Relation Between Nasal/Voice Accelerometric Values and Interval Estimates of Hypernasality

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Nasal/throat accelerometric ratios were obtained from 12 hypernasal and three normal children. The accelerometric voltages comprising the ratio were analogs of nasal and anterior-neck tissue vibrations. Audio recordings, which were obtained simultaneously with the accelerometric voltages, were later judged for hypernasality using an equal-appearing-interval (EAI) scale. High correlations were evident between accelerometric and EAI values when a stimulus sentence contained obstruents, semivowels, and vowels. No correlation existed between accelerometric measures and hypernasality judgments when a sentence contained primarily nasal phonemes and vowels.

The complicated spectral changes associated with inappropriate nasal coupling are not always easy to quantize perceptually. Dichotomous hypernasality judgments are accomplished readily by most clinicians when comparing a normal speaker to a hypernasal speaker. Valid and reliable severity judgments are more difficult to obtain, since these clinical impressions appear to be influenced by the hypernasal speaker's phonatory mode and articulatory proficiency, the phonetic characteristics of the speech sample, and the clinician's training and experience (Bradford et al, 1964; Bzoch, 1979).

These perceptual uncertainties have led clinical workers to seek trustworthy physical correlates of either velopharyngeal function or hypernasal resonance. Radiographic, aerodynamic, and acoustic measures have traditionally been obtained to augment perceptual impressions of hypernasality. Recently, the battery of physical measures has incorporated endoscopic imaging, photoelectric detection of velopharyngeal opening, and nasal accelerometry.

Nasal accelerometry appears to be particularly promising as well as clinically attractive. Accelerometers, contact microphones, and crystal transducers have been used to detect head/neck tissue vibrations (Horii, 1980; Hultzen, 1942; Leeper, 1966; Lippmann, 1981; Mease, 1961; Stevens et al, 1975; Stevens et al, 1976). The nasal vibrational analog produced by these devices has been linked principally to hypernasality magnitude (Garber and Möller, 1979; Horii, 1980; Stevens et al, 1975).

Early work typically evaluated absolute nasal vibrational amplitude which was plotted in either linear or logarithmic units across time. While this approach could detect the presence of abnormal nasal resonance, the degree of hypernasality was somewhat more elusive. A speaker's loudness level appeared to markedly affect nasal vibrational amplitude (Garber and Moller, 1979; Stevens et al, 1975). Other factors confounding nasal vibrational magnitude included speaker-idiosyncratic nasal tissue characteristics, articulatory postures which increased intraoral pressure (e.g., labial, lingual, or mandibular elevation), and transducer pressure, angle, and torque (Leeper, 1966; Mease 1961; Redenbaugh, 1984).

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To alleviate some of these shortcomings, Horii (1980) proposed a computer-assisted ratio of nasal accelerometric magnitude to voice-source magnitude, the Horii Oral Nasal Coupling Index (HONC). The HONC data are computer normalized using as a reference the ratio of nasal amplitude to voice amplitude during a fully nasalized /m/. The values are expressed in logarithmic units (i.e., decibels) relative to the speaker's sustained /m/ reference voltage.

Redenbaugh and Reich (1985) reported a somewhat easier-to-use analog modification of the HONC, the Nasal Accelerometric Vibrational Index (NAVI). The NAVI system employs nasal and anterior neck ("throat") accelerometers, with analog circuitry providing a normalized nasal/throat voltage ratio. The NAVI voltage ranges from 0 mV (no nasal coupling) to 1,000 mV (maximal nasal coupling). An analog approach was employed to reduce cost, facilitate data interpretation, and encourage the use of time-varying NAVI signals in clinical biofeedback applications.

Correlational studies (Horii, 1983; Horii and Lang, 1981; Leonard, 1981; Redenbaugh and Reich, 1985) utilizing each of the above nasal/voice accelerometric techniques have reported strong relationships between the accelerometric ratio and perceptual values. However, these investigations have either evaluated *simulated* hypernasality or used sophisticated hypernasality scales (e.g., paired comparison or direct magnitude estimation), procedures common in experimental research but not in clinical settings. For example, Horii and Lang (1981) reported a Spearman rank correlation of 0.81 between HONC and EAI scale values for individuals simulating hypernasality. While the EAI procedure is often used clinically, the results of this particular study were based on *simulated* rather than naturally occurring hypernasality. Redenbaugh and Reich (1985) reported a Pearson correlation of 0.91 between NAVI values and direct-magnitude estimates of naturally occurring hypernasality for an obstruent-loaded sentence.

This study was designed to extend our previous work to include a perceptual scale more commonly used by clinicians. Specifically, we sought to explore the relationship between NAVI values and EAI estimates of naturally occurring hypernasality in children.

METHODS

Speakers

Twelve children who had velopharyngeal incompetence (VPI) and mild to very severe hypernasality were recruited from two maxillofacial clinics. Seven VPI speakers had repaired cleft palates; five had no palatal cleft histories. The VPI group included six males and six females ranging in age from 5 to 12 years ($\bar{X}$ = 8.8, S.D. = 2.5). One normal male and two normal females also served as control speakers. They ranged in age from 7 to 12 years ($\bar{X}$ = 9.3, S.D. = 2.5).

The following speaker participation requirements were met either by file documentation, interview, or screening examination:

1. Absence of gross neurologic signs, head trauma history, or other indications of neurologic impairment
2. Normal intelligence as revealed by standardized test scores or academic progress within one grade level of age-matched peers
3. Absence of severe craniofacial anomalies resulting from malformation syndromes or ablative surgery, cleft lip and palate excepted
4. Normal hearing (25 dB HL or better) in at least one ear as determined by pre-experimental audiometric screening at 500, 1,000, 2,000, and 4,000 Hz
5. Nasal patency as evidenced by audible nasal airflow during alternating nares occlusion
6. Absence of denasality as demonstrated by a marked loudness level decrease when the nostrils were occluded during a sustained /m/
7. Ability to produce all of the experimental sentences without oral articulation errors
8. American English as a first language

Speech Stimuli

Three sentence stimuli were constructed, each having a markedly different phonetic composition. "Pete draws pussy cats" (PDPC) consisted of obstruents, a non-nasal semivowel, and vowels. "We hear Lilly Lou" (WHLL) consisted of semivowels, a glottal fricative, and vowels. "Ron may know May" (RMKM) consisted of a semivowel, nasals, and vowels. Three auxiliary sentences, similar in phonetic design and linguistic complexity to the above sentences, were also recorded to provide familiarization sentences for the perceptual scaling tasks.

Nasal Accelerometric Vibrational Index

Two accelerometers (Knowles Electronics BU-1771) were employed to transduce nasal and anterior-neck tissue vibrations. Each transducer was housed in a 5 mm × 7 mm metal casing, weighed less than 1.8 g, had a sensitivity (in dB relative to 1.0 V per g) of −45 dB, and exhibited a flat (±2.0 dB) frequency response to 3,000 Hz.

Since nasal septal deviation is common in children with cleft palate, the nasal accelerometer site was chosen carefully. The nasal airway's more patent side was determined by visual, tactual, and airflow observations during isolated /m/ prolongations and during quiet nasal breathing while the nares were alternately occluded. The nasal accelerometer was then placed on the superior nares wall of the more patent side, overlying the lateral nasal cartilage and immediately anterior to the nasal bone, corresponding to Lippmann's (1981) position six. The anterior-neck ("throat") accelerometer was placed on the skin over the thyroid lamina, just lateral to the midline on the side that was tactually determined to exhibit the greatest anterior-neck tissue vibration.

The accelerometric signals were preamplified, rectified, and smoothed prior to index computation. The throat accelerometric channel had a fixed preamplifier gain; the nasal accelerometric gain was continuously variable (Fig. 1). The NAVI, similar to the HONC (Horii, 1980), was expressed mathematically as:

$$\text{NAVI} = \frac{k(A_n)}{f(A_t)}$$

where A_n = nasal amplitude; A_t = throat amplitude; f = fixed throat gain: and k = adjusted nasal gain which produced a NAVI value of 1,000 mV during a moderately loud sustained /m/. The "k" correction factor (adjusted for each individual after accelerometer placement) is designed to compensate for speaker-specific, nasal-tissue attenuation characteristics and accelerometric sensitivity or gain differences that result from transducer angle, torque, and pressure.

A NAVI value ideally would be expressed as a voltage ranging from 0 V (presumably signaling little or no nasal resonance) to 1 V (presumably signaling maximal nasal resonance). However, some nasal acoustic energy transmission occurs even during perceptually nonhypernasal voiced speech; hence a 0-V NAVI value generally is not encountered. In addition, a NAVI value greater than 1 V may result from excessive vocal effort or inaccurate nasal ac-

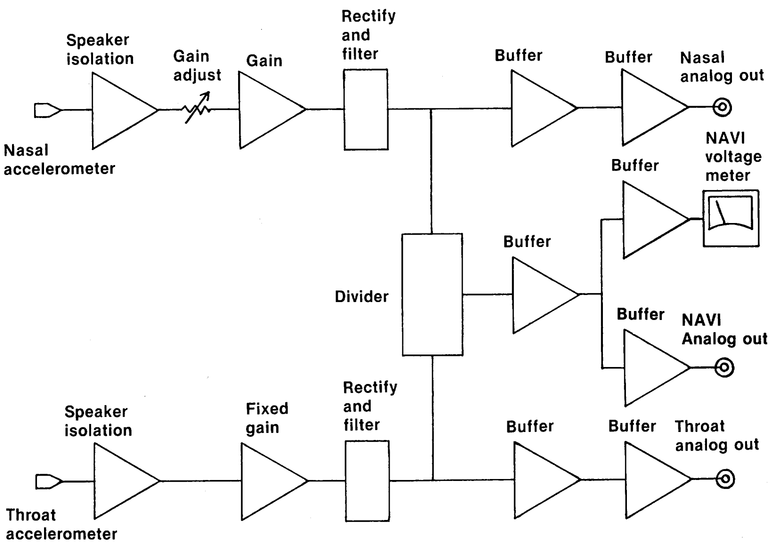

FIGURE 1. NAVI instrumental block diagram.

celerometric gain adjustment (Horii, 1980). Therefore, a NAVI output range of 0 to 1,400 mV was provided to avoid overdriving the system.

Audio Recording Procedure

A condenser microphone (Teac ME-120) was placed 7.0 cm from each child's lips. The microphone signals were AM recorded (Teac A2340SX) at 7.5 IPS and FM recorded (Honeywell 5600) at 3.75 IPS. A sound-level meter microphone (Quest 214R) was mounted adjacent to the audio microphone. All speakers were required to maintain a conversational level during sentence production (75 to 85 dB Sound Pressure Level (SPL) re: a 7.0-cm microphone distance). In addition, the speakers were monitored with an analog fundamental frequency (f_0) extraction system (F-J Electronics FFM-6502) and required to be ± 20 Hz of their predetermined average conversational f_0. The children were not provided with instrumental feedback regarding their average SPL and f_0 during the recording. Nevertheless, they had ample opportunity to practice the sentence stimuli and hence had little difficulty meeting the conversational SPL and f_0 requirements.

Experimental Assessment Procedure

Simultaneous NAVI measures and audio recordings were gathered in a sound-treated laboratory. Double-faced tape was used to adhere the two accelerometers to the nares and anterior-neck walls as outlined previously. A microphone stand with headrest assured the required 7.0-cm microphone-lip distance. The audio recorder gain was adjusted while the speaker sustained /m/ and practiced the experimental and auxiliary sentences. Following practice and recording-level adjustments, each speaker sustained an /m/ for approximately 3 seconds at 75 to 85 dB SPL while the nasal accelerometric gain was adjusted to yield a 1,000-mV NAVI output. All subsequent NAVI voltages were FM recorded.

Each experimental and auxiliary sentence was produced three times at a normal speech rate. The three tokens were designed to evaluate intrasubject variability informally and to ensure at least one error-free production of each sentence.

NAVI Calibration Procedure

A 1-V dc signal was FM recorded following each speaker's NAVI and audio assessment. The recorded 1-V signal was used to construct a calibration scale for measuring the NAVI millivolt values.

Listening Tape Production

Two 20-minute listening tapes (one forward-play and one backward-play) were used for EAI scaling. The two different playback modes were included since each reportedly provides somewhat different results when scaling hypernasality (Sherman, 1954). Forward-played speech may allow attention to acoustical attributes not directly related to perceived hypernasality but to more general speech deviations (e.g., misarticulation, nasal air emission, temporal pattern alteration, or dialect). Backward-played speech may reduce these contaminating influences in some cases, thereby allowing attention to be focused on hypernasality severity (Moll, 1964; Sherman, 1954). The merits of backward-played speech, however, have been questioned (Black, 1973; Counihan and Cullinan, 1970; Fletcher, 1976). Initially, a forward-play listening tape was constructed. This tape was then used to produce a backward-play tape that was identical to the forward-play tape except for its reversed sentence order and speech.

Each listening tape consisted of hypernasality severity exemplars, a practice rating segment, and an experimental rating segment. The hypernasality severity exemplars represented three speakers demonstrating mild, moderate, and severe hypernasality respectively. The exemplar speakers were not represented elsewhere on the listening tape. The exemplars were followed by a nine-sample practice segment, identical to the experimental listening segment in format but constructed from the auxiliary sentences. Each experimental segment consisted of 54 experimental sentence dyads (15 subjects $\times$ 3 sentences = 45 + 9 repeated reliability sentences = 54). Sentences of one type were grouped together to facilitate the rating task and reduce listener confusion. Each experimental sentence token was presented twice with a one-half second interval between repetitions. Each experimental sentence dyad was followed by a 10-second rating interval.

Experimental Listening Session

Twenty speech and hearing sciences graduate students judged the hypernasality of the experimental sentence dyads utilizing an EAI scale. The listeners were assigned equally and randomly to one of two listening sessions. The sessions were counterbalanced with respect to which playback mode was presented first. The counterbalancing was designed to control for learning, fatigue, or other order effects. All listeners demonstrated normal speech, language, and hearing skills, as determined by experimenter observation, listener confirmation, or both.

EAI Rating Procedure

The EAI task required the listeners to rate recorded speech samples ranging from normal resonance to very severe hypernasality. The listeners were asked to rate the hypernasality of each experimental sentence dyad on a 5-point EAI scale where 1 represented normal resonance and 5 represented very severe hypernasality. The judges were seated in a sound-treated laboratory and listened binaurally via earphone headsets (Telephonics TDH-39) at approximately 80 dB SPL.

Following listener instruction, the hypernasality severity exemplars, the nine-sample practice segment, and the experimental segment were played without interruption in the forward-play or backward-play mode. The session consisted of listening to and rating two 20-minute experimental tapes. A 5-minute rest interval was provided between playback modes.

NAVI Data Analysis

An X-Y digitizing tablet (Altek AC90C-S) assisted the measurement of the NAVI analog voltages from mingographic chart recordings (Siemens 804). The NAVI signals which corresponded to the sentences on the experimental listening segments were chart recorded at 250 mm/sec. A typical chart recording is presented in Figure 2. The NAVI voltage of the voiced speech segments was measured every 0.20 inches (5.08 mm) within the voiced intervals (operationally defined as those intervals where the peak amplitude of the throat signal exceeded 10 mV). This measurement scheme produced a NAVI amplitude sample every 20 msec during the voiced intervals. With the assistance of a microcomputer (IBM-PC), each NAVI Y-coordinate value in inches was converted to millivolts using a conversion scale derived from the FM-recorded, 1-volt calibration signal. The samples were reduced to a mean NAVI voltage for each experimental sentence, then grouped by speaker and sentence type for statistical analysis.

EAI Data Analysis

EAI means were calculated for each experimental sentence (collapsed across listeners). These means were then grouped by speaker, sentence type, and reproduction mode for statistical analysis.

RESULTS

NAVI-EAI Correlations

The NAVI means of the VPI and normal (NL) speakers for each stimulus sentence are

FIGURE 2. Sample mingographic chart recording representing a speaker's nasal accelerometric vibrational index (NAVI) and corresponding throat accelerometric (TA) analogs. The speaker was producing "Pete draws pussy cats." Amplitude measurements were taken from the NAVI baseline every 0.20 inches within the intervals where the throat signal amplitude was greater than 10 millivolts (mV).

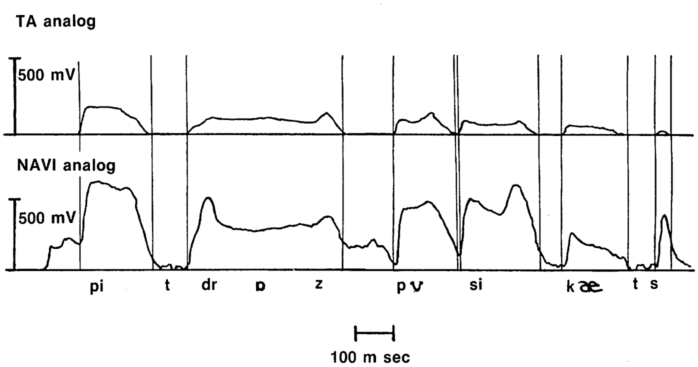

TABLE 1. Nasal Accelerometric Vibrational Index (NAVI) and Equal-Appearing-Interval (EAI) Means and Standard Deviations for the Velopharyngeal Incompetent (VPI) and Normal (NL) Groups*

Groups	*Sentences*						*Group Mean*
	PDPC†		*WHLL†*		*RMKM†*		
	$\bar{X}$	*S.D.*	$\bar{X}$	*S.D.*	$\bar{X}$	*S.D.*	
VPI(N = 12)							
NAVI	398.3	226.0	531.4	108.6	605.1	89.5	511.5
EAI-FP	3.3	1.3	3.0	1.1	3.0	0.7	3.1
EAI-BP	3.7	1.0	3.2	0.9	3.2	0.6	3.4
NL(N = 3)							
NAVI	85.8	77.5	82.1	4.1	689.2	15.4	285.7
EAI-FP	1.1	0.1	1.2	0.3	1.7	0.6	1.3
EAI-BP	1.7	0.4	1.6	0.2	2.5	0.6	1.9

* All data are presented by sentence. NAVI values are in millivolts; EAI values are dimensionless. The EAI values are for the forward-play (FP) and backward-play (BP) listening modes. The number of speakers in each group is presented in parentheses.
† PDPC = Pete draws pussy cats; WHLL = We hear Lilly Lou; RMKM = Ron may know May

presented in Table 1. NAVI values are in millivolts. EAI values are dimensionless and are presented for the FP and BP listening modes.

The NAVI voltages for each speaker and sentence were correlated with the corresponding mean EAI values of the 20 listeners. Table 2 displays the Pearson product-moment coefficients and coefficients of determination by sentence and listening mode. The correlation coefficients between the NAVI and EAI values for the PDPC and WHLL sentences revealed moderate to strong, significant ($p \leq 0.05$) relationships. Nonsignificant correlations were apparent for the RMKM sentence.

To determine whether the NAVI and EAI measures similarly ordered hypernasality, Spearman rank-order correlations were calculated. Only the non-nasal sentences (PDPC and WHLL) were included in the analysis because of their high correlations with the NAVI values in the previous analysis and because similar sentences are used frequently in clinical settings. Table 3 shows the rank-ordered data collapsed across the non-nasal sentences. The normal speakers consistently had the lowest NAVI, EAI-FP, and EAI-BP ranks. The Spearman rank-order coefficients for the FP and BP listening modes were each 0.92.

To determine the similarity of the listener's ratings for the two listening modes, Pearson product-moment correlations were calculated between the EAI-FP and EAI-BP values by sentence. The strong correlations of Table 4 suggest that the listening modes produce proportionately similar judgments and that either would be appropriate for perceptual verification of NAVI values.

NAVI Reliability

In order to evaluate measurement error, 9 (20 percent) of the 45 NAVI signals were remeasured. Three signals from each of the three different sentences were selected randomly for

TABLE 2. Pearson Product-Moment Correlation Coefficients (r) and Coefficients of Determination (r^2) Between the Nasal Accelerometric Vibrational Index (NAVI) and Equal-Appearing-Interval (EAI) Values for each Sentence in the Forward-Play (FP) and Backward-Play (BP) Listening Modes

*Sentence**	*r*	r^2
PDPC-FP	0.90†	0.81
PDPC-BP	0.85†	0.72
WHLL-FP	0.86†	0.74
WHLL-BP	0.85†	0.72
RMKM-FP	−0.16	0.03
RMKM-BP	−0.10	0.01

* PDPC = Pete draws pussy cats; WHLL = We hear Lilly Lou; RMKM = Ron may know May.
† Significant at or beyond the 0.05 level

TABLE 3. Nasal Accelerometric Vibrational Index (NAVI) and Equal-Appearing-Interval (EAI) Values for the Velopharyngeal Incompetent (VPI) and Normal (NL) Speakers

Speakers	*NAVI*	*Rank*	*EAI-FP*	*Rank*	*EAI-BP*	*Rank*
NL-2	21.6	1	1.4	3	2.0	3
NL-1	77.1	2	1.0	1	1.5	1.5
NL-3	153.2	3	1.1	2	1.5	1.5
VPI-11	163.0	4	1.5	4.5	2.1	4
VPI-1	211.5	5	2.1	6	2.7	6
VPI-8	276.3	6	1.5	4.5	2.6	5
VPI-9	311.5	7	2.5	8	3.1	8
VPI-12	387.7	8	2.4	7	2.8	7
VPI-7	389.0	9	2.8	9	3.4	9.5
VPI-2	518.4	10	4.5	14	4.9	15
VPI-10	546.5	11	3.8	11	3.4	9.5
VPI-5	582.5	12	3.7	10	4.0	11.5
VPI-6	606.2	13	4.8	15	4.6	13.5
VPI-4	775.6	14	3.9	12	4.0	11.5
VPI-3	810.4	15	4.3	13	4.6	13.5

The values represent the mean NAVI and EAI values collapsed across the non-nasal sentences "Pete draws pussy cats," and "We hear Lilly Lou." The NAVI values are rank-ordered from least to most millivolts. The corresponding EAI values for the forward-play (FP) and backward-play (BP) listening modes are presented with their respective rank order.

remeasurement. A Pearson correlation between the original and repeated measures revealed a very strong positive relationship ($r = 0.99$, $p \leq 0.05$), indicating very consistent voltage measurements. Thus, the measurement variance could be estimated at $1-(0.99)^2$ or about 2 percent of the total variance. In addition, the absolute measurement error was estimated by calculating the amplitude difference between the original and repeated measures, yielding a mean difference of 1.92 mV.

The mean /m/ calibration values were evaluated to determine the consistency of the NAVI gain adjustment across speakers. The mean NAVI value for the sustained /m/ collapsed across all speakers was 979.5 millivolts (S.D. = 30.4).

TABLE 4. Pearson Product-Moment Correlation Coefficients (r) and Coefficients of Determination (r^2) Between Equal-Appearing-Interval (EAI) Forward-Play (FP) and EAI Backward-Play (BP) Values for Each Sentence

*Sentence**	*r*	r^2
PDPC	0.96	0.92
WHLL	0.95	0.90
RMKM	0.89	0.79

* PDPC = Pete draws pussy cats; WHLL = We hear Lilly Lou; RMKM = Ron may know May. All correlations were significant at or beyond the 0.05 level.

EAI Reliability

In order to determine how similarly individual listeners judged the sentence stimuli, intraclass correlation coefficients were calculated. The high correlations (Table 5) imply strong correspondence between any listener's assigned EAI values and those of the other 19 listeners. The rating consistency within individual listeners was also evaluated by comparing the EAI values of the original and repeated (reliability) sentence presentations for the FP and BP playback modes. The obtained product-moment correlations of 0.89 (FP) and 0.96 (BP) indicate that individual listeners were quite consistent in arriving at EAI ratings.

DISCUSSION

This study explored the relation between an analog-implemented, nasal/throat accelerometric ratio and listeners' interval estimates of hypernasality. Twelve children with velopharyngeal incompetence and three children with normal speech were assessed with the NAVI while

TABLE 5. Listener Reliability for the Equal-Appearing-Interval (EAI) Values

*Intraclass Correlation Coefficients**	*Sentence†*	*EAI-FP*	*EAI-BP*
	PDPC	0.98	0.97
r_{22}	WHLL	0.97	0.96
	RMKM	0.94	0.98

* Intraclass correlation coefficients (r_{22}) represent between-listener reliability. The data are presented by sentence for the forward-play (FP) and backward-play (BP) listening modes.

† PDPC = Pete draws pussy cats; WHLL = We hear Lilly Lou; RMKM = Ron may know May. All correlations were significant at or beyond the 0.05 level.

producing three sentences differing substantially in phonetic composition. Audiotape recordings were obtained simultaneously and later rated for hypernasality under both FP and BP listening conditions. An EAI scale was employed since interval scales are used more frequently than ratio scales in clinical settings. NAVI-EAI correlations were moderate to strong for non-nasal sentences but non-significant for a nasally loaded sentence. The NAVI-EAI relationship was not affected by playback mode as evidenced by the strong correlations between the EAI-FP and EAI-BP values. High interlistener and intra-listener reliability and low NAVI measurement error were apparent.

These results and those of our related study of the same speakers using direct magnitude estimation (Redenbaugh, 1984; Redenbaugh and Reich, 1985) provide strong support for the clinical utility of nasal/throat accelerometry, at least with the particular VPI speakers that we employed. The moderate to strong product-moment and rank-order correlations between NAVI and EAI values imply that nasal/throat accelerometric measures may be used to accurately predict hypernasality magnitude.

This study was not designed to examine systematically the influence of a sentence's phonetic composition. The sentence stimuli were limited to but one token per sentence type, and the sentence types were grouped rather than randomized on the listening tape. Therefore, one cannot rule out sentence sampling bias or order effects. Nevertheless, a sentence's phonetic composition may well influence the NAVI-EAI relationship and warrants further research. Only sentences which exclude or minimize the occurrence of nasal phonemes would appear to differentiate normal and VPI speakers adequately. The PDPC sentence accurately discriminated the speaker groups, presumably because the phonetic requirements for firm velopharyngeal closure during obstruent production are not readily achieved by VPI speakers. The WHLL sentence was likely effective in detecting hypernasality due to the acoustical and perceptual continuity provided by its predominantly voiced phonetic segments. On the other hand, the RMKM sentence phonetically required frequent nasal coupling, thereby rendering the normal speakers' performance more similar to that of the VPI speakers

The NAVI-EAI correlations of the present study are higher than those reported for absolute nasal accelerometric voltages (Garber and Moeller, 1979; Stevens et al, 1976), presumably because of the NAVI's ability to control the contaminating effects of glottal source magnitude. The present correlations are similar to those of previous nasal/voice accelerometric research (Horii, 1983; Horii and Lang, 1981; Leonard, 1981; Redenbaugh and Reich, 1985). Horii and Lang (1981) reported a Spearman rank-order correlation of 0.81 between HONC and listeners' EAI ratings. Horii (1983) reported a Pearson correlation of 0.92 between HONC and listeners' pair-comparison values. In both of the Horii studies, the hypernasality was *simulated* by young adult females. Leonard (1981) reported a non-nasal sentence correlation of 0.64 between HONC values and perceptual rankings of clinically hypernasal speakers. The present correlation of 0.90 between NAVI values and EAI ratings of hypernasality for an obstruent-loaded sentence compares favorably to the 0.91 correlation reported for direct magnitude estimates of the same sentence produced by the same speakers (Redenbaugh and Reich, 1985). The small speaker (N = 7) and listener (N = 10) groups and the relatively narrow hypernasality severity range may have contributed to the lower correlation reported by Leonard (1981).

The accelerometric data of Horii and his colleagues (Horii, 1980, 1983; Horii and Lang, 1981; Leonard, 1981) were computer-assisted and presented in logarithmic units (i.e., decibels). Absolute millivolt (mV) rather than decibel (dB) values were selected for the NAVI to facilitate an analog implementation of nasal/voice accelerometry and thereby encourage the use of time-varying NAVI signals in clinical biofeedback applications. The strong similarity between HONC and NAVI values has been established previously (Redenbaugh, 1984; Redenbaugh and Reich, 1985).

The present and previous data suggest that nasal/throat or nasal/voice accelerometric measures provide useful indirect information regarding velopharyngeal gestures and nasal resonance. The NAVI and other similar instruments may assist us in differential diagnosis, treatment planning, and evaluation of treatment effectiveness.

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