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LOUISIANA STATE UNIVERSITY
NASALANCE PROTOCOL STANDARDIZATION

A Thesis

**Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
In partial fulfillment of the
Requirements for the degree of
Master of Arts**

in

The Department of Communication Disorders

by

**Kathryn Ruth Kendrick
B.A., Louisiana State University, 2002**
May 2004

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I was amazed at how inviting, responsive, and supportive my committee was during this experience. Many times students think of a thesis and avoid pursuing projects like this due to the amount of work and anticipated struggles they may endure. I have found that if you have a strong and supportive committee the experience can be a delightful one. My committee was welcoming for questions, editing, and discussion, they provided me with advice, resources, contacts, and were able to interact with this project from many different perspectives, which resulted in a well-rounded and well-supported final project.

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ABSTRACT

It was the purpose of this study to obtain nasalance values using the Nasometer and a resonance evaluation created at the Louisiana State University (LSU) Speech and Hearing Clinic. The Nasometer was used to measure the amount of nasal acoustic energy in the speech of 40 normal young adults during sustained vowel production, consonant vowel reduplications, and connected speech using the Rainbow Passage. Means and standard deviations are presented for the individual speech tasks and according to gender. Nasalance values for the sustained vowels were significantly higher for the high front vowel /i/ than any other vowel, and the lowest nasalance value was obtained by the high back vowel /u/. The vowels in descending order of nasalance values were as follows: /i, ae, a, u/. No significant gender differences were found for sustained vowel production or the Rainbow Passage. Correlation values indicated that three phonemes /u, k, g/ from the resonance protocol were the best predictors of nasalance according to the reading passage. The results are discussed with regard to potential reasons why minimal gender differences were found, why the phonemes were found to be the best predictors of nasalance, and how the LSU protocol can be modified to provide a more effective and efficient resonance evaluation.

CHAPTER 1
INTRODUCTION

There is considerable information available concerning the acoustic characteristics of abnormal and normal resonance, as well as clinical assessment and management of resonance impairments. Most normative data were collected from English speaking Caucasian American children and adults using reading passages as stimuli (e.g., Rainbow, Zoo, and Nasal Passages). The Rainbow Passage contains a mixture of oral and nasal consonants in the approximate proportion found in standard American English, also known as a phonetically balanced (PB) passage. The Zoo Passage contains only oral speech sounds and was designed to assess the degree of hypernasality in a subject's speech. The Nasal Passage contains 35% nasal consonants, which is three times greater than the frequency of occurrence of nasals in standard American English and was designed to test for the presence of hyponasality in a person's speech (Seaver, Dalston, Leeper, & Adams, 1991). There are limited data concerning individual vowel and consonant nasalance values. It was the purpose of this study to collect normative data on Caucasian young adults using the Nasometer 6200 (Kay Elemetrics Corp., Pine Brook, NJ.) and the resonance protocol created at the Louisiana State University (LSU) Speech and Hearing Clinic.

The LSU resonance protocol systematically measures the nasalance in the production of each of the phonemes, which are organized in hierarchical order from the least to most mechanical stress each test item places on the velopharyngeal (VP) system. The protocol begins with productions of sustained vowels, which are periodic sounds requiring low intraoral pressures and, thus, are presumed to be less taxing on the VP system. The vowels included are: (high – low and front – back /i, I, e, E, ae, u, ʊ, o, ɔ, a, ʌ, ɝ/).   The protocol continues with consonant vowel (CV) reduplications in which the neutral vowel /ʌ/ is paired with approximants /w, j, l, r/ (e.g., wʌ, wʌ, wʌ), plosives /p, b, t, d, k, g/, fricatives /ɵ, ð, f, v, s, z, ʃ, ʒ/, and affricatives /ʧ, ʤ /. The LSU protocol uses the mean to represent nasalance during production of sustained vowels and connected speech using the Rainbow Passage and the mean of the maximum values to represent nasalance during consonant production. Collectively, these utterances demand a range of VP control capabilities. It is the purpose of this study to obtain normative data for all speech tasks, the significance of each speech task, and/or redundancy within the protocol. The following questions are proposed for this project: (1) What are the normative resonance values for the individual speech tasks for each gender? (2) Which evaluation items are the best predictors of nasalance from the reading passages and spontaneous speech sample?

CHAPTER 2
REVIEW OF LITERATURE

Creation of Resonance Instrumentation

Fletcher (1970) created an electronic instrument for quantitative measurement of resonance quality of speech that separated oral and nasal resonance. The instrument was known as Tonar (The Oral Nasal Acoustic Ratio) and was created to measure the intensity ratio between nasal and oral acoustic outputs. The separation of signals was intended to circumvent the effect of distortion and masking of frequency content. Three aspects of distortion that were essential to electronic instrumentation approaches and their measurement were: (1) During connected speech, two channels (i.e., oral and nasal cavities) are simultaneously generating and emitting acoustic energy that have the capacity to mask critical characteristics of each other. (2) Diversion of acoustic energy from a primary transmission channel due to abnormal VP anatomy and/or physiology may be expected to have altering effects (i.e., hypo- or hypernasal) upon signals being transmitted through that channel. (3) Overlap of the oral and nasal outputs with altered shifts (i.e., being masked and/or abnormally diverted) in acoustic energy will be reflected as speech distortion (Fletcher, 1970). For these reasons, it was critical that the instrument have the capacity to separately measure the nasal and oral acoustic outputs during speech production.

Fletcher (1970) discussed the significance of masking to the perception of sound signals, and its relevance to hypernasality. He defined masking as the reduction in one signal's audibility when it coexists with another frequency within its' "critical band," (i.e., the range of frequencies capable of masking out the particular tone). The possibility of masking to occur increases as the frequency ranges of two competing signals expand and have greater overlap. Hypernasal speech involves inadequate coupling of the oral and nasal cavities, thus allowing sound to resonate through both cavities simultaneously during speech production. Each cavity has unique characteristics that filter and affect the resonance quality of the sound emitted from them. As sound is diverted through the nasal cavities, it will mask the output of the oral cavity. The second type of acoustic distortion proposed by Fletcher (1970) is the loss of energy within speech (i.e., hyponasal speech). Hyponasal speech occurs when there is a reduction or elimination (i.e., denasality) of nasal resonance by blockage of the nasal cavities. When this occurs, the nasal acoustic energy is altered and/or eliminated and could lead to the disruption in the normal balance (i.e., oral and nasal) of acoustic energy as it is distributed among phonemes (Fletcher, 1970). Tonar was designed to separate the oral and nasal acoustic outputs during speech, to filter the two channels with identical bandwidths and frequency ranges to prevent masking of the acoustic signals, to transmit between 50 and 20,000 Hz without distortion, to quantify and display the ratio between sound levels in each of the channels and within selectable frequency bands, and to generate data that can be interpreted by clinicians (Fletcher, 1970).

Prior to Tonar, speech-language pathologists (SLPs) relied solely upon their perceptual judgment for resonance evaluations. Fletcher (1970) sited two limitations for clinical use: (1) subjective and qualitative judgments are undependable for repeated assessment and among different clients and (2) the basic parameters of the disability are not objectively defined. Tonar made use of electronic technology, which allowed for a more precise, quantitative, and objective measurement of nasality relating to resonance disorders. Tonar proved to be a useful way of measuring nasality that correlated well with listener perception and pressure-flow measurements (Fletcher, 1973; Fletcher, 1976; Instruction Manual. Kay Elemetrics Corp., Pine Brook, NJ).

Nasometer

Kay Elemetrics introduced the Nasometer, the first commercially practical system for the measurement and treatment of resonance impairments in 1986. The Nasometer operates using the same principles as Tonar, but was redesigned using technological advances such as, electronic design and personal computers for display and calculations. The Nasometer was introduced to aid in the measurement and management of velopharyngeal impairments, and is now considered a standard instrument for resonance assessment (Dalston, Warren, & Dalston, 1991a; Dalston, Warren, & Dalston, 1991b; Flege, 1988; Litzaw & Dalston, 1992; Seaver et. al., 1991). A major advantage of the Nasometer is its non-invasiveness and relative ease of use for acoustic assessment of velopharyngeal function. The Nasometer is a microcomputer-based system that provides the user with a numeric output indicating the relative amount of nasal acoustic energy in a participant’s speech. With this device, oral and nasal acoustic signals are sensed by microphones on either side of a sound separator plate that rests on the upper lip. The signal from each of the microphones is filtered and digitized by custom electronic components and then processed by the computer and accompanying software. The resultant signal is a ratio of nasal to nasal-plus-oral (total) acoustic energy that is multiplied by 100 and expressed as a “nasalance” value (Instruction Manual, Kay Elemetrics Corp., Pine Brook, NJ; Seaver et al., 1991).

Nasometric Validity

Since its introduction, the Nasometer has proven to be an effective tool for aiding in the assessment and diagnosis of resonance disorders (Dalston et al., 1991a; Dalston et. al., 1991b; Instruction Manual. Kay Elemetrics Corp., Pine Brook, NJ; Kummer, Myer, Smith, & Shott, 1993). Dalston et al. (1991a) investigated the extent to which acoustic assessments of speech, made utilizing a Kay Elemetrics Nasometer, corresponded with clinical judgments of hyponasality and aerodynamic measurements of nasal cross-sectional area. The results were obtained using the Nasal Passage as stimuli and 76 participants (38 adults and 38 children) that were referred to an Oral-Facial and Communicative Disorders Program. Among the 38 adult participants, the sensitivity in correctly identifying moderate to severe hyponasality was 0.38, whereas the specificity in identifying the absence of hyponasality was 0.92. Data analyses for comparison across age groups were not possible due to the variability of nasal airway size in children until the age of 15 years (Dalston et al., 1991a). Among the entire group of patients, the sensitivity was 0.48 and specificity was 0.79. When patients with audible nasal emissions were eliminated from analysis the sensitivity of the Nasometer ratings rose to 1.0 and the specificity rose to 0.85. The authors suggested that artificially high nasalance values were obtained due to audible nasal emissions being detected by the nasal microphone when examinees produced oral speech sounds during the Nasal Passage. Audible nasal emissions occur when air being exhaled nasally becomes turbulent and generates noise and, in turn would increase nasalance values. High nasalance values should correlate with perceived hypernasal speech. Therefore the high nasalance values (i.e., due to nasal emissions during oral speech sounds) and the perceptual judgment of moderate to severe hyponasal speech led to a low degree of agreement between the Nasometer results and listener judgments when all participants were included.

Dalston et al. (1991b) determined the correspondence between acoustic assessments of speech using the Kay Elemetrics Nasometer and clinical judgments of moderate to severe hypernasal speech. Acoustic data were obtained using 117 adult and child participants (ranging from 5 years, 6 months to 56 years) reading the phonetically balanced Rainbow Passage. A cutoff score was set at 32% to specify a clinically significant level of hypernasality. With this criterion, the sensitivity in correctly identifying participants with moderate to severe hypernasal speech was 0.89. The specificity in identifying the absence of hypernasality was 0.95. In order to determine the percent of correlation between nasometric categorization and perceptual judgment of resonance status Dalston et al. (1991b) created an efficiency rating. These results correlated to an efficiency rating of 93% for the Nasometer in this study. Thus, the Nasometer provided reliable measurements of hypernasality relative to clinical impressions using the Rainbow Passage.

Kummer et al. (1993) investigated the sensitivity and specificity of the Nasometer for hyponasality and hypernasality using the three standardized passages. The results were obtained using 15 children (six boys, nine girls, with a mean age of 6;8) who all had a diagnosis of upper airway obstruction resulting in hyponasal speech and were undergoing adenotonsillectomy to remove the obstruction. When examining hyponasality, Kummer et al. (1993) found the sensitivity of the Zoo, Rainbow, and Nasal Passages to be 0.88, 0.63, and 0.63, respectively. The specificity in this case for these passages was 0.77, 0.86, and 0.91, respectively. When examining hypernasality, the authors found the sensitivity of all three passages to be 1.00. The specificity for the Zoo, Rainbow, and Nasal Passages in this case was 0.96, 0.78, and 0.78, respectively.

Three studies investigated the sensitivity and the specificity of the Nasometer to determine the correspondence between acoustic assessments of speech and clinical judgments of resonance quality. Dalston et al. (1991a) found the sensitivity of the Nasometer in correctly identifying moderate to severe hyponasality to be 1.0 and the specificity to be 0.85 using the Nasal Passage in all participants who did not exhibit nasal emissions during the speech task. Dalston et al. (1991b) found the sensitivity in correctly identifying moderate to severe hypernasality to be 0.89 and the specificity to be 0.95 using the Rainbow Passage. Kummer et al. (1993) found the sensitivity of the Nasometer in correctly identifying hyponasality for the Zoo, Rainbow, and Nasal Passages to be 0.88, 0.63, and 0.63, respectively, and the specificity for these passages to be 0.77, 0.86, and 0.91, respectively. When examining hypernasality, they found the sensitivity of all three passages to be 1.00 and the specificity for the Zoo, Rainbow, and Nasal Passages to be 0.96, 0.78, and 0.78, respectively. From the results of the three studies, it appears that the Nasometer is less sensitive in identifying hyponasality than it is for hypernasality using the standard passages. Overall, the authors concluded that the Nasometer provided an objective means for the assessment of resonance, but should not be interpreted without an accompanying perceptual evaluation by a qualified speech-language pathologist (Dalston et al., 1991a; 1991b; Kummer et al., 1993).

Normative Studies

Several studies have focused on establishing normative resonance data using the three standard reading passages in regard to age. Norms have been developed across the three reading passages for children, adults, and the elderly. In general, it has been shown that nasalance values increase with age, resulting in lower values for children and higher values for elderly speakers (Anderson, 1996; Fletcher, Adams, & McCutcheon, 1989; Hutchinson, Robinson, & Nerbonne, 1978; Leeper, Rochet, & MacKay, 1992; MacKay & Kummer, 1994; Seaver et al., 1991).

Children

Fletcher et al. (1989) studied 117 children ranging in age from five to twelve years and published normative data using the Nasometer and the three standard passages. Results indicated a mean nasalance value of 15.53% for the Zoo Passage, 35.69% for the Rainbow Passage, and 61.01% for the Nasal Passage (Fletcher et al., 1989). MacKay and Kummer (1994) published normative data using 250 normal children between the ages of three and nine years as a function of phonetic context using the Simplified Nasometric Assessment Procedures (SNAP Test) (MacKay & Kummer, 1994) and reported nasalance values similar to those found by Fletcher et al. (1989). Leeper et al. (1992) studied nasalance in Canadian bilingual speakers of English and French using the Nasometer, Standard English reading passages, and approximate correlations of French reading passages. They found that younger age groups (seven-twelve and thirteen-nineteen) had significantly lower nasalance scores in comparison to the older age groups (20-85+ years) on all reading passages in both languages and, therefore, concluded that nasalance values change as a function of age for normal speakers (Leeper et al., 1992).

It has been proposed that children obtain lower nasalance values on reading tasks because coarticulation during connected speech is a learned behavior (Flege, 1988; Thompson & Hixon, 1979). The temporal characteristics of coarticulation in the speech of children and adults have been investigated by examining the effect of vowels on preceding consonants (Flege, 1988; Thompson & Hixon, 1979). Coarticulation is the influence of one speech segment upon another where one phoneme adopts one or more of the articulatory features of a preceding (left-to-right/carryover) or proceeding (right-to-left/anticipatory) phoneme. This phenomenon occurs extensively throughout connected speech in which phonetic context, consonant environment, and syllable stress influence speech production. According to Flege (1988), the velopharyngeal port (VPP) must be open during at least a portion of the time the tongue forms a constriction at the alveolar ridge during production of the nasal phoneme /n/, resulting in anticipatory coarticulation of the vowel preceding the nasal consonant production. It has also been stated that the VPP typically begins opening at or near the onset of vowels in oral consonant-vowel-nasal consonant (CVN) words in the speech of adults (Parush and Ostry, 1986). Thompson and Hixon (1979) found significant differences in the temporal aspects of nasal coarticulation in relation to age groups when they investigated nasal airflow during normal speech production of 112 children and adults. They found that although 50% of adults showed nasal airflow at the midpoint of vowels preceding /n/, only 14% of three to six year-olds, 20% of six to nine year-olds, and 43% of nine to twelve year-olds engaged in anticipatory nasal coarticulation. These results led the authors to conclude that anticipatory nasal coarticulation occurred more rapidly as age increased and may be a learned behavior (Thompson & Hixon, 1979). Flege (1988) investigated the temporal aspects of anticipatory and carry-over nasal coarticulation in the speech of children (five and ten years of age) and adult females. He determined the time at which VPP opening began during vowels /i, u/ preceding a nasal consonant spoken in the context of CVN (i.e., anticipatory nasal coarticulation) and when VPP closing reached completion in vowels spoken in the context of NVC (i.e., carry-over nasal coarticulation). All three age groups began opening the VPP near the onset of vowels in the /CVN/ context and exhibited similar durations of nasalization during vowels spoken in the context of /NVC/ (Flege, 1988).

Adults

Seaver et al. (1991) studied the nasometric values of 148 normal adult speakers from four geographic regions of North America using the three standard passages. The participants consisted of 92 females and 56 males with a mean age of 33 years. Results indicated a mean nasalance value of 16% for the Zoo Passage, 36% for the Rainbow Passage, and 62% for the Nasal Passage. Females were found to have higher nasalance values across the three reading passages, with significantly higher nasalance on the Nasal Passage (Zoo Passage, 16%, Rainbow Passage, 36%, and Nasal Passage 63%) than did males (Zoo Passage, 15%, Rainbow Passage, 35%, and Nasal Passage 61%) (Anderson, 1996; Hutchinson et al., 1978; Leeper et al., 1992; Seaver et al., 1991).

Elderly Speakers

According to Hutchinson et al., (1978), the process of human aging is typically accompanied by deteriorations in sensori-motor skills. If resonance quality was affected due to decreasing VP control, one could obtain evidence of this occurrence using acoustic analysis. Thus, the velopharyngeal adequacy in 60 dialectally homogeneous normal elderly participants was investigated using the three standard passages and sustaining the vowel /a/ as speech stimuli. Nasalance values were calculated using Tonar-II precomputer interface. Mean nasalance values using the four stimuli were found to be 22% for the Zoo Passage, 28% for the Rainbow Passage, 43% for the Nasal Passage, and 20% for the sustained vowel /a/. Significant gender differences were observed, as females obtained significantly higher nasalance values compared to males across all speech tasks. The mean nasalance values in regard to gender were as follows: for the Zoo Passage Females (F)-27% and Males (M)-17%; for the Rainbow Passage F- 32% and M- 24%, for the Nasal Passage F- 48% and M- 38%, and when sustaining the vowel /a/ F-24% and M-16% (Hutchinson et al., 1978).

The results demonstrated that older participants obtained significantly higher nasalance values across all speech stimuli in comparison to the nasometric data obtained by Fletcher (1976) with young adults using Tonar-II. On average, the elderly speakers exhibited nasalance values greater than the range of normal limits established by Fletcher (1973) for hypernasality using the Zoo Passage (oral consonants only), which is indicative of abnormal oral-nasal coupling associated with hypernasal resonance values during speech production. Seaver et al. (1991) found similar results using the Nasometer, where older participants (+ 38 years), exhibited higher nasalance values on the Zoo Passage in comparison to younger adults (18 to 38 years). Overall, it can be inferred from the increased nasalance values, that when relatively continuous demands for VP closure were required, as in the Zoo Passage, normal older adults and elderly participants exhibited less VP closure and control in comparison to normal young adults (Hutchinson et al., 1978).

Gender

Within the adult population, the published normative data across gender will be reviewed and the speculations as to why, in general, females achieve higher nasalance values compared to males (Anderson, 1996; Flege, 1988; Hutchinson et al., 1978; Leeper, et al., 1992; McKerns & Bzoch, 1970; Seaver et al., 1991; Stevens & House, 1961; Thompson & Hixon, 1979; Watterson, York, and McFarlane, 1994; Zajac, Lutz, & Mayo, 1996a; Zajac & Mayo, 1996b; Zajac, Mayo, & Kataoka, 1998). Seaver et al. (1991) found adult Caucasian females, regardless of geographic region, to have 2-3% higher nasalance values on the passages containing predominately nasal consonants (i.e., the Nasal Passage) when compared to males. Mean nasalance data according to gender were specified and are as follows: the Zoo Passage, 16%, the Rainbow Passage, 36%, and the Nasal Passage 63% (Seaver et al., 1991). However, none of the investigators reportedly perceived a difference in the nasal quality of the females' speech compared to males. Hutchinson et al. (1978) found that elderly female participants exhibited significantly greater nasalance values across all speech tasks (three reading passages and sustaining the vowel /a/) in comparison to the male elderly participants.

Leeper et al. (1992) studied the characteristics in bilingual Canadian speakers and reported in general, that female speakers demonstrated greater nasalance values within each language. Anderson (1996) obtained group mean nasalance scores using 40 normal Puerto Rican Spanish-speaking females using the Nasometer and three connected speech stimuli similar in phonetic make-up to the three standard American English reading passages. Anderson (1996) reported mean nasalance values that fell within the range of values previously reported by Seaver et al. (1991). In conclusion, linguistic and dialect differences affect nasalance scores, and across both parameters females have been shown to obtain increased resonance values in comparison to males (Anderson, 1996, Leeper et al., 1992, Seaver et al., 1991).

In an attempt to determine why females achieved higher nasalance values, several authors have investigated the anatomical and/or physiological velopharyngeal gender differences (Kuehn & Moon, 1998; McKerns & Bzoch, 1970; Thompson & Hixon, 1979; Watterson et al., 1994; Zajac & Mayo, 1996b). McKerns and Bzoch (1970) used cinefluoroscopy to observe VP valving and found that two basic configurations of VP closure existed in relation to gender during connected speech production. Females were observed to have a shorter velum, use less velar elevation, and a greater amount of velar contact against the pharyngeal wall to achieve closure. The closure configuration of the velum for females was described as having the appearance of a "right angle" within the pharynx. The authors attributed these gender related differences to the sites of muscle insertion involved in VP closure (i.e., levator palatini, palatoglossus, and palatopharyngeus muscles), and oral and pharyngeal dimensions (McKerns & Bzoch, 1970). Kuehn and Moon (1998) investigated VP closure force in varying phonetic contexts using 14 normal college-aged participants (seven male, seven female). No statistically significant gender differences were found in VP closure force using different vowel and consonant productions, voicing, place, manner, or sequencing conditions. However, it was observed that females utilized less mean closure force with more levator muscle activity and a more constant closure force, whereas the males exhibited increased mean closure force with less levator muscle activity and significant differences in closure force across the various phonetic contexts (Kuehn & Moon, 1998). Zajac & Mayo (1996b) studied the aerodynamic and temporal aspects of VP function in 42 normal young Caucasian adult (21 male and 21 female; mean age 24, 23) speakers during production of the nasal-plosive sequence /mp/ in the strong-weak stressed word, “hamper.” Significant gender differences were demonstrated where females exhibited significantly lower levels of peak intraoral air pressure and longer durations in the rise of pressure during the production of the /p/ segment, indicating less occlusion of the VPP. It was speculated that differences in preferred intensity levels and respiratory and velar physiology between genders might have accounted for some of the findings (Zajac & Mayo, 1996b). Watterson et al. (1994) studied the effects of vocal loudness on nasalance values using the Zoo and Nasal Passages and 30 normal young adult female participants. The nasalance values obtained were similar to those reported by Seaver et al. (1991), regardless of the level of vocal intensity or passage. Thus, the authors concluded that nasalance values were not significantly influenced by vocal intensity.

Thompson and Hixon (1979) studied 112 normal children and adults and reported a gender difference in relation to anticipatory coarticulation of nasal airflow. They found that females engaged in anticipatory coarticulation of a nasal consonant earlier by exhibiting increased nasal airflow during the midportion of a vowel that preceded a nasal consonant and demonstrated a greater degree of nasal airflow during the production of high-pressure consonants in comparison to males. Zajac, Mayo, and Kataoka (1998) investigated the influence of gender on nasal coarticulation in normal speakers using 20 adults (ten male, ten female) and the production of a vowel-nasal-vowel (VNV) sequence /ini/ within a carrier phrase using two stress patterns (i.e., with equal stress placed on both syllables and with contrastive stress placed on the second syllable). They found that syllable stress affected VP closure force and the overall level of anticipatory and carryover nasal airflow during vowel production; however, neither gender nor syllable stress affected the presence or absence of nasal airflow at the midpoints of the vowels. All participants, regardless of gender, exhibited similar patters of anticipatory and carryover nasal coarticulation evidenced by similar timing and amounts of nasal airflow preceding and following the vowel in both stress environments. These results contrast with the findings of Thompson and Hixon (1979). They found that females exhibited more nasal airflow during the midportion of a vowel preceding a nasal consonant, engaged in anticipatory coarticulation of a nasal consonant earlier, and that females produced more nasal airflow during nasal consonant production. The results of Thompson and Hixon (1979) are in accordance with the findings of Seaver et al. (1991), that females obtained higher nasalance values during reading passages containing nasal consonants.

Litzaw and Dalston (1992) studied the effect of gender upon nasalance scores, fundamental frequency, and nasal cross-sectional area using 30 normal Caucasian young adult speakers (15 male, 15 female; mean age 24, 28) and the three standard reading passages. They reported no statistically significant gender differences of nasometric values using the Nasometer and a weak correlation between nasalance and fundamental frequency using the Visi-Pitch, (Kay Elemetrics). These findings conflict with the previous data reported by Seaver et al. (1991) that found significant gender differences based on nasal sentence productions. Both studies found the average gender difference to be of only two nasalance percentage points, but the latter used a larger sample size, which may have accounted for the significant differences (Litzaw & Dalston, 1992; Seaver et al., 1991). It has been suggested that because of the Nasometer's filter specifications, certain frequencies may be passed more effectively, and this may account for the reported gender differences in nasalance values (Leeper et al., 1992; Seaver et al., 1991). Zajac et al. (1996a) investigated microphone sensitivity and fundamental frequency gender differences as sources of variation in nasalance values. Results from Litzaw and Dalston (1992) and Zajac et al. (1996a) concluded that the filtering characteristics of the Nasometer did not affect nasalance values and thus, are insensitive to gender differences.

Overall, the trends for normal female nasometric values when compared to males include: (1) nasalance values being greater across dialect (Seaver et al., 1991), age (Hutchinson et al., 1978), and language variations (Anderson, 1996; Leeper et al., 1992),

(2) speculated subtle differences in underlying anatomy and physiology related to VP closure, where females have a shorter velum, use less velar elevation, have a greater amount of velar contact against the pharyngeal wall, achieve less mean closure force using more levator muscle activity, use similar VP closure force across various phonetic contexts, and achieve lower levels of peak intraoral air pressure over longer durations, (suggesting that females require more time to achieve less VPP occlusion) (McKerns and Bzoch, 1970; Seaver et al., 1991; Stevens & House, 1961; Thompson & Hixon, 1979; Zajac & Mayo, 1996b), and (3) anticipatory coarticulation occurring earlier exhibited by increased nasal airflow preceding and during the production of nasal consonants, which in turn may lead to overall increased nasalance values (Flege; 1988; Thompson and Hixon, 1979; Zajac & Mayo, 1996b). Other research has indicated that vocal intensity, fundamental frequency, and filtering characteristics of the Nasometer have not been found to cause gender related differences in nasalance values (Litzaw & Dalston, 1992; Watterson et al., 1994; Zajac et al., 1996a).

The research has shown that males obtain lower nasalance values in comparison to females across dialect (Seaver et al., 1991), age (Hutchinson et al., 1978), and language (Leeper et al., 1992). Seaver et al. (1991) found adult Caucasian males, regardless of geographic region, to have two-three percent lower nasalance values on the reading passages when compared to females. Mean nasalance data for the male participants were as follows: 15% on the Zoo Passage, 35% on the Rainbow Passage, and 61% on the Nasal Passage. However, none of the investigators perceived a gender difference in resonance quality. These results indicated mean nasalance values for normal adult Caucasian English-speaking males to be significantly lower from female data only on the passage containing predominately nasal phonemes (i.e., the Nasal Passage).

It has been shown through various research studies that subtle differences in VP anatomy and physiology exist, which may explain why males generally achieve lower nasalance values in comparison to females (McKerns and Bzoch, 1970; Seaver et al., 1991; Stevens & House, 1961; Thompson & Hixon, 1979; Zajac & Mayo, 1996b). McKerns and Bzoch (1970) used cinefluoroscopy during connected speech to observe the VP valving mechanism and revealed gender specific VP closure patterns. Males were observed to have a longer velum and achieve a more elevated and angled velar closure against the posterior pharyngeal wall using a smaller mean amount of contact. The closure configuration of the velum for males was described as having the appearance of an “acute angle” within the pharynx, in contrast to the female velar configuration of a more “right angled,” position. The authors attributed these gender differences to the site of muscle insertion involved in VP closure (i.e., levator palatini, palatoglossus, and palatopharyngeus muscles), and oral and pharyngeal dimensions (McKerns & Bzoch, 1970). Kuehn and Moon (1998) investigated the VP closure force in varying phonetic contexts. No statistically significant gender differences were found. However, males achieved greater mean closure force values using less levator muscle activity in comparison to females and utilized significant differences in amount of closure force across the various phonetic contexts. The authors explained their findings by stating that because females have been shown to attain less “velar height,” they may have a more limited range for changes in VP closure force (Kuehn & Moon, 1998; McKerns and Bzoch, 1970). Zajac and Mayo (1996b) studied the aerodynamic and temporal aspects of VP function during the production of the nasal-plosive sequence /mp/ in the strong-weak stressed word, “hamper.” Gender differences were demonstrated, as male participants achieved significantly higher levels of peak intraoral air pressure during the production of the /p/ segment in less time than their female participants. Due to the phonetic context (i.e., weak syllable stress, abutting releaser, voiceless, bilabial plosive) of the stimuli, the results provided information relative to the time and amount of VP closure exhibited by males during the /p/ segment. Explanations for the differences concerned preferred intensity levels and respiratory and velar physiology. Zajac and Mayo (1996b) concluded that intrinsic physiologic characteristics of the respiratory system allowed males to achieve peak pressure in shorter intervals due to greater lung elasticity. These results were consistent with results of velar movement patterns and duration reported by McKerns and Bzoch (1970). Zajac et al. (1998) investigated the influence of gender on nasal coarticulation using a VNV sequence and two stress patterns (equal and contrastive). They found that syllable stress affected the VP closure and the overall level of anticipatory and carryover nasal airflow during vowel production. However, neither gender nor syllable stress affected the presence or absence of nasal airflow at the midpoints of the vowels. All speakers, regardless of gender, exhibited similar patters of anticipatory and carryover nasal coarticulation evidenced by similar timing and amounts of nasal airflow preceding and following the vowel in both equal and contrastive stress environments. These results contrasted with an earlier study by Thompson and Hixon

(1979). They found that males exhibited less nasal airflow during the midportion of a vowel preceding a nasal consonant thereby, being less likely to engage in anticipatory coarticulation of a nasal consonant. They also reported that males produced less nasal airflow during nasal consonant production, which was in accordance with the findings of Seaver et al. (1991), where males obtained lower nasalance values on all three reading passages with significantly lower nasalance values on the Nasal Passage.

Overall, the trends for normal male nasometric values when compared to females include: (1) lower nasalance values across dialect (Seaver et al., 1991), age (Hutchinson et al., 1978), and language variations (Leeper et al., 1992), (2) speculated subtle differences in underlying anatomy and physiology related to VP closure, in which males have a longer velum, achieve increased velar elevation and amount of closure force using less mean amount of velar contact with the posterior pharyngeal wall and less levator muscle activity, use different amounts of closure force dependant across different contexts, and achieve increased peak intraoral air pressures in less time, (suggesting that males require less time to achieve more VPP occlusion) (McKerns and Bzoch, 1970; Seaver et al., 1991; Stevens & House, 1961; Thompson & Hixon, 1979; Zajac & Mayo, 1996b), and (3) anticipatory coarticulation occurring less frequently and decreased nasal airflow preceding and during nasal consonants, which in turn may lead to overall lower nasalance values (Flege; 1988; Seaver et al., 1991;Thompson and Hixon, 1979; Zajac & Mayo, 1996b).

It has been shown that in regard to gender, there are several possible factors causing variation within nasalance values. There is not one accepted explanation of these differences. According to McKerns and Bzoch (1970), "The different velar orientations and configurations could have some special significance to the acoustic and oral-nasal air flow output during speech. The differences in the measurements of the variables contributing to the configurations could represent physiological adjustments in one sex or the other to compensate for the basic difference in fundamental frequency compounded by differences in the oral and pharyngeal cavities in order to achieve comparable phonetic results" (p. 660).

Dialect and Language

Normative resonance data are available for English speakers, as most of the studies have been conducted with native English Caucasian speakers. These data, in turn, indicated that normal speakers within the same language obtained different nasalance values. Seaver et al. (1991) investigated the influence of dialect on nasalance in normal speakers and found significant differences in mean nasalance values on all three standard reading passages. The four regional speech patterns studied were (1) Mid-Western (participants primarily from Illinois), (2) Mid-Atlantic (participants primarily from North Carolina), (3) Southern (participants primarily from Alabama), and (4) Ontario, Canada. Adult mean nasalance values according to dialect are as follows: Zoo Passage Mid-West (M-W) 15.0%, Mid-Atlantic (M-A) 21.5%, Southern (S) 13.0%, and Ontario (O) 11.5%; the Rainbow Passage M-W 35.0%, M-A 39.5%, S 33.0%, and O 34.5%, and on the Nasal Passage M-W 62.0%, M-A 65.0%, S 60.0%, and O 59.5%. Results indicated that Mid-Atlantic speakers obtained significantly higher nasalance values on all three reading passages. These results stress the importance of developing normative data for various subgroups in the general population (Anderson, 1996; Leeper et al., 1992; Seaver et al., 1991).

Leeper et al. (1992) obtained nasalance values from 1751 bilingual English and French speaking Canadian participants. The three French Passages were designed to correlate with the standard American English passages used in current research to obtain normative nasalance values. The French Passage #1 contained no nasal consonants (i.e., correlate to the Zoo Passage), #2 contained 13.75% nasal consonants (i.e., Rainbow Passage), and #3 contained 28% nasal elements (i.e., Nasal Passage). Significant differences were found among the data for the passages containing nasal phonemes (i.e., nasal consonants and vowels in the Rainbow and Nasal Passages and the French #2 and #3 Passages), where the bilingual speakers using the French Passages exhibited lower nasalance values overall, compared to the English counterparts. Several hypotheses were provided to explain the differences such as: (1) different qualities of nasal phoneme (consonants and vowels) production in each language, (2) the balance of nasals between equivalent passages in the two languages, and (3) coarticulation of nasal phonemes and segments. Nasal phonemes in English are consonants and coarticulated nasalized vowels and in French a large proportion of the nasal phonemes are nasalized vowels. Leeper et al. (1992) concluded that the VP mechanism functions in part by an articulatory set typical of a particular dialect and/or language.

Anderson (1996) obtained group mean nasalance scores using 40 normal Puerto Rican Spanish-speaking females using the Nasometer and three speech stimuli similar in phonetic make-up to the three standard American English reading passages: (1) sentences containing nasal consonants, (2) a reading passage with both oral and nasal consonants, and (3) a reading passage with oral only consonants. Anderson (1996) found group mean nasalance values that fell within the range of values previously reported by Seaver et al., (1991) using the three standard reading passages. Using the Nasal Passage the mean ranged from 61 to 66, the Puerto Rican mean value using the nasal sentences was 62. Using the Rainbow Passage, the mean ranged from 34 to 36, while using the oral-nasal passage, the Puerto Rican mean was 36.02. Finally, using the Zoo Passage the mean ranged from 12 to 22, and the Puerto Rican group mean was 21.95. In conclusion, linguistic and dialect differences affected nasalance scores and across both parameters females were shown to obtain increased resonance values in comparison to males.

Overall, the research indicates that during normal speech production nasalance values vary according to dialect and language, which in turn points to the importance of developing normative data for various subgroups in the general population (Anderson, 1996; Leeper et al., 1992; Seaver et al., 1991).

Resonance Evaluation

Any test design needs to consider physiologic and acoustic properties of phonemes. Because syllables are the motor output unit of speech and vowels are the nucleus of syllables, which are temporally stable, the properties of vowels need to be considered in designing test items. Other than the Zoo, Rainbow, and the Nasal Passages, there are few formal tests designed to systematically assess the velopharyngeal system. The MacKay-Kummer Simplified Nasometric Assessment Procedures (SNAP) is an assessment tool marketed for children, non-literate patients of all ages, and noncompliant patients with resonance disorders. The test passages have been normed on 250 children whose ages ranged from three to nine years. The SNAP test includes three subtests: (1) 14 syllable-repetition tasks, (2) five picture-cued passages, and (3) two reading passages. A description of each subtest is as follows: (1) The Syllable-Repetition Subtest requires participants to repeat a consonant-vowel (CV) syllable six to ten times (e.g., ti-ti-ti…) over a two-second interval. The 14 CV syllable repetitions contain the following sounds /p, t, k, s, ʃ, m, n/ in combination with the vowels /i, a/. Normative data are provided for the CV stimuli that differ only with respect to the vowel. (2) The Picture-Cued Subtest consists of simple, repeated carrier phrases with concrete, picturable words for each passage. The subject is instructed to produce three sentences using picture cues and then repeats each sentence for a total of six sentences per passage and 30 sentences total. This subtest focuses on production of bilabial, alveolar, velar, sibilant, and nasal phonemes /p, b, t, k, s, m, n/. (3) The Reading Subtest is designed for readers and consists of two short, easy-to-read passages, one loaded with plosives /p, b/ and the other with sibilants /s, z/.

Administration of all subtests is not necessary in a routine nasometric evaluation. Specific passages of a subtest can be selected depending on articulation, reading ability, and diagnostic information being sought. MacKay and Kummer stated that the SNAP Test reduces the amount of time and effort associated with nasometric evaluation and that, in many cases, four or five of the syllable-repetition passages provides more clinical information with a wider variety of patients than can currently be obtained using the Zoo Passage.

The SNAP Test was developed in order to eliminate some of the problems in administration and to improve the diagnostic value of nasometry. The advantages of the SNAP Test over the current standardized passages are as follows: (1) it eliminates the requirement of literacy, (2) the materials are semantically, pragmatically, and lexically simple, (3) the materials induce few production errors and may be used with patients displaying systematic articulation errors, (4) materials include subtests that are short and simple, and can be used with persons who offer little cooperation, and (5) it allows the examiner to isolate certain phonemes or types of phonemes for assessment, which improves the diagnostic value of nasometry.

Vowels

The Nasometer was designed primarily to measure the acoustic energy in vowels; therefore, the vowel content of short stimuli would be of particular interest (Fletcher et al., 1989) during resonance assessment. Previous research has also revealed that nasalance values are influenced by vowel content. Thus, a look at acoustical theory and vowel production will follow. Stevens and House (1961) discussed the implications of vowel production regarding acoustical theory. They proposed that when vocal tract size changes, the resonance frequency also changes. For example, lengthening the vocal tract tends to lower the frequency (i.e., lengthen the pharyngeal cavity results in a lower F1, whereas lengthening the oral cavity will lower F2), while shortening the tract raises the frequencies of all resonances. Stevens and House (1961) established the range of intensity levels for the common vowels in American English to be roughly 4 to 5 dB, where /i, u/ exhibit the lowest and /ae, a, ɔ/ exhibit the highest intensity levels. The authors explained that the frequency of the first resonance is closely related to the size of the mouth opening and vowel intensity is determined largely by the frequency of the first vowel resonance, since the level of that resonance is always greater than that of higher resonances. The acoustical theory predicts that during the course of a CVC syllable, the over-all intensity builds to a maximum value in a central (vocalic) portion and then decreases due to the releasing and arresting qualities of the consonants surrounding the vowel. This prediction by Stevens and House (1961) is consistent with the findings of nasalance values being vowel dependent (Fletcher et al., 1989; Lewis et al., 2000; Mac-Kay & Kummer, 1994). MacKay and Kummer (1994) obtained nasalance values using short stimuli that were significantly influenced by vowel content. Normative data provided on the syllable repetition subtest of the SNAP Test revealed differences occurring only with respect to the vowels /i, a/. The nasalance values for all stimuli with the high front (HF) vowel /i/ were markedly higher than the stimuli using the low back (LB) vowel /a/. Lewis, Watterson, and Quint (2000) studied the influence individual vowels have on nasalance by comparing the values for nine different speech stimuli with vowel content controlled using 19 children with velopharyngeal disorder (VPD) and 19 normal children. The nine speech stimuli included four vowels /i, u, ae, a/ sustained in isolation and five sentences. Four of the five sentences were loaded with high front (HF) /i/, high back (HB) /u/, low front (LF) /ae/, or low back (LB) /a/ vowels, and the fifth sentence contained a mixture of vowel types. For the non-VPD group, the mean nasalance value for the sustained vowel productions were highest on the HF vowel /i/ and were the same for /u, ae, a/. Analysis of variance (ANOVA) procedures revealed significant differences across nasalance values for sustained vowels, where /i/ was significantly higher than any other vowel, /u/ was significantly higher than either of the low vowels /ae/ or /a/, and there was no significant difference between /ae, a/ for both groups (VPD and non-VPD). Therefore, Lewis et al. (2000) and MacKay and Kummer (1994) found consistent results in support of the view that nasalance scores using short stimuli were significantly influenced by vowel content.

Vowels and Duplicated Syllables

Lintz and Sherman (1961) investigated the influence of phonetic elements in relation to the perception of nasality using 20 adult male participants (ten nasal and ten nonnasal). The seven vowels /i, E, ae, ʌ, a, ʊ, u/ were produced in isolation and combined with each of the eight consonants /t, d, k, g, f, v, s, z/ to form 56 CVC syllables using the same consonant as onset and coda (i.e., to release and arrest the syllable). Thirty-five experienced listeners used a seven-point scale to calculate median scale values of nasality. Nasal and nonnasal groups followed a similar pattern of perceived nasality, with results differing more on CVC syllables than on sustained vowel production. Perceived nasality of the vowels in the consonant environments (i.e., voiced, voiceless, plosive, fricative, front, back placement in the oral cavity) varied with respect to height of tongue position and degree of VP closure, where the high vowels and back vowels were perceived to be less nasal than the low vowels and front vowels. The vowels from least to most perceived nasality were: /u, ʊ, ʌ, i, E, a, ae/; with /a/ always being judged as being more nasal regardless of syllable environment compared to all other vowels, except /ae/. The authors concluded that the degree of perceived nasality was influenced by acoustic characteristics, which varied with height of tongue position. As tongue height increased from /a, ae/ to /i, u/, velar elevation also increased (Kuehn & Moon, 1998), resulting in more precise closure for high versus low vowels. Overall, the trend for perceived amount of nasality during sustained vowel production decreased as tongue height increased. According to the authors, individual consonant environments (i.e., voicing, manner, and place) exerted different influences from vowel to vowel, where voicing produced the greatest effects on nasal perception. Vowels in voiced environments and fricative environments were found to be longer in duration, lower in fundamental frequency, and greater in intensity than vowels in voiceless or plosive environments. The perception of nasality increased when these acoustic correlates (i.e., longer duration, lower fundamental frequency, and higher intensity) accompanied the phonetic context. Results indicated that perception of nasality followed this progression from least to most: (1) voiceless plosive environments /p, t/, (2) voiceless fricative /s, f/ and voiced plosive environments /g, d/, and (3) voiced fricative environments /v, z/. Overall, tongue height and voicing were found to have the most significant influence on the perception of nasality (Lintz & Sherman, 1961).

Several explanations have been discussed in the research as to why nasalance values differ within and across speech categories such as: velar position, air pressure/air flow, acoustic and perceptual goals, and VP closure force (Kuehn & Moon, 1998; Lintz & Sherman, 1961; McKerns & Bzoch, 1970; Stevens & House, 1961; Zajac & Mayo, 1996). Kuehn and Moon (1998) studied the VP closure force and levator veli palatini activation levels in varying phonetic contexts for groups of male and female participants with normal VP mechanisms. The speech stimuli consisted of high, low, front, and back vowels / i, ae, u, a / produced in isolation and within voicing (fricatives /s, z/), place (alveolar /t/ versus palatal /k/ plosives), and manner (plosive /t/, fricative /s/, and nasal /n/) consonant environments. The results revealed that VP control for vowels involved VP positioning different from nasal and nonnasal obstruents. The amount of levator veli palatini activity, involved in velar elevation, varied for nasal and nonnasal consonants, and also within the class of nonnasal speech sounds for normal individuals. They suggested that closure force was adjusted to meet the momentary demands of the system determined in part by the phonetic context being produced, to avoid excessive nasal coupling. Previous research has shown that the velum continues its upward movement past the point at which velum-to-pharyngeal wall contact is made (Kuehn, 1976), reflecting the need to exert greater force of closure in certain contexts. Data concerning mean closure force for vowel production revealed that (a) high vowels induced greater closure force than low vowels (both sexes), (b) /u/ greater than /ae, a/ (both sexes), and (c) /i/ greater than /ae/ (males). These results suggested a relationship between the degree of VP closure force and velar height during vowel production. Because high vowels are produced with higher velar positions in comparison to low vowels, it is likely that the influence of tongue position on VP closure extends to adjacent speech sounds as well. When data were grouped across vowel categories, there were no differences found in VP closure force between voiceless and voiced consonants, for manner of production, or during nasal-nonnasal sequencing for either sex. As expected, closure force during /n/ was found to be significantly less than for /t, s/ for both sexes, indicating VP closure to be tighter for plosive and fricative consonants than nasal consonants. Previous velar position studies (Kuehn, 1976) have indicated that variations in place of production do not have a large effect on velar activity, and any such effects noted may be indirectly related to tongue position. The results of this study demonstrate the versatility of the normal VP mechanism in meeting the demands imposed by varying phonetic contexts (Kuehn & Moon, 1998).

The research for vowels and consonants reveal the following: (1) vowel intensity ranges from 4-5 dB with the low vowels /ae, a, ɔ/ being characterized by higher intensity than the high vowels /i, u/ (Stevens & House, 1961), (2) the high front (HF) vowel /i/ exhibited a higher nasalance value than the HB vowel /u/, the LF vowel /ae/, and the LB vowel /a/ during sustained vowel production, the HB vowel /u/ had a nasalance value greater than /ae, a/, and no significant differences were found between the LF and LB vowels /ae, a/; thus, nasalance values were vowel dependent when using short stimuli (Lewis et al., 2000), (3) the perception of nasality decreased as tongue height increased (Lintz & Sherman, 1961), vowels in descending order according to perceived nasality /u, ʊ, ʌ, i, E, a, ae/, and consonants in descending order according to perceived nasality were voiceless plosive, voiceless fricative, voiced plosive, and voiced fricative (i.e., /k, t, s, f, g, d, v, z/), and (4) mean closure force for vowels was higher for the high vowels than the low, with /u/ using the most and /ae/ using the least amount of mean closure force, no significant difference was observed during consonant production regarding manner, or place of production, nasals were found to use less velar closure force than nonnasal obstruents, and the significant influence on VP closure force was suggested to be tongue position and voicing (Kuehn & Moon, 1998).

Reading Passages

The three standard passages provided in the manufacturer's manual (Instruction Manual. Kay Elemetrics Corp., Pine Brook, NJ.), were created to assess resonance during connected speech tasks, with the amount and type of phoneme content controlled. The passages are as follows:

The Zoo Passage contains only oral consonants and was designed to assess the degree of hypernasality in a participant's speech and is as follows:

> Look at this book with us. It's a story about a zoo. That is where bears go. Today it's very cold out of doors, but we see a cloud overhead that's a pretty, white fluffy shape. We hear that straw covers the floor of cages to keep the chill away; yet a deer walks through the trees with her head high. They feed seeds to birds so they're able to fly (Fletcher, 1972).

The Rainbow Passage contains a mixture of oral and nasal consonants in the approximate proportion found in everyday speech containing 11.5% nasal consonants and 88.5% oral consonants, and is as follows:

> When the sunlight strikes raindrops in the air, they act like a prism and form a rainbow. The rainbow is a division of white light into many beautiful colors. These take the shape of a long round arch, with its path high above, and its two ends apparently beyond the horizon. There is, according to legend, a boiling pot of gold at one end. People look, but no one ever finds it. When a man looks for

something beyond his reach, his friends say he is looking for the pot of gold at the end of the rainbow (Fairbanks, 1960).

The Nasal Sentences contain 35% nasal consonants, which is three times greater than nasals frequency of occurrence in standard American English sentences. These sentences were designed to test for the presence of hyponasality in a participant’s speech. The sentences are as follows:

Mama made some lemon jam.

Ten men came in when Jane rang.

Dan’s gang changed my mind.

Ben can’t plan on a lengthy rain.

Amanda came from Bounding, Maine.

Pros/Cons of Using Vowels and Duplicated Syllables

It is believed that by creating a phoneme specific resonance evaluation one would be able to detect the influence each vowel and consonant in Standard American English have on nasalance values. By using this type of protocol a clinician is able to determine if the client exhibits phoneme-specific resonance distortions indicating, a learned articulatory behavior versus a true resonance disorder. This evaluation is also time-consuming and young children may not be compliant in completing the 33-speech task protocol (12 vowels, 20 CV syllables, and a reading passage). Thus, the purpose of the present study was to determine the significance of each speech task and/or redundancy within the protocol, with the goal of creating a more efficient and effective resonance evaluation.

LSU Protocol

The LSU Resonance protocol was described below indicating the phonetic nature of the speech tasks, what acoustic values were collected according to the speech tasks, and their expected nasalance values.

- **Vowels**: The client was instructed to sustain the vowels over a four second interval using a steady pitch. The vowels ordered from high to low, front to back were /i, I, e, Ɛ, ae, u, ʊ, o, ɔ, a, ʌ, ɝ/. The clinician was careful to begin and end data collection while the client was phonating to avoid capturing data while the client was in and out of physiological rest. The minimum, mean, and the maximum values were collected, with the mean values representing nasalance during sustained vowel production.
- **Approximants**: These phonemes were ordered from the least to most amount of mechanical stress they place on the VP mechanism /wʌ, jʌ, lʌ, rʌ /. The client was instructed to produce the approximants paired with the vowel /ʌ/ as reduplicated CV syllables with each phoneme over a four second interval using a steady and even rate of production. The clinician had the client produce the CV syllables at a moderate rate of three-four syllables per second and avoided a slower rate to prevent the VP mechanism from opening and closing between syllables (i.e., in and out of physiological rest). This was achieved by providing an appropriate model of speech rate for the client to follow. Minimum, mean, and maximum values were collected. The maximum values represented the

percentage of nasalance on the peaks, where the articulators were restricted and more nasal energy flowed through the nasal cavity during consonant production, thus, the maximum values were used to represent nasalance during consonant production.

- **Plosives**: Plosives demand a period of pseudo-silence where the articulators achieve closure and then are followed by a sharp noise burst upon release of production, plosives utilize increased intraoral pressures, and are produced using a short consonant duration (60-80 ms). Maximum flow of nasalance during plosive production was expected due to manner and duration of production. The client was instructed to produce the plosive paired with the vowel /ʌ/ as reduplicated CV syllables with each phoneme over a four second interval using a steady and even rate of production. The plosives were ordered from voiceless to voiced and front to back placement within the oral cavity, and were as follows: /pʌ, bʌ, tʌ, dʌ, kʌ, gʌ/. The minimum, mean, and maximum values were recorded, with the maximum values representing nasalance during consonant production.
- **Fricatives**: Sibilants have high frequency components from sustained airflow through narrow, constricted channels, which create a friction noise upon production. Fricatives are longer in duration (60-125 ms) compared to plosives (60-80 ms); therefore, lower nasalance values were expected during fricative production due to manner and duration of consonant production (compared to plosives). The client was instructed to produce the fricative paired with the vowel

/ʌ/ as reduplicated CV syllables with each phoneme over a four second interval using a steady and even rate of production. The phonemes progressed in order from voiceless to voiced and placed increasing amounts of mechanical stress on the VP mechanism and were as follows: /θʌ, ðʌ, fʌ, vʌ, sʌ, zʌ, ʃʌ, ʒʌ/. The minimum, mean, and maximum values were collected, with the maximum values representing nasalance during consonant production.

- **Affricates:** Affricates are sounds that combine the plosive and fricative manner of production into a one sound. These sounds obtain complete and then partial stricture and have the longest duration, giving the oral speech sound no acoustic flow, and then reduced acoustic flow, which places increased mechanical stress upon the VP mechanism. The client was instructed to produce the affricate paired with the vowel /ʌ/ as reduplicated CV syllables with each phoneme over a four second interval using a steady and even rate of production using the two speech sounds /ʧʌ, ʤʌ/. The minimum, mean, and maximum values were collected, with the maximum values representing nasalance during consonant production.
- **Phonetically Balanced:** Rainbow Passage: This passage was read by the client over a 40 second interval and represented the phonetic balance found in spontaneous speech according to the phoneme frequency of occurrence within Standard American English. The mean nasalance value collected was compared with normative data (Fletcher et al., 1989; Seaver, Dalston, Leeper, Adams, 1991).

- **Oral**: Zoo Passage: This passage was not used for data collection during this study, but can be used with the LSU protocol. Here the duration of the speech signal is increased and uses a variety of oral speech sounds over a longer duration. The display window needs to be changed to 40 seconds, while the client reads or repeats the passage. The passage includes no nasal consonants, but the extended utterances require the VP mechanism to alter velar height and position within the pharynx in regard to phonetic context. The mean value collected can be compared to the normative data (Fletcher et al., 1989; Seaver, Dalston, Leeper, Adams, 1991).
- **Nasal**: This passage was not used for data collection during this study, but an be used with the LSU protocol. The Jam Passage or Nasal Sentences can be read or repeated using a 40 second interval. These passages contain 35% nasal phonemes, which is three times greater than nasals' frequency of occurrence in Standard American English. These passages are used only when the clinician suspects the client to use hyponasal speech and the data can be compared to normative data (Fletcher et al., 1989; Seaver, Dalston, Leeper, Adams, 1991).

Purpose

It was the purpose of this study to collect nasalance values for normal adult speakers using a protocol created at the LSU Speech and Hearing Clinic for resonance assessment and the Nasometer 6200-2 model. The following questions were proposed for this project: (1) What are the normative resonance values for the individual speech tasks? (2) Are there gender differences in these values? (3) Which evaluation items are the best predictors of nasalance from the reading passage and spontaneous speech sample?

CHAPTER 3
METHODS

Participants

The participants consisted of 40 Caucasian normal young adult college students who spoke English as their native language. All participants were judged by the investigators to possess speech and hearing within normal limits and reportedly were free of upper respiratory infection. None of the participants had a history of craniofacial anomalies or velopharyngeal impairment. The 40 participants (20 males, 20 females) ranged in age from 18 to 29 years with a mean age of 21. The participants used in this study were all from Louisiana and Texas, and were judged to use a speech pattern characteristic of Southern dialect.

Instrumentation

The Kay Elemetrics Nasometer was used to measure resonance using a lightweight headset made up of a harness that holds a (oral/nasal) separation plate. The separation plate was fit firmly against the area between the nose and the upper lip and had two directional microphones mounted on either side of it, which collected the separated acoustic signals. The signals were transmitted to the computer database where they were calculated and analyzed by the Nasometer software. The resultant acoustic values were a ratio of nasal to nasal-plus-oral acoustic energy, which was multiplied by 100, and expressed as a “nasalance.” Prior to testing, the Nasometer was calibrated and disinfected in accordance with the procedures outlined in the instruction manual.

Stimuli

The stimuli consisted of sustained vowel productions, CV reduplications, and connected speech. Sustained vowel productions included high – low and front – back vowels: /i, I, e, Ɛ, ae, u, ʊ, o, ɔ, a, ʌ, ɝ/. Consonant vowel (CV) reduplications included approximants /w, j, r, l/, plosives /p, b, t, d, k, g/, fricatives /ɵ, ð, f, v, s, z, ʃ, ʒ/, and affricatives /ʧ, ʤ / paired with the vowel /ʌ/. By holding the vowel constant, the influence of each consonant on nasalance values was determined. The Rainbow Passage was used to collect nasalance values during connected speech.

Procedure

All participants were required to engage in spontaneous conversation with the investigator about their chosen major and future career plans. The conversation was recorded using a SONY micro cassette-recorder (M-P4) with SONY 60-minute microcasette tapes. Next, the participants' hearing was screened from 250-4000 Hz using a portable audiometer. In order for hearing to be considered normal each frequency was responded to at 25 dB in both ears. If speech and hearing was judged to be within normal limits the Nasometer headset was placed and fitted onto the participant and the resonance protocol was completed.

Each participant was given instructions and examples of how to perform the tasks appropriately in regard to vowel production, CV reduplication, and respiration control. A live clinician-produced model was given before each task for participant imitation of loudness level, production rate, and phonetic content. Each participant was then instructed to produce the speech tasks (sustained vowel or CV reduplication) on the LSU resonance protocol, which were randomized to ensure reliable client performance and resulting data collection. Following the individual speech productions, each participant was instructed to read the phonetically balanced Rainbow Passage silently and then a second time aloud.

Data Analysis

Each speech task was recorded while the participant was phonating to avoid skewed data collection during physiologic rest. The data were analyzed using the Nasometer software and subsequently the minimum, mean, and maximum values were recorded for all speech stimuli. The mean values represented the amount of nasalance produced during sustained vowel production and the Rainbow Passage. The maximum values represented the percentage of nasalance during peak consonant production. To answer the first question regarding potential differences among the speech samples, average values calculated for all of the participants for each of the speaking tasks were compared. The second question regarding potential gender differences was addressed by comparing the group means for male and female participants on each task using t-statistics. The third question regarding the relationships between the individual speaking tasks was evaluated by calculating correlation coefficients (R) between the individual test items and the reading values and by using step-wise regression to find the individual speaking tasks that best predicted reading.

CHAPTER 4
RESULTS

Nasalance Values for Individual Tasks

Table 1 displays the means and standard deviations of nasalance for each of the tasks. Among the vowels, the values are ordered from highest to lowest as /i, ae, e, a, E, I, ɔ, ɝ, ʌ, ʊ, u, o/. This rank ordering includes all of the front vowels among the top 50% of the distribution and all of the mid and back vowels, with the exception of /a/, in the bottom 50%. The probability of the front vowels occurring this often in this position compared to the mid and back vowels is less than .05 (Mann-Whitney U = 2). Thus, there appears to be a strong effect of tongue horizontal position on the nasalance of vowels. Back vowels may have lower nasalance values because some of the muscles that pull the body of the tongue back also pull the velum down securing a tight closure between the two structures. To keep the velum from lowering during vowel production, the muscles that elevate the velum may be more active during back vowel production than front vowel production to counteract the downward force of the muscles pulling the tongue back.

Vowel height may contribute to nasalance, at least among the front vowels, as the HF vowel /i/ was produced with the highest nasalance. However, this was not a strong effect inasmuch as the front vowel with the second highest value was the LF vowel /ae/ and the back vowel with the highest nasalance was LB vowel /a/.

Table 1: Nasalance Values for Sustained Vowel Production averaged across all participants

Stimulus Vowel	Mean of the mean	Standard Deviation
i	20.61	14.09
I	11.32	11.98
e	14.74	11.58
E	12.01	10.92
ae	17.30	11.78
u	8.24	6.08
ʊ	8.55	8.94
o	5.66	5.38
ɔ	10.11	10.15
a	12.83	11.24
ʌ	8.77	8.92
ɝ	9.05	9.67

Analysis of the consonant values revealed the following rank ordering from highest to lowest nasalance: /ʤ, g, d, ð, j, b, ʧ, z, v, t, ʒ, k, l, p, r, s, ɵ, ʃ, f, w/. The six highest values were associated with voiced consonants. A comparison of voiced versus voiceless consonants revealed that this difference was statistically significant (Mann-Whitney $U = 15$, $p < .05$). Voiced consonants may have higher nasalance because of the necessity to maintain a pressure drop across the glottis to maintain voicing. This pressure drop could be accomplished by allowing air pressure from the oropharynx to leak into the nasal cavities, thus keeping the pressure above the glottis lower than the pressure below the glottis.

The orders within the voiced /ʤ, g, d, ð, j, b, z, v, ʒ, l, r, w/ and voiceless /ʧ, t, k, p, s, ɵ, ʃ, f/ categories, appeared to show a difference with noncontinuant sounds having higher values than continuants. This difference was statistically significant for both voiced (Mann Whitney U = 2, $p < .05$) and voiceless (Mann Whitney U = 0, $p < .05$) consonants. The higher nasalance values of the noncontinuant sounds may result from the rapid elevation of oral air pressure behind the complete constriction of the vocal tract causing a leakage of sound into the nasal cavities.

Table 2: Nasalance Values for CV Reduplication averaged across all participants

Stimulus Consonants	Mean of the max	Standard Deviation
wʌ	15.20	11.20
jʌ	33.13	22.37
lʌ	20.09	14.62
rʌ	18.75	13.52
pʌ	19.06	8.08
bʌ	30.45	20.89
tʌ	26.30	15.34
dʌ	40.52	23.94
kʌ	23.87	15.13
gʌ	41.64	24.39
θʌ	17.43	14.56
ðʌ	34.95	22.97
fʌ	16.07	17.10
vʌ	26.84	18.47
sʌ	17.66	12.49
zʌ	29.26	18.62
ʃʌ	16.68	14.32
ʒʌ	24.26	11.39
ʧʌ	30.01	18.13
ʤʌ	44.19	24.86

The group mean nasalance value for the Rainbow Passage was 29.99%, with a standard deviation of 6.31%. This result is lower than those reported in the literature (Seaver et al., 1991).

Table 3: Mean Nasalance Value for the Rainbow Passage averaged across all participants

Stimulus	Mean	Standard Deviation
Rainbow Passage	29.99	6.23

Table 4: Mean of the Maximum Nasalance Value for the Rainbow Passage averaged across all participants

Stimulus	Mean of the Max	Standard Deviation
Rainbow Passage	95.21	2.06

Nasalance Values According to Gender

Table 5 displays the mean nasalance values and standard deviations for each speech task for the separate genders. A statistical comparison of the genders for the Rainbow Passage revealed no difference with the males averaging a mean nasalance value of 30.26 (s.d. = 6.31) and females averaging 29.72 (s.d. = 6.31). A statistical comparison of the genders for the Rainbow Passage using the mean of the maximum values, revealed no difference with males averaging a nasalance value of 95.13 (s.d. = 2.53) and females averaging a nasalance value of 95.28 (s.d. = 1.57). The two groups did not differ significantly (t = .222, degrees of freedom = 38, p >.05). Among the other tasks, the males were higher on 26 speech tasks, including 12 vowels and 19 consonants. Females achieved higher nasalance values on five /I, u, ʊ, o, ɝ/of the 12 vowels and one

/ʧ/ of the 20 consonant productions. However, analysis via t-statistic with a Bonferroni correction for the number of comparisons made revealed that none of these differences were statistically reliable.

Table 5: Nasalance Values associated with each task produced by gender

Stimulus	Male		Female		t	Significance
	Mean	SD	Mean	SD		
i	21.59	11.22	19.64	16.72	-.432	.334
I	10.12	10.35	12.53	13.57	.632	.266
e	15.07	11.04	14.41	12.37	-.179	.430
ɛ	13.56	12.27	10.46	9.44	-.897	.188
ae	19.94	11.42	14.66	11.82	-1.436	.080
u	8.13	4.78	8.36	7.29	.117	.454
ʊ	8.11	9.09	9.00	8.99	.309	.0380
o	5.31	4.02	6.01	6.55	.406	.344
ɔ	12.23	11.90	7.98	7.76	-1.340	.094
a	14.37	12.52	11.30	9.88	-.862	.197
ʌ	9.40	9.16	8.14	8.86	-.442	.331
ɝ	8.36	8.20	9.73	11.12	.443	.330
wʌ	16.22	10.45	14.18	12.09	-.571	.286
jʌ	35.59	20.16	30.67	24.67	-.691	.247
lʌ	23.31	14.94	16.86	13.91	-1.413	.083
rʌ	19.63	12.20	17.88	14.99	-.404	.334
pʌ	20.27	8.56	17.84	7.59	-.950	.174
bʌ	33.53	22.04	27.37	19.75	-.930	.179
tʌ	29.48	18.36	23.12	11.15	-1.323	.097
dʌ	47.43	25.73	33.61	20.33	-1.885	.034
kʌ	27.24	18.77	20.49	9.66	-1.429	.081
gʌ	46.28	25.66	36.99	22.74	-1.212	.117
θʌ	18.55	8.66	16.31	18.90	-.481	.317
ðʌ	40.99	25.44	28.90	18.94	-1.704	.048
fʌ	21.06	21.96	11.08	8.10	-1.907	.032
vʌ	30.67	22.65	23.02	12.50	-1.322	.097
sʌ	19.57	15.08	15.74	9.22	-.967	.170
zʌ	29.49	21.07	29.03	16.35	-.077	.470
ʃʌ	17.47	11.67	15.88	16.84	-.347	.366
ʒʌ	26.12	11.63	22.39	11.11	-1.036	.154
ʧʌ	27.14	11.59	32.88	22.86	1.002	.162

Table Continued

dʒʌ	50.51	27.76	37.86	20.35	-1.643	.055
Rainbow Passage Mean	30.26	6.31	29.72	6.31	-.273	.394
Rainbow Passage Max	95.13	2.53	95.28	1.57	.222	.825

Prediction of Connected Speech Values from the Speech Tasks

Pearson correlation coefficients were calculated to investigate the relationships between the individual speech tasks and the reading passage. Table 3 contains the correlations found for these variables. All 33 speech tasks were significantly related to the connected speech task with a range from r =.353 for /E/ to .745 for /u/.

Table 6: Correlation of each Sustained Vowel Production with the Rainbow Passage

Stimulus Vowel	Correlation	Significance
i	.715	.0001
I	.419	.004
e	.431	.003
E	.353	.013
ae	.471	.001
u	.745	.0001
ʊ	.420	.003
o	.407	.005
ɔ	.323	.021
a	.578	.0001
ʌ	.376	.008
ɝ	.429	.003

Table 7: Correlation of each CV Reduplication with the Rainbow Passage

Stimulus Consonant	Correlation	Significance
wʌ	.578	.0001
jʌ	.483	.001
lʌ	.424	.003
rʌ	.474	.001
pʌ	.547	.0001
bʌ	.577	.0001
tʌ	.408	.004
dʌ	.661	.0001
kʌ	.731	.0001

Table Continued

gʌ	.689	.0001
θʌ	.442	.002
ðʌ	.565	.0001
fʌ	.586	.0001
vʌ	.555	.0001
sʌ	.424	.003
zʌ	.605	.0001
ʃʌ	.530	.0001
ʒʌ	.459	.001
ʧʌ	.436	.002
ʤʌ	.597	.0001

Step-wise regression analysis with forward inclusion was used to determine the best predictors of nasalance in the Rainbow Passage from among the individual speech tasks. Three of the speech tasks added significantly to the prediction of the connected speech values. The strongest predictor was the high back vowel /u/, followed by the velar stops, /k/ and /g/. The r of .84 indicated that these variables accounted for 71.5% of nasalance in the Rainbow Passage.

The regression equation used to predict the passage values was:

Passage nasalance = 20.685 + 0.426 /u/ value + 0.130 /k/ value + 0.0654 /g/ value.

The high-back vowel /u/ was found to have the highest correlation with the reading passage. The vowel /u/ may have had the strongest predictive value because it is a vowel and most of the passage reading time would contain vowels. The measurement used for the individual vowels and the passage was the mean nasalance value, rather than the maximum value used for the consonant items. As seen above, the vowel /u/ had the second lowest nasalance, indicating that it may be a good indicator of the ability to produce reduced nasalance on vowels. Once the strong predictive ability of /u/ values was removed from the prediction, the next two most predictive tasks involved velar stops.

CHAPTER 5
DISCUSSION

Nasalance Values

Vowel

Nasalance values for sustained vowel production revealed a pattern where front vowels produced higher values than back vowels, with the HF vowel /i/ producing the highest nasalance value and the HB vowel /u/ producing the lowest. During data collection the participants produced two vowels /e and o/ as dipthongs /ei and ou/, which resulted in a nasalance value representative of two transitioned vowel productions during one sustained vowel task. For the sake of comparing nasalance values, the dipthongs were not compared to the monothong vowels. A vowel from each position (i.e., HF, LF, HB, LB) was chosen to represent the hierarchy of nasalance values from high to low, and were as follows: /i/ (20.62%), /ae/ (17.30%), /a/ (12.84%), and /u/ (8.25%). These results correlated with the findings by Lintz and Sherman (1961) who found that the perception of nasality increased as tongue height decreased during sustained vowel production (i.e., low vowels were perceived as more nasal than high vowels for normal speakers). From the results of this study and those from Lintz and Sherman (1961) it was speculated that tongue height was a major influence on the amount of VP closure affecting nasalance values and the perception of nasality.

The results obtained in this study differ with previous research by Lewis et al. (2000) and MacKay and Kummer (1994), that found the high vowels /i, u/ obtained higher nasalance values than the low vowels /ae, a/ during sustained vowel production. Reasons for these differences may lie in the participant sample. The participant sample in both studies consisted of children, whereas the 40 participants used in this study were between 18 and 29 years of age.

From the results in this study it was speculated that tongue position had the greatest influence on nasalance values during sustained vowel production. If the tongue was in an elevated and retracted position, as was on the HB vowel /u/, the velum achieved increased velar elevation and tighter VP closure, resulting in lower nasalance values for the normal speaker. The palatoglossus muscle, which is involved in tongue and velar functions, is active in achieving a front tongue position and at the same time pulls downward on the velum. This would result in less velar elevation, loose VP closure, and in turn higher nasalance values. Previous research has demonstrated that tongue height during vowel production significantly influenced nasalance, and the results from this study were in agreement with that statement (MacKay & Kummer, 1994; Kuehn & Moon, 1998; Lintz & Sherman, 1961).

Consonants

The normative values for oral consonant production revealed that voiced consonants obtained higher nasalance values than voiceless, with manner and place of production not having a significant influence on nasalance values; however affricates and plosives consistently achieved greater nasalance values compared to fricative and approxiamants in both voiced and voiceless categories. These results support the research of Kuehn and Moon (1998) and Kuehn (1976) that found closure force was not significantly different across nonnasal obstruents. Speculations regarding why tongue position was not as influential during CV production may be due to other acoustic and physiologic properties associated with their phonetic content such as intraoral air pressure, manner of production, duration, and/or intensity of consonant production.

Gender

Nasalance values according to gender did not reveal significant differences during sustained vowel production or the Rainbow Passage. The mean and standard deviation of the sustained vowel productions revealed a pattern where females achieved greater nasalance on high vowels including the HF vowel /i/, all three HB vowels /u, ʊ, o/, and the high center vowel /ɝ/. McKerns and Bzoch (1970) found that females had a shorter velum, used a multidirectional "right angle" pattern of velar closure within the pharynx, and achieved less velar height over longer durations. High vowels have been shown to utilize increased velar elevation and tighter VP closure. Therefore, females should exhibit higher nasalance values during high vowel production due to the increased time it takes females to achieve loose VP closure in comparison to males (Kuehn & Moon, 1998). No significant gender differences were found among the consonant productions, possibly due to the speech tasks consisting of oral consonant productions paired with the neutral vowel /ʌ/. Previous research on sustained vowel production by Lewis et al. (2000) and MacKay and Kummer (1994) did not separate their data according to gender; thus, comparisons between studies cannot be made.

Using two-way Analysis of Variance (ANOVA) the results revealed significant gender differences on /d, f, ð/, with males producing significantly higher nasalance values than the females. Reasons for this occurrence are not clear because while these phonemes are all produced in the front of the oral cavity, manner and voicing differ among the phonemes, /d, ð/ exhibited nasalance values in the top 25% and /f/ in the bottom 25%. Therefore, it was speculated that the significant differences found between these phonemes were random occurrences. Also, no literature was found that investigated CV production using individual consonants paired with a neutral vowel to compare results.

Seaver et al. (1991) used the Rainbow Passage and found group mean nasalance values according to gender for males to be 35% (s.d. = 6) and for females to be 36% (s.d. = 6). When the resonance values were separated by dialect Seaver et al. (1991) found that males speaking a Southern dialect obtained a mean nasalance value of 32% (s.d. = 4) and females obtained a mean nasalance value of 34% (s.d. = 7) on the Rainbow Passage. The results obtained in this study used participants from Louisiana and Texas who were all subjectively judged to use a Southern dialect. Males produced 30.26% (s.d. = 6.31) nasalance and females produced 29.72% (s.d. = 6.31) nasalance for the Rainbow Passage. The nasalance results obtained in this study are lower than those previously found, but fall within the range found by Seaver et al. (1991).

Correlation

Three phonemes were found to correlate most with the Rainbow Passage and predicted 71.5% of nasalance in connected speech. The HB vowel /u/ was found to have the highest correlation with the reading passage. Several reasons are discussed such as: (1) the value used for both vowel production and the passage was the mean of the mean, (*remember the mean of the max was used for consonant production) and (2) previous research has shown that HB vowels are produced with higher velar positions and increased closure force mainly due to the tongue utilizing an elevated and retracted position (Kuehn & Moon, 1998; Lintz & Sherman, 1961). The next best predictor of nasalance from the individual speech tasks was the voiceless, velar plosive /k/. Normal production of /k/ involves tongue elevation and retraction making complete contact with the velum before releasing the plosive. Previous research has shown that intraoral air pressure is greater for voiceless and plosive consonants because the articulators achieve complete stricture before releasing the phoneme. It is speculated that due to the velar place of production and increased intraoral pressure, an increased closure force was utilized (Kuehn & Moon, 1998). The 3rd best predictor was /g/, the voiced cognate of /k/. It was speculated that /g/ was the next best predictor for reasons similar to /k/, (i.e., tongue and velar contact make complete closure and increased intraoral air pressures). Overall, it appears that these 3 phonemes had the highest correlation with the Rainbow Passage for a variety of reasons, primarily due to tongue position (i.e., elevated and retracted) within the oral cavity upon production of /u, k, g/. This being the case, one could predict nasalance based upon the physiologic principles involved in the phonetic context of these phonemes (tongue position being retracted and elevated, achieving complete stricture between the back of the tongue and the velum, plosives using the shortest duration, and increased intraoral pressures). If anatomical or physiological problems existed in the individual being tested, due to the physical properties involved in the production of these three phonemes, the nasalance values would evidence abnormal resonance in conjunction with a trained clinical judgment. Therefore, these phonemes were found to be the best predictors of nasalance for the phonetically balanced Rainbow Passage.

Conclusion

The paper presented answered the questions proposed: (i.e., normative resonance values for the speech tasks in the protocol for each gender and which evaluation items were the best predictors of nasalance from the reading passages and spontaneous speech sample), where the results revealed no statistically significant gender difference across speech tasks, the three best nasalance predictors (i.e., /u, k, g/), and tongue position and voicing were significantly influential on nasalance values. The purpose of the paper was to determine the significance and/or redundancy within the protocol and create a modified resonance evaluation, which the study did not adequately provide. The results found in this study did not conclude significant data for simplifying the LSU protocol. The four cardinal vowels /i, ae, a, u/ and a consonant with the lowest nasalance value from each consonant category could be used to create a modified protocol. Future studies should test this new protocol.

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