does exist between the variables of interest here.

Another factor possibly affecting the results of this study was the restricted range of talent of the sample. The results of the hypernasality judgment revealed that five of the eight subjects were judged to demonstrate no or very slight hypernasality. Also, five of the eight subjects were judged to be demonstrating complete or near complete closure on the panendoscopic judgment task. It is known that a restriction in the talent of a sample will serve to reduce the magnitude of a correlation between two variables; but one may only conjecture as to what affect increasing the sample size and
widening the range of talent might have upon the magnitude of the relationship between the two variables of interest here.

A number of other factors dealing with the design of the study need to be discussed as to their influence on the results.

Paramount is the problem of attempting to subjectively evaluate physiological movements according to psychological scaling procedures. A number of problems arise in using this procedure. The term 'no closure' on the panendoscopic rating scale allowed for a wide variation in interpretation by the judges. Theoretically, it was established to mean no closure and inferentially no movement within the velopharyngeal ports. According to the rating scale that was used in this study, no closure could be represented by anything except the number one. A more representative and descriptive scale might have been achieved if the number one had been made to represent complete closure—no opening and the number five to represent no closure—no movement.

Consideration must also be given to the procedure of having the judges base their final ratings on observations of both ports. Not only does this have a tendency to reduce the ratings to a mean impression, but it adds the influence of the variables asymmetry and memory, which add to the subjectivity of the judgments.

Other factors possibly interacting in the velopharyngeal closure judgments are the intra-subject variations in closure on phonemes and the inconsistent presence of saliva in the port areas.

If the presence of saliva in the port area goes undetected in those subjects with near complete closure, there may be a tendency

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to rate the subjects as demonstrating complete closure while an amount of opening may actually exist.

Intra-subject variations in closure on phonemes add further to the subjectivity of the panendoscopic closure evaluations. It has been demonstrated in numerous studies that speakers do not possess total closure on all oral phonemes during connected speech (Hagerty and Hill, 1960; Moll, 1960; Moll, 1962; Moll and Daniloff, 1971). There do not exist data to contraindicate this in subjects with cleft palate. This would not only tend to support the hypothesis about the subjectivity of the closure judgments of this study, because of the visual averaging, but would raise question as to the use of the category complete closure on the rating scale. In light of the studies mentioned above, one would expect complete closure to coincide with a pathological rather than normal speech output.

Taking into consideration the obvious subjectivity of the velopharyngeal closure scale and the very restricted range of differences in velopharyngeal opening in the sample, it becomes obvious that a test of relationship between two variables that utilizes rank order data would be very susceptible to a low magnitude if one of those variables was measured on a scale not capable of detecting small differences between subjects. While there was a percent of agreement between the judges above chance for all of the subjects on both tasks (Table 8), there was a very small, almost undetectable difference between the rankings of the subjects as evidenced by the median score values (Table 5).
<table>
<thead>
<tr>
<th>Subject</th>
<th>Percent Agreement (PJ)</th>
<th>Percent Agreement (LJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40</td>
<td>80</td>
</tr>
<tr>
<td>2</td>
<td>70</td>
<td>40</td>
</tr>
<tr>
<td>3</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>4</td>
<td>80</td>
<td>70</td>
</tr>
<tr>
<td>5</td>
<td>50</td>
<td>60</td>
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<tr>
<td>6</td>
<td>70</td>
<td>90</td>
</tr>
<tr>
<td>7</td>
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<td>100</td>
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<tr>
<td>8</td>
<td>50</td>
<td>80</td>
</tr>
<tr>
<td>Mean</td>
<td>60</td>
<td>71.25</td>
</tr>
</tbody>
</table>

Table 8: Percentages of agreement of the judges on the experimental panendoscopic (PJ) and listener judgment (LJ) tasks.
While discussing the intra-phonemic variations in closure, the effect of the stimuli of this study on the judgment procedures must also be analyzed.

Table 9 lists the frequency of usage of the vowels in the test stimuli. Inspection of the data reveals a high percentage of low vowels. One must question what effect using a predominance of vowels found to exhibit less nasality (Spriestersbach and Powers, 1959a) has upon the relationship between the judged nasality and the nasality presented under conditions of phonemic balancing or normal conversational speech. While this question is not of major importance in the interpretation of the results of this study, it is one of major concern in the clinical use of oral panendoscopy. Also, the insertion of the panendoscope into the oral cavity restricts the movement of the tongue during speech production, and the question of how this alters the velopharyngeal mechanism and the perceptual output must be raised.

Before any hypothesis can be formulated regarding this variable, a number of questions must be dealt with. The stimuli in this study contain a predominance of the pressure consonants, and their influence on the amount of closure on preceding and following vowels, and how this is perceived through panendoscopy must be further analyzed. What is the nature of the mechanical relationship between tongue movement and height and velopharyngeal movement and velar height? Are the differences in the perception of nasality on vowels better thought related to the differences in the ratio between oral cavity
<table>
<thead>
<tr>
<th>Phoneme</th>
<th>Words</th>
<th>Sentences</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>ae</td>
<td>40.0</td>
<td>24.1</td>
<td>29.5</td>
</tr>
<tr>
<td>A</td>
<td>20.0</td>
<td>27.6</td>
<td>25.0</td>
</tr>
<tr>
<td>a</td>
<td>20.0</td>
<td>34.5</td>
<td>29.5</td>
</tr>
<tr>
<td>u</td>
<td>6.7</td>
<td>-</td>
<td>2.3</td>
</tr>
<tr>
<td>u</td>
<td>13.3</td>
<td>13.8</td>
<td>13.6</td>
</tr>
</tbody>
</table>

Table 9: Relative frequency of usage of vowels in the test stimuli. Percentages are figured relative to the vowel usage only.
opening and velopharyngeal opening? If so, how does the insertion of the panendoscope influence this ratio?

All of these questions must be taken into consideration while interpreting the results of this study.

The analysis of variance revealed a significant difference between the two types of surgical procedures. The subjects having undergone inferiorly based pharyngeal flaps were judged to be demonstrating more hypernasality and less velopharyngeal closure than the subjects possessing superiorly based pharyngeal flaps. These results must be thought to be due primarily to subject selection. The inferiorly based flap group used in this study must be thought to represent both a poorer closure and more severe hypernasality group than the superiorly based group.

By no means should these findings be thought to represent a comparison of the effectiveness of the two surgical procedures. The difference is only an artifact of the subject selection.

Another variable which may have been interacting in the finding of a significant difference is the visual appearance of the inferiorly based flap as opposed to the superiorly based flap. It has been observed by this investigator that visual differences exist between the panendoscopic films of the two types of secondary surgical procedures. The inferiorly based flap appears both larger and nearer to the optic lens than the superiorly based flap. Also, it is more difficult to determine if movement or contact is made in the lateral pharyngeal ports because of the superior plane of movement of the lateral pharyngeal tissue. Often the contact between lateral tissue
and the pharyngeal flap is made far superior to the visual portion of the flap. Because of this difficulty in discerning closed from open velopharyngeal ports, and because the judges had not been trained in viewing inferiorly based pharyngeal flaps, question must be given to the possible interaction of these variables in the significant difference found.
CHAPTER V

SUMMARY AND IMPLICATIONS

This study has attempted to investigate the relationship between visual observations of velopharyngeal physiology using oral panendoscopy and perceptual listener judgments of hypernasality.

A Spearman rank correlation coefficient of moderate strength was found to exist between the two variables, but was found to be significant above the ten percent level only.

Based on the results of this study one must conclude that the most optimal clinical use of oral panendoscopy would be in conjunction with perceptual listener judgments of the speech output.

It must also be stated that the degree of closure determined by any means of visual observation has been shown to be a very poor predictor of the resulting vocal output. If we accept the fact that research has demonstrated that a relationship of about .6 exists between visual observations of velopharyngeal opening and perceptual listener judgments of hypernasality, then a prediction of only about forty percent accuracy can be expected. Possibly other factors as pre-movement port area, and the amount, rate and type of patterning of movement should also be considered when making a clinical adequate-inadequate judgment about the velopharyngeal mechanism.

Undoubtedly a more optimal comparison could be obtained if panendoscopic assessments were administered concomitant to direct quantitative measure of velopharyngeal port area. Not only would these data be significant from the standpoint of investigating the
existence of ranges of port area accompanying various levels of perceived nasality, but in the information it would yield in further research, and in the pre-corrective assessment of velopharyngeal insufficiency.

This study has also served to illustrate the need for continued research utilizing the panendoscope. In addition to the areas mentioned, there is the need for the compilation of a base of objective normative data upon which to design further studies of pathological behavior.

Oral panendoscopy has been used extensively at Western Michigan University and Butterworth Hospital in Grand Rapids, Michigan in aiding the plastic surgeon and the oral cleft team in selecting and carrying out the most beneficial treatment program for the velopharyngeal insufficient individual (Willis and Blocksma, 1970). The establishment of a possible range of velopharyngeal port area for normal speech production or a more sophisticated understanding of the role of all of the variables in speech that might possibly contribute to hypernasality, would aid the oral cleft team in better selecting the procedure best suited for each individual, and in assisting the plastic surgeon not only in procedure selection, but in the placement and dimensions of the specified corrective aid.
APPENDIX I

Test Stimuli

<table>
<thead>
<tr>
<th>Words</th>
<th>Sentences</th>
</tr>
</thead>
<tbody>
<tr>
<td>have</td>
<td>Ruff papa, puff.</td>
</tr>
<tr>
<td>lap</td>
<td>Hop fool, hop.</td>
</tr>
<tr>
<td>lab</td>
<td>Laugh pal, laugh.</td>
</tr>
<tr>
<td>pal</td>
<td>Up fool, up.</td>
</tr>
<tr>
<td>fab</td>
<td>Buff papa, buff.</td>
</tr>
<tr>
<td>huff</td>
<td>Huff pal, huff.</td>
</tr>
<tr>
<td>laugh</td>
<td>Loop pal, loop.</td>
</tr>
<tr>
<td>wool</td>
<td>Hop papa, hop.</td>
</tr>
<tr>
<td>papa</td>
<td>Lap fool, lap.</td>
</tr>
<tr>
<td>hop</td>
<td></td>
</tr>
<tr>
<td>loop</td>
<td></td>
</tr>
<tr>
<td>fool</td>
<td></td>
</tr>
<tr>
<td>buff</td>
<td></td>
</tr>
<tr>
<td>puff</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX II

Sample Score Sheets

Hyponasality Rating Scale

Subject No. _______ Date ________

1.  3.  5.

2.  4.

NAME

Panendoscopic Rating Scale

Subject No. _______ Date ________

1.  3.  5.

2.  4.

NAME
APPENDIX III

Judgment Procedures' Directions

Listener judgments

You are going to hear eight speech samples of nine sentences and fourteen words. At the completion of each sample I want you to circle the number on the rating scale which you feel represents that subject's degree of nasality.

The rating scale continues from one of no hypernasality to five of severe hypernasality. Remember, one represents no hypernasality and five, severe hypernasality.

Before each sample, make sure that the number on the top of your score sheet corresponds to the sample number on the tape.

Are there any questions?

Panendoscopic judgments

You are going to see eight samples of velopharyngeal valving aided by pharyngeal flaps. For six of the samples you will first see tapes of the left lateral port while reading a series of words and short sentences, followed by film of that subject's right lateral port while reading the same words and sentences. For two of the subjects only one port (the left) will be observable.

I want you to rate each subject according to the rating scale you have before you, going from one of complete closure to five of no closure. Remember, one represents complete closure, and five, no
closure. Just circle the number you feel representative of the subject's closure.

Please wait until the entire sample of the subject has been played before making your selection.

Before the start of each sample make sure the subject number on your score sheet corresponds with the number of the sample to be played.

Are there any questions?
BIBLIOGRAPHY


Kanter, C. E., Diagnosis and prognosis in cleft palate speech. J. Speech Hearing Dis., 13, 211 (1948).


