ABSTRACT

Title of Document: NASOMETRIC ASSESSMENT OF SPANISH/ENGLISH BILINGUAL SPEAKERS

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The purpose of this study was to examine the effect of native language on speech tasks requiring velopharyngeal closure, particularly the standardized Nasometric assessment of voice resonance. Comparison of ten native-English-speaking adults (N) and ten bilingual Spanish/English speakers (B) indicates that native language did not significantly influence standardized assessment scores, although the effect of gender remains ambiguous, with female participants generally producing higher nasalance scores. Within-subject comparison of the bilingual speakers' individual scores on the English and Spanish stimuli indicated significant differences in the scores obtained on the nasal sentence sets and the oro-nasal paragraphs. Highly fluent bilingual English/Spanish speakers, like the participants of this study, can be accurately assessed using the standardized English nasometry passages. Nevertheless, future researchers and diagnosticians investigating velopharyngeal movement and voice resonance should be aware of the possible gender effect and its potential interaction with native language.

NASOMETRIC ASSESSMENT OF BILINGUAL SPANISH/ENGLISH SPEAKERS

By

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List of Abbreviations

ANOVA = analysis of variance

B = bilingual Spanish/English group

EMG = electromyography

ES = English Nasal Sentences

N= monolingual English group

NL = native language (as an ANOVA factor)

NN = nasal paragraph (Rainbow Passage, La Oveja)

NO = non-nasal paragraph (Zoo Passage, Texto El Bosque)

SS = Spanish nasal sentences (Oraciones Nasales)

VPD = velopharyngeal dysfunction

Introduction

Anatomy of Speech & Resonance

Sound production for speech integrates several different anatomical systems, including those needed for respiration, phonation, and resonance. It is a learned process that demands significant coordination, particularly because the same structures are also dedicated to additional, life-sustaining processes such as breathing and swallowing. Vocal onset is initiated when sustained respiratory exhalation is paired with the vibration of the laryngeal structures. This sound source is further modified by the filtering effects of the vocal tract. Much of what makes individual voices sound distinctive is due to the pharynx, oral cavity, and nasal cavity, which filter and shape the acoustic energy of phonation. The resonating tract shaped by these structures amplifies or suppresses the fundamental frequency and its selected harmonics, creating the complex acoustic patterns perceived as speech sounds.

The oral cavity, or mouth, is an important part of the resonating tract because it contains major articulators including the lips, tongue, soft palate, teeth, and alveolar ridge. The oral cavity is coupled with the nasal cavity via the velopharyngeal port surrounded by the velum in the front and pharyngeal walls on both sides and in the back. A sphincter-like action of the velar and pharyngeal muscles pulls the velum up and back to close the velopharyngeal port and separate the oral and nasal cavities.

Successful velopharyngeal closure involves both the velum and the lateral and posterior pharyngeal walls (Poppelreuter et al., 2000). Simulations by Bell-Berti et al. (1984) attempted to separate the effects of palatal lowering and those of nasal resonance using an articulatory synthesizer. Lowering the velum without incorporating any nasal resonance primarily affected the F_2 and F_3 frequencies. Creating nasal resonance without lowering the velum altered F_1. Overall, opening the velopharyngeal port had a greater acoustic effect than did lowering the velum, but both components contributed to the perceptual effect (Bell-Berti et al., 1984).

When raised, the velum moves upward and backward to help close the velopharyngeal port between the oral and nasal cavities. Depending on the sound being produced, velum height may vary slightly while keeping the velopharyngeal port closed (Karnell, Linville, & Edwards, 1988). When this closure is complete, air is restricted to the oral cavity and sound is muffled by the palate (Gildersleeve & Dalston, 2001). Efficient and intelligible production of high-pressure consonants requires such velopharyngeal closure to build up sufficient intraoral pressure. Velopharyngeal closure, which precedes the onset of phonation, is maintained until the speaker produces a nasal consonant or a vowel adjacent to a nasal consonant, or stops speaking entirely (Shelton et al., 1964). When closure is incomplete, however, air and sound can pass through the nasal cavity, which then acts as an additional resonating chamber. The production of nasal sounds—in English, /m/, /n/, and /ŋ/—requires this additional resonance.

The bulk of the velum consists of the levator veli palatini muscle, which arises from the temporal bone and the medial Eustachian tube cartilage. It is the primary muscle of velar elevation. The dorsomedial portions of the soft palate contain the musculus uvulae. The paired musculus uvulae course the length of the soft palate on both sides of the midline and insert into the mucosa covering the velum. They shorten the soft palate and form a prominence on the nasal side of the velum, which may help with the contact between the velum and the posterior pharyngeal wall during velopharyngeal closure. The palatoglossus and palatopharyngeus muscles depress the velum and assist in fine control of velar height.

The levator veli palatini, may be capable of achieving velopharyngeal closure by moving the velum up and back, even without the assistance of other muscles (Dickson & Dickson, 1972). Achieving a specific velar position, however, probably requires a balance between the levator lifting the palate and the palatoglossus or palatopharyngeus depressing it (Kuehn et al., 1982). Having noted that the palatoglossus involvement for speakers of Hindi was somewhat different from that reported for speakers of French, Dixit et al. (1987) concluded that the contribution of various muscles for velopharyngeal closure may be speaker, or even language, specific.

Instrumental Assessment of Velopharyngeal Function

The clinical standards for instrumental examination of velopharyngeal function are videofluoroscopy and videoendoscopy in real time (Poppelreuter et al., 2000). Magnetic resonance imaging (MRI) and computer tomography (CT) technology are also used for velopharyngeal imaging, although only in a static context since neither technology can capture sufficient data quickly enough to portray velopharyngeal movement (Poppelreuter et al., 2000, p. 158). All of these methods allow the clinician to directly view the velopharyngeal mechanism. However, they all require expensive equipment, careful training, and have various technology-specific limitations. MRIs, for instance, cannot be done on patients with implanted metal devices such as pacemakers or dental braces. In addition, some of these assessments are invasive. Patients undergoing videoendoscopy may require anesthesia in order to tolerate the procedure. Videofluoroscopy involves radiation exposure. Therefore, a non-invasive and less expensive assessment to quantify nasality is more convenient and practical in a speech-language pathologist's practice.

One such assessment is acoustic analysis. Equipment for such analysis includes the Nasometer, which will be discussed in greater detail later, and the more recent NasalView (Tiger Electronics, Inc., Seattle, WA) and OroNasal System (Glottal Enterprises Inc., Syracuse, NY). These instruments examine velopharyngeal function indirectly, by calculating the nasal sound energy relative to the total sound energy. This requires recording the oral and nasal acoustic signals separately, adding them to generate a total sound energy, and dividing the nasal sound energy by this combined sound energy to yield an average ratio known as the nasalance score. The score is then compared to norms. Thus, a clinician using these systems is measuring a symptom of velopharyngeal dysfunction (VPD)—an excessively high proportion of nasal acoustic energy—rather than explicitly looking at velopharyngeal closure. However, these indirect measures are relatively non-invasive and require less training and less expensive equipment than the direct measures mentioned previously (Bressman, 2005). Additionally, nasalance equipment can provide immediate biofeedback. This makes it a popular choice for clinics and therapy programs.

Perceptual Assessment of Velopharyngeal Function

Perceptual, or subjective, measures of velopharyngeal function include rating scales for clients and clinicians; they are generally believed to be the most ecologically valid means of voice assessment because they reflect actual, real-time impact of symptoms on communication ability. Human listeners, for instance, can take into account the social appropriateness of nasality (Rammage et al., 2001, p. 22). Moreover, perceptual measures can be used in a variety of real-life situations and with numerous conversational partners.

While perceptual measurement is, "in the final analysis, the most telling evaluation possible," practical concerns limit its use in standardized assessment (Mathieson et al., 2001, p. 414). Currently, the lack of a consistent system for describing vocal resonance, as well as the fluctuating nature of some voice disorders, makes accurate perceptual classification difficult (Mathieson et al, 2001; Fletcher, 1976). Even if such a system were developed, it would likely require a great deal of training and experience to accurately and consistently rate speakers. Inter-rater reliability is a serious problem with perceptual measurement. Wynter and Martin (1981) spent five years unsuccessfully trying to train speech pathology students to identify dysphonic symptoms in a way that matched the classifications of more highly-trained speech pathologists. Listeners have to resist the influence of halo effects, created by secondary characteristics such as pitch or linguistic sophistication, that might impact their judgment (Fletcher, 1976, p. 606). At the same time, listeners also must judge independently of any bias created by familiarity with speakers, dialects, etc. (Pittam, 2001; Rammage et al., 2001, p. 22). Therefore, in order to accurately diagnose voice conditions and assess treatments, listeners must be trained and experienced, but not so accustomed to a particular speaker or disorder that they no longer notice individual variations. This is, understandably, a difficult balance to achieve in practice.

Thus, instrumentation provides more clearly defined data that remain consistent over time. Such data are less likely to be skewed by experience or exposure and can be used in the double-blind experimental design that is the gold standard for evidence-based practice. However, instrumental data must still be recorded and analyzed, so it is not completely accurate to label it ‘objective’. Also, the standardization that makes it possible to set norms and standard deviations may prevent some instrumental measures from reflecting everyday speech patterns. Some instrumental assessments are based chiefly on a single steady-state vowel. Many require the reading of passages that artificially include or juxtapose certain speech sounds. Consequently, critics complain that instrumental measures seem “to ‘represent only a fraction of the set of all measures used by the human listener’” (Mathieson, 2001, p. 414).

In terms of evidence-based practice, the advantages of perceptual and instrumental voice assessment parallel the statistical concepts of validity and reliability. Validity is the degree to which an assessment tool measures the skill in question, without being obscured by related or confounding skills. Perceptual assessments of resonance disorders are generally more valid than instrumental assessments because resonance disorders are defined perceptually. Therefore, while an instrument may be a valid tool for assessing the underlying anatomical cause of a resonance disorder, it is a less valid measure of clinical qualities such as voice quality or intelligibility. However, instrumental assessments are generally valued for their reliability, or their tendency to provide the same results over repeated administrations. Research cited by Keuning et al. (2002), for instance, indicates that perceptual judgments of hypernasality in cleft palate speech can be skewed by the judges’ experience, the phonetic context, and the type of speech sample. Instrumental assessments are unlikely to be affected by familiarity with the speaker, assessment experience, or topic of conversation.

Ideally, instrumental assessments quantify and support perceptual judgments, and some research has found this to be true. In a 1976 study, Fletcher compared nasality, the perceptual judgment of nasal energy, and nasalance, the instrumental measure of the same quality (1976). The instrumentation used was the TONAR II, a predecessor of the Nasometer. He found that the majority of listeners tended to agree with the instrumental assessment, eventually reaching a correlation of .91 for some recordings.

More recent studies comparing nasalance and nasality have produced more ambiguous results. Dalston et al. (1991a) found a correlation of only .65 when a single listener's judgments of 76 speakers were compared with the Nasometer's assessment. This improved to .87 when speakers with audible nasal emission were eliminated from the study; the authors hypothesized that the Nasometer detected nasal emission, producing elevated nasalance scores. Using a cutoff score of 50, the authors determined that 90% of nasalance scores accurately matched clinical judgments of hyponasality. In a similar study, a comparison the Nasometer's assessment of hypernasality with that of a single trained listener yielded a correlation of .82 (Dalston et al., 1991b). Hardin et al. (1992) cited a 1991 study by Paynter et al. comparing Nasometer scores to the judgment of a panel of listeners. Across three reading passages, there was moderate agreement between mean nasality ratings and the nasalance scores: .66 for the Nasal Sentence and the Zoo Passage, and .63 for the oro-nasal Rainbow Passage. However, Hardin et al. (1992) noted that when nasalance scores were compared to listener judgments of normal hypernasality for the Zoo Passage, the specificity was .60 and sensitivity was .78. Thus, only 60% of speakers whom listeners judged to be hypernasal were identified as such by their nasalance scores. Only 78% of those with normal resonance were correctly identified by the Nasometer. Hardin et al. (1992) found high agreement—91%—when the scores of 45 subjects (23 typically-developing children and adults and 22 children and adults with cleft palates) were calculated without including data from patients whose clefts had been repaired with a pharyngeal flap.

Nasometer: resonance and timing assessment

One of the instruments most frequently used in the assessment of speech resonance disorders is the Nasometer (KayPentax, Lincoln Park, NJ). This micro-computer device separates, records, and analyzes oral and nasal acoustic energy during speech tasks. During administration of a speech task, the subject wears a headset that includes two microphones with a separator plate between them (see Figure 1). The plate rests against the subject's upper lip, so that oral energy output is recorded by one microphone and nasal energy output is recorded by the other. The analog acoustic signals are filtered and converted into the ratio score called nasalance. The nasalance score is calculated by dividing the total nasal energy output by the combined oral and nasal output, thus determining how much of the total acoustic energy includes nasal resonance. The original Nasometer, introduced in 1986, used analog circuitry; the most recent version, the Nasometer II-Model 6400, converts the analog to a digital signal before computing nasalance (Bae et al., 2007).

A speaker's nasalance score is usually determined by having him/her read standardized American English passages aloud. These include the Zoo Passage, which contains only oral sounds, and the Rainbow Passage, a mixed paragraph which contains both oral and nasal sounds. 11.5% of the sounds in the Rainbow Passage are nasal, which approximates the percentage of nasal sounds found in conversational English (Kay

Elemetrics Corp., 2003; Dalston & Seaver, 1992). The value of a purely oral paragraph has been debated, since a completely non-nasal sample does not provide the opportunity for the rapid velopharyngeal movements required in conversational speech. In addition to the paragraphs, there is a five-sentence set that contains a heavy proportion of nasal sounds. 35% of these Nasal Sentence phonemes are nasal consonants, over three times as many as in most American English sentences (Kay Elemetrics Corp., 2003). For illiterate, non-compliant, or very young subjects, data can be elicited using the Simplified Nasometric Assessment Procedures (The MacKay-Kummer SNAP Test) that uses pictures and syllable repetition (MacKay & Kummer, 1994).

Although the reading passages are standardized, the question of how much leeway a clinician is allowed with regard to the published norms is hotly debated in the professional literature. Even Kay Elemetrics (2003), in its Nasometer operations manual, advised that “there are no rules engraved in stone governing when a patient’s nasometric assessment results should be considered abnormal” (p. 60). Since nasalance is determined by dividing nasal acoustic energy by the sum of nasal and oral energy—creating a ratio of nasalized to total energy—the nasalance score of a typical speaker would increase with the proportion of nasalized phonemes in a given passage. Speakers who are perceived as hypernasal should, in theory, have higher nasalance scores than typical speakers because a higher percentage of their speech is nasalized (Dalston et al., 1991a). Dalston et al. (1993) used the nasometer and a cross-sectional velopharyngeal analysis as well as perceptual assessment to determine the specificity and sensitivity of the device with various cut-off values. With a cut-off value of 32, the Nasometer’s sensitivity—the ability to accurately detect people with VPD—was 78. Its specificity—

the ability to identify people without VPD as having normal resonance—was 79. Its sensitivity and specificity with regards to hypernasality was 89 and 95, respectively. Dalston and colleagues concluded that “the Nasometer can be used with considerable confidence in corroborating clinical impressions of hypernasality” in patients with orofacial clefts (1991, p. 187). The validity ratings for VPD, although lower than those for hypernasality, nevertheless “suggest a relative strength of association between a test and the condition for which it being employed” (Dalston et al., 1991, p. 187).

Factors Affecting Nasometry Scores: Gender and Age

Numerous studies have obtained Nasometer-determined nasalance scores for speakers perceived as having normal resonance, although results have been ambiguous at times (see Table 1). Gender appears to influence nasalance scores in some studies. Seaver et al. (1991) found women had significantly higher nasalance scores than men when reading nasal

sentences. Leeper et al. (1991) confirmed these results in a study with 1751 participants, women had significantly higher nasalance scores when reading nasal sentences and the Rainbow Passage. However, Litzaw & Dalston (1992) and Kavanaugh et al. (1994) found no gender difference in nasalance scores.

Mayo et al. (1996) noted a gender difference, but only when American-English speaking participants were also of different races. They were careful to limit their participants to those who spoke with a mid-Atlantic dialect of American English, since the dialect of native English-speakers has been shown to affect nasalance score. Even so, they found that their twenty white male participants had higher Zoo Passage scores than their twenty African-American male participants. Moreover, when reading nasal sentences, Caucasian participants had higher nasalance scores than African-American participants, regardless of gender. This is in keeping with earlier research that indicated listener's perceive Caucasian speakers as sounding more nasal than African-Americans (Walton & Orlinkoff, 1994). Mayo et al. (1996) felt that any racial difference would be too insignificant to justify separate norms for different races. Nevertheless, they advised taking into consideration the cultural-linguistic background of clients, suspecting that the higher nasalance scores of Caucasian participants was due to culturally-determined nasality threshold.

Table 1

Summary of English Nasometry Research: Gender, Age, and Dialect Differences

Studies	N	Participants	Results regarding age and gender
Seaver, et al., 1991	148	US Adult	Female participants have significantly higher nasal sentence scores
Litzaw & Dalston, 1992	30	US Adult	No gender difference
Leaper et al., 1992	1751	Canadian Adult	Female participants have significantly higher nasal sentence and Rainbow Passage scores
Kavanaugh et al., 1994	52	Canadian Adult	No gender difference
Mayo, 1996	80	US Adult	No significant gender difference for nasal sentences or Zoo Passage; racial differences noted between Caucasian and African-American participants
Van Doorn & Purcell, 1998	245	Australian children (4-9 years)	No age or gender difference
Sweeney, et al. 2003	80	Irish children (4:11-13 years)	No gender difference

The potential influence of dialect on nasalance score has also been investigated. Van Doorn and Purcell (1998) recorded the nasalance score of 245 typically developing

Australian children, ages 4 to 9. They found that their mean nasalance score for the Zoo Passage and nasal sentences were about two points lower than those obtained by Fletcher et al. (1989) for American children and slightly higher than the scores obtained by Leeper et al. (cited in Tachimura et al., 2000) on a group of typically developing children from Canada. They suggested that these differences resulted from a dialectical difference in nasality that exists even among children whose native language is English.

Operating strictly on the statistical definition of ‘normal,’ Van Doorn and Purcell (1998) found that several of their Australian children were identified as having nasalance scores more than 2 standard deviations (SD) from the mean although listeners had considered them to have normal resonance. Moreover, 20% of the Zoo Passage readings differed by two or more points when they were repeated; 30% of nasal sentence repetitions differed by three or more points. This indicates that strict statistical cut-off points may vary.

Another study, measuring the nasalance of typically developing, English-speaking Irish children, identified a similar pattern. Sweeney, et al. (2003) recorded nasalance data for 80 English speaking children in Ireland between the ages of 4:11 and 13 years. The Irish children’s nasalance scores were an average of 6 to 10% lower than those of American children reading similar nasal and oro-nasal stimuli, although there was no difference with purely oral stimuli. It is worth noting that the stimulus items in Sweeney, et al. (2003) consisted of sentences adapted from the Great Ormond Street Speech Assessment rather than the Rainbow and Zoo passages used in the United States.

Nasometry Research in Languages Other than English

Researchers have conducted studies to develop a protocol for using the Nasometer with languages other than English. Generally, the purpose of these studies is to determine the validity of nasal, oro-nasal, and mixed reading stimuli; consequently, the stimulus materials do not correlate exactly with those used in English studies. Nevertheless, comparison of the resulting data with English-language norms indicates that the norms are not interchangeable. Hirschberg et al. (2006), for instance, found that Hungarian speakers reading oral Hungarian sentences have a mean nasalance of 11-13. Their mean nasalance scores for a nasal and a mixed sentence is 56 and 30-40, respectively. A similar study by Whitehill (2001) sought to determine the validity of nasal, oral, and oro-nasal sentences for a group of Cantonese-speaking women. Whitehill (2001) suspected the influence of "other factors" such as vowel nasalization since the norm scores for Cantonese speaking women reading a nasal paragraph was lower than that of English speakers reading a nasal paragraph, despite the greater proportion of nasal sounds in Cantonese (p. 123). Whitehill (2001) also analyzed nasometry stimulus across various languages and noted "a high degree of consistency in mean nasalance scores for oral materials across languages" (p. 123).

Tachimura et al. (2000) suspected that the phonological structure of Japanese—which contains no /CCV/, /CVC/, or /VCC/ syllables—might limit the application of English norms to Japanese speakers. They obtained nasalance data on 50 men and 50 women who were native speakers of the Mid-West (Osaka) dialect of Japanese. The reading stimulus, the Kitsutsuki Passage, contained four Japanese sentences with a total of 27 non-nasal syllables and was intended to parallel the English Zoo Passage. Results indicated that Japanese-speakers have lower nasalance and therefore should not be assessed using the norms devised for English-speaking populations. The authors suggested that this difference may be due to either language or craniofacial morphology. That is, the high percentage of vowels in Japanese increases the oral energy in a given passage. At the same time, earlier research indicates differences in the mid-facial morphology of Asian and European-American children, which may prompt acoustic production differences even in adult speakers.

Van Lierde et al. (2001) found that the nasalance of Flemish speakers reading nasal texts differed significantly from that found for North Dutch, Spanish, and the North American and Canadian dialects of English. Flemish, which is spoken in the majority of northern Belgium, is phonologically similar to English and has a linguistic structure akin to North Dutch. However, the Flemish group had lower nasalance scores than English speakers on oro-nasal, nasal, and mixed passages, regardless of gender. The Flemish female speakers also had significantly lower nasalance than Spanish-speaking women. The oro-nasal and nasal scores for Flemish and North Dutch were also different. Additionally, two reading passages indicated a gender difference, although the authors did not feel these differences were clinically significant. They concluded that this provides more evidence of significant differences in cross-linguistic nasality.

Two studies have looked at the nasalance scores of Spanish-speaking women. Anderson (1996) obtained nasalance scores from 40 Puerto Rican Spanish-speaking adult women as they read a set of nasal sentences, an oro-nasal paragraph (La Oveja), and an oral paragraph (Texto el Bosque) in Spanish. She found the expected distribution of group nasalance scores, with the oro-nasal paragraph producing higher nasalance scores than the oral paragraph. Additionally, the group nasalance scores fell within the suggested English-language norms.

Anderson (1996) concludes that "results….suggest that the nasometer is an effective tool for evaluating resonance in Spanish speakers" (p. 335). However, several factors limit the generalization of her results. First, Anderson (1996) had no English-speaking control group: she compares her Spanish speakers' data to English norms established by Seaver et al. (1991). Thus, while all participants were adult females, there was no attempt to match them by more specific criteria, such as age. Also, since Seaver et al. (1991) and Anderson (1996) recorded data under different conditions and for different purposes, the two sets of results may not be comparable. Secondly, her group scores are based on a single reading of each stimulus item by each participant. These place the Spanish group norm very close to the upper range of the English norms. The mean nasalance score for the Spanish oral paragraph, for instance, was 21.95, quite close to the upper limit of the 12-22 English range. Anderson's (1996) group means for both the nasal sentences is 62.07; Seaver et al. (1991) reported nasometric values for nasal sentences that ranged from 34-63. Examined individually, significant group differences were observed for 4 of the 5 nasal sentences. The group mean nasalance score for the Spanish oro-nasal paragraph is 36.02, with the English range being 34-36. Additional repetitions of the stimulus items might have created more reliable results. Lastly, all of Anderson's (1996) participants spoke the Puerto Rican dialect of Spanish and were life-long residents of Puerto Rico. Given the previous research about cross-dialectical and cross-linguistic differences, Anderson herself states that "mean nasometric values obtained for a specific linguistic group may not be valid for use with other groups"

(Anderson, 1996, p. 336). This is supported by other monolingual studies. She also noted a high between-subject variability that indicates the influence of sociocultural norms about acceptable nasality. Consequently, while Anderson's (1996) results validate the use of the nasometer with Spanish-speaking populations, in that Spanish stimuli yield trends similar to that of English results, further investigation is needed to address limitations in her study.

Nichols (1999) conducted a second nasalance study with Spanish speakers, in which he investigated possible age and gender nasalance effects for Mexican participants. A previous study on children who spoke Castillian (Peninsular) Spanish had suggested that Spanish children reading Spanish stimuli had nasalance scores that were higher for the non-nasal paragraph and lower for the nasal sentence than were reported for American children (Santos-Terrón et al., 1991). Nichols divided 152 male and female participants into three age groups: 6-8 years, 11-13 years, and 20-40 years. He found insignificant age and gender differences that concur with more definitive results from research with other populations. The main significant difference for average non-nasal scores was due to location: speakers from Mexico City had a non-nasal group mean of 16, while speakers from the smaller southern city of Cuernavaca had a non-nasal group mean of 19 (Nichols, 1999, p. 62). Evidently, dialect influences nasality in Spanish as well as in English (Seaver et al., 1991). Thus, research on Spanish-speaking populations that includes speakers of only one dialect may not reflect the full range of acceptable nasality.

To date, there has been no investigation of the nasalance scores of bilingual speakers that focused on the potential effects of their bilingualism or the interaction of their two languages.

Nasalance, Phonology, and Native Language

Regardless of population, researchers studying the nasalance of normal speakers encourage caution in applying standardized norms to linguistically diverse populations (Nichols, 1999; Anderson, 1996). This is in keeping with the growing awareness that simply translating existing English assessment material for use with non-English-speaking populations may yield results that are culturally biased (Figueroa, 1990; Javier, 2007). Whalen and Beddor (1989), citing research as far back as 1867, noted that sound production is generally constrained by two factors: “the physical mechanisms of human speech production and the reorganization imposed by the perceptual system” (p. 457). Both of these constraints are likely to be affected by a speaker’s native language. Tachimura et al. (2000) has noted the possible influence of a speaker’s native-language phonology. Moon et al. (1994) suggest that differences in English and Japanese velopharyngeal closure force may be linguistically determined: Japanese may require greater closure force. Sweeney (2003) found that English-speaking Irish children reading American-English passages often omitted words that were not culturally relevant for them, thus changing the phonetic make-up of the passage. Evidently, native-language may alter naslance score directly or indirectly.

Given the Nasometer’s ability to detect differences even among dialects of the same language (Nichols, 1999; Seaver, 1991), it is reasonable to assume that it may also be sensitive to accents other than the American English. When accented speakers are assessed, their velopharyngeal timing, phonological representation, or culturally ingrained beliefs about acceptable nasality (Bae et al., 2007; Ha et al., 2003; Anderson, 1996; Mayo et al., 1996) may result voice resonance that is classified as abnormal according to English norms. Consequently, a speaker with adequate velopharyngeal function and acceptable resonance may be incorrectly diagnosed. This is particularly likely when one considers that nasalance measures for typical speakers in languages other than English do not always correspond with the American-English norms (Van Lierde et al., 2001; Haapanen, 1991; Santos-Terrón et al., 1991).

Many researchers have encouraged the use of language-specific norms for non-native populations, since “differences in phonetic contexts and differential use of nasal [phonemes] result in differences in nasalance values across languages” (Anderson 1996, p. 333). However, the development of these norms has been slow because of the research entailed (Anderson, 1996). Once devised, these norms may be of limited use in countries such as the US because of the scarcity of multi-lingual speech pathologists (Hua, par. 10). In the absence of non-English norms and bilingual speech pathologists, voice assessments, like speech and language evaluations, are generally administered in English. If having a non-American accent does in fact influence a speaker’s scores on a standardized instrumental voice resonance assessment in English, such as nasometry, then the need for language-specific tools becomes even more significant. At the very least, clinicians must be aware that English-only stimuli may not yield truly accurate information about the velopharyngeal competence of non-native, bilingual, or accented speakers. Conversely, if accent is not a meaningful factor in these measurements, then speech-language pathologists can continue to administer English-only assessments of nasality with greater confidence. However, the significance of factors such as accent on accurate speech assessment must be researched in order to determine the appropriateness and practicality of devising language norms for non-native English speakers with resonance issues.

This research project is intended to provide information about the validity of nasometry results for bilingual Spanish/English speakers assessed using standardized speech tasks in both languages. Using nasometry, this study aims to determine if bilingual adults' nasalance scores differ significantly when they use Spanish as opposed to English stimulus materials. It is hypothesized that the phonology of different languages may be dissimilar enough to influence nasalance scores in the absence of any physiological difference. Additionally, the experiment will provide more preliminary normative data on the nasalance scores of Spanish-speaking adults.

The research questions to be answered are (1) what is the average nasalance scores of Spanish-speaking adults? (2) Can English-language norms be used with bilingual populations? (3) is there an interaction between native language and gender?, and The probable influences of language preferences and habits, as well as implications for speech assessment, will also be discussed.

Methods

In order to help determine the accuracy and validity of English norms for non-native English speakers, a protocol was devised to investigate the nasalance scores of bilingual Spanish/English speakers (group B) with perceptually normal resonance using Spanish and English reading tasks. The average group nasalance for both English and

Spanish tasks were then compared to the group nasalance of age- and gender-matched monolingual native American-English speakers (group A).

Participants

Twenty-two adult participants were recruited for this study. All participants' conversational samples were reviewed independently by the investigator, a native speaker of Mid-Atlantic English, and a native speaker of Peruvian Spanish. Data sets from two participants were excluded from analysis because of perceived irregularities in their conversational speech samples.

The data analyzed and discussed here were collected from twenty participants consisting of ten native English speakers and ten Spanish/English bilingual speakers. 'Native Spanish speakers' were defined as people who learned Spanish before the age of 5 years, the earliest critical period cut-off for the development of a phonological system (Collier, 1989). Additionally, participants were asked which language they use primarily with their families, and what percentage of their speech communication is conducted in each language. In order to be classified as a native Spanish-speaker, participants had to self-identify as speaking Spanish at least 40% of the time in at least one of the two contexts. The difficulty of recruiting and assessing participants during the pilot study period discouraged the use of a large experimental group (Doetzer & Tian, 2007).

All participants were asked about their level of education, the length of time they have spoken English, their self-rated level of English fluency (i.e. *do you speak English fluently?: yes/with difficulty/ no*), and their intelligibility to native English speakers (i.e. *when you speak English to an English-speaker you haven't met before, can he/she understand you clearly without your repeating?: yes/sometimes/ no*). All of the bilingual speakers had spoken English for at least eight years. According to the research questionnaire, all ten bilingual speakers considered themselves very fluent in English and reported no difficulties communicating with English speakers. The native English-speaking examiner rated all of the bilingual speakers as highly intelligible, which confirmed these self-reports. The native Spanish-speaking reviewer rated each of the ten Spanish-speaking participants as being both highly intelligible and highly fluent in Spanish based on their Spanish conversational samples. One of the male English speakers reported knowing phrasal Tagalog in addition to English as a child, but did not consider himself fluent. None of the other native-speaking participants reported speaking any other languages before high school.

The screening questionnaire ruled out any speakers who had colds or nasal blockage within the preceding month. Participants who had received surgery on the larynx, pharynx, nose or sinuses were also eliminated. Combined with the review of the conversational speech samples, these measures were intended to limit the participants to people who were perceived to have normal speech intelligibility and resonance, thus eliminating the confounding factors of pre-existing speech or voice disorders.

The participants' ages ranged from 18 to 36 years with an average age of 22.3 years (see Table 2). Two participants, an English-speaking female and a bilingual Spanish male, were over thirty, creating a slight upward skew. The average age of English speakers was 23 years; the average age of bilingual speakers was 21.6 years. There was no significant difference between these average ages.

The gender breakdown for the two language groups was identical: seven female participants and three male participants in each group. The average age of male participants was 23.3 years. For female participants, the average age was 21.9 years. At an $\alpha=0.05$ level of significance, there was no significant difference between the average ages of NE females and BE females, or between NE males and BE males (see Table 2).

Table 2

Summary of Participants' Ages in Years

Language Group	Gender		Average Age
	Female (n = 14)	Male (n= 6)	
Bilingual (n = 10)	20	25.6	21.6
Monolingual (n = 10)	20.14	21	23

Stimuli

All participants read the English speech tasks (see appendix A) twice in succession. This set of stimulus materials consisted of the Zoo Passage (paragraph with no nasal phonemes), the Rainbow Passage (paragraph containing a mixture of nasal and non-nasal phonemes), and the five Nasal Sentences (sentences heavily loaded with nasal phonemes). Use of these stimulus items permitted the use of standardized norms and enabled comparison of this research with previous investigations (Van Doorn & Purcell, 1998; Mayo, 1996; Kavanaugh et al., 1994; Litzaw & Dalston, 1992; Seaver, et al. 1991), the majority of which have used some combination of these passages. The Spanish/English bilinguals read additional Spanish tasks (see appendix B): the Texto el bosque (non-nasal paragraph), La Oveja passage (mixed paragraph), and the five Oraciones Nasales (nasal sentences). Although there are no widely recognized norms for any Spanish tasks used in nasometry, these are the materials used by Anderson as “comparable to the type of English passages that are already in use for developing normative data” (1996, p. 334). Texto el bosque was also used by Dalston et al. (1993), so its use provides some continuity with earlier research. The version of Texto el bosque used in this investigation was slightly modified to eliminate wording that confused participants during pilot research. These changes do not alter the phonetic content of the passage. La Oveja was designed to match the proportion of nasal and non-nasal sounds in conversational Spanish (Anderson, 1996; Goldstein & Iglesias, 1996). The original source of theses Spanish stimuli could not be determined despite a lengthy review of the related literature. A summary of speech tasks used in the present study appears in Table 3.

Table 3

Summary of Speech Tasks Used for Nasometry

Language	Nasal	Oro-nasal	Oral
English (appendix A)	Nasal Sentences	Rainbow Passage	Zoo Passage
Spanish (appendix B)	Oraciones Nasales (Anderson, 1996)	Oveja Passage	Texto el Bosque

Equipment

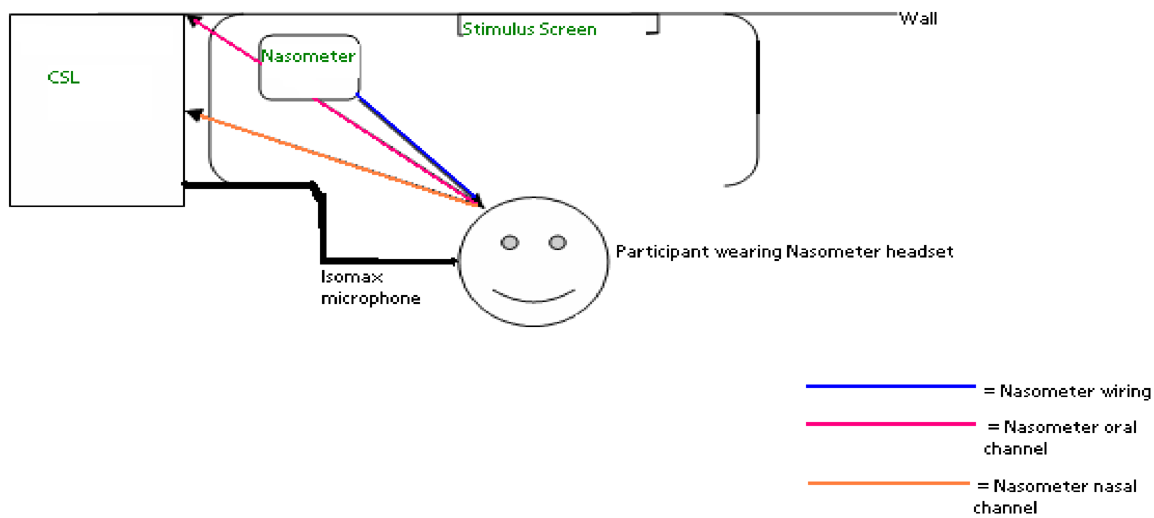
The speech samples were recorded in a quiet room using a Computerized Speech Lab (CSL) 4400 (Kay Elemetrics Corp., Lincoln Park, NJ) and a Nasometer II 6400 (Kay Elemetrics Corp., Lincoln Park, NJ) simultaneously. The setup details are as follows:

There were three microphones used for recording (see Figure 2).

1. An Isomax B3 omnidirectional condenser microphone (Countryman Associates, Inc., Menlo Park, CA) provided a recording of the sound from both the oral and nasal sides of the Nasometer separator plate. This round electret microphone was clipped to the separator plate of the Nasometer headset facing away from the speaker. The recorded audio signal was fed into channel 1 of the CSL.
2. The two nasometric microphones sat on the upper (nasal) and lower (oral) sides of the separator plate on the nasometer headset. The output of the Nasometer's nasal and oral microphones were split and directed into CSL channels 3 and 4, respectively, and merged into the input port on the computer on which the Nasometer software had been installed (Kay Elemetrics Corp., Lincoln Park, NJ).

The sampling rate of CSL recording was 44.1 kHz, while that of the Nasometer recording was 11.025 kHz as it was the highest limit for the Nasometer. Both the Nasometer and the CSL sent their signals to a Dell Vostro 200 desktop computer programmed with analysis software.

Figure 1. Experimental Set Up



Program

The nasalance scores was calculated using the Nasometer II program (Kay Elemetrics Corp., Lincoln Park, NJ) and saved as the third channel in the nasometric data. The Nasometer was re-calibrated before each session in accordance with the instructions in the Kay Elemetrics manual (Kay Elemetrics, 2003).

Assessment Procedures

After familiarizing themselves with copies of the stimulus materials, participants were asked to provide a two-minute spontaneous speech sample on a topic of their choice. The bilingual speakers were recorded twice, once in English and in Spanish. These were recorded using the Isomax microphone on CSL channel 1, which was clipped to the participant's clothes 6 inches away from his/her mouth. Then, the examiner fitted the calibrated Nasometer headset onto the participant's head. The Isomax microphone was clipped to the upper edge of the separator plate, 3 inches from the speaker's nose/mouth and angled away from the speaker's face to record both the oral and nasal signals equally. Wearing both the headset and the Isomax microphone, the participant read the standardized stimulus materials while seated in front of the computer monitor screen on which the materials were projected. The English materials were read from the computer screen directly. Because the Spanish materials could not be correctly entered into the Nasometer software, paper copies of the materials were superimposed on the computer screen. The speaker's position in relation to the stimulus materials remained unchanged across recordings. The speakers were instructed to read the stimulus items at their regular conversational pace, pitch, and loudness. Each speaker read the passages and sentences in the same order, alternating English and Spanish. Thus, members of the NE group read the following:

1. Zoo Passage (two repetitions)
2. Rainbow Passage (two repetitions)
3. Nasal Sentences (two repetitions)

Members of the SE group—that is, the bilingual speakers—read the following:

1. Texto el Bosque (two repetitions)
2. Zoo Passage (two repetitions)
3. La Oveja (two repetitions)
4. Rainbow Passage (two repetitions)
5. Oraciones Nasales (two repetitions)

Speakers who skipped, repeated, or distorted words during recording were re-recorded. Data were collected only from complete and relatively fluent recordings. The most common error was a tendency for the bilingual participants to read *plan* as *play* in the fourth of the English Nasal Sentences.

Nasalance Scores of Paragraphs and Sentences

During the resonance trials of bilingual speakers, mean individual and group nasalance scores were calculated as the average of the two repetitions of the Spanish and English oral paragraphs, the Spanish and English oro-nasal paragraphs, and the ten nasal sentences (five in English, five in Spanish). For the English speaking control group, mean individual and group nasalance scores were calculated as the average of the two repetitions of the English oral paragraph, the oro-nasal paragraph, and the five English Nasal Sentences (see Table 4).

Table 4

Variables for Acoustic Analysis of Paragraphs and Sentences.

Variable	Description
Individual nasalance (English)	Average of each participant's two readings of the Zoo Passage, the Rainbow Passage, and the Nasal Sentences
Individual nasalance (Spanish)	Average of each bilingual participant's two readings of the Texto el Bosque, La Oveja, and Oraciones Nasales
Mean group nasalance (Bilingual)	Average of the individual nasalance scores from the bilingual participants
Mean group nasalance (Monolingual)	Average of the individual nasalance scores from the bilingual group.

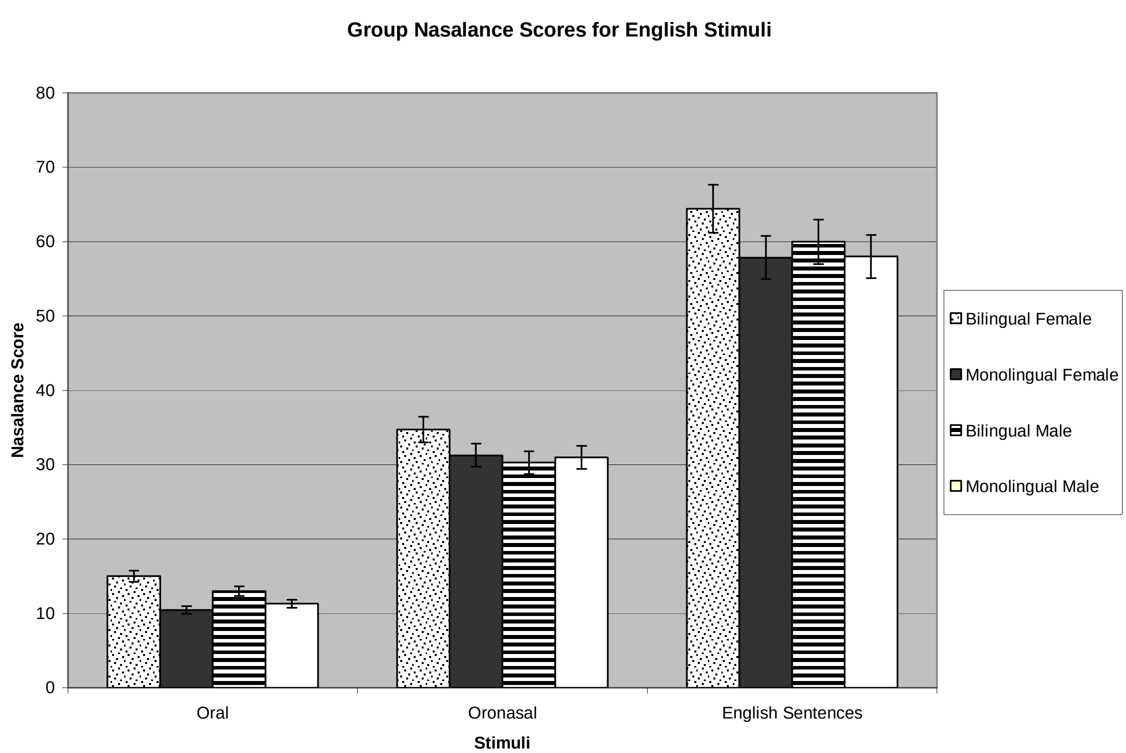
Statistical Analysis for the Nasalance Scores

The factors investigated by this study included native language and gender effects with the nasalance score as the independent variable. A 2 × 3 between-subject Multivariate Analysis of Variance (MANOVA) was used to investigate the effect of native language on nasalance scores for three different English tasks between English Native speakers and bilingual Spanish/English speakers. A 2 × 3 within-subject MANOVA was used to find the effect of the task language on nasalance scores within Spanish/English speakers. The Levene test of equality of error variance was set at the .05 level to test the variance equality of the dependent variables in both MANOVAs. Type III Sums of Squares were used because of the unbalanced number of participants in the gender groups. MANOVA are relatively robust even in unbalanced cases, particularly with equal or nearly equal sample sizes (Lomax, 2007). For language groups, the independent variable of primary interest, the sample sizes were equal.

Results

The nasalance scores from the two repetitions of each text passages were averaged for each speaker (see Appendix C). These average nasalance scores were, in turn, averaged into groups based on the speaker's gender and native language (see Figure 4). The male native-English speaking data for the Rainbow Passage, for instance, consisted of the average composite nasalance scores for all male native English speakers reading that passage.

Figure 2. Group Nasalance Scores for English Stimuli.



The result of the between-subject MANOVA was presented in Table 5. There was no significant difference in the nasalance scores between English native speakers and

Spanish/English speakers when the English speech tasks were used. Neither was there significant difference between genders. The Levene's Test of Equality of Error Variance demonstrated no violation of equal variance across groups ($p > .05$).

Table 5

MANOVA results for between-subject comparison

Multivariate Tests[c]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Intercept	Pillai's Trace	.993	810.4	3	16	.000	.993	2431.289	1.000
	Wilks' Lambda	.007	810.4	3	16	.000	.993	2431.289	1.000
	Hotelling's Trace	151.956	810.4	3	16	.000	.993	2431.289	1.000
	Roy's Largest Root	151.956	810.4	3	16	.000	.993	2431.289	1.000
Bilingual	Pillai's Trace	.208	1.399[a]	3	16	.279	.208	4.197	.301
	Wilks' Lambda	.792	1.399[a]	3	16	.279	.208	4.197	.301
	Hotelling's Trace	.262	1.399[a]	3	16	.279	.208	4.197	.301
	Roy's Largest Root	.262	1.399[a]	3	16	.279	.208	4.197	.301

a. Exact statistic

b. Computed using alpha = .05

c. Design: Intercept + Bilingual

Spanish Paragraphs & Sentences

The bilingual speakers' nasalance scores on the Spanish stimuli showed a gradation identical to that of the English stimuli pattern (Table 6). The nasal sentences once again generated the highest scores, followed by the oro-nasal paragraph. The readings of the non-nasal paragraph produced the lowest nasalance scores.

Since no English speaking participants recorded the Spanish stimuli, native language was not a factor in analyzing the Spanish paragraphs and sentences. Gender was the sole independent variable, with nasalance score again serving as the dependent variable. The scores for bilingual females fell within the range of group scores acquired by Anderson (1996) for a group of monolingual Puerto Rican women.

Table 6

Average Differences for Bilingual Participants' Nasalance Scores on English and Spanish Stimuli

Speech Task	Non-nasal Paragraph		Oro-nasal Paragraph		Nasal Sentences	
	English	Spanish	English	Spanish	English	Spanish
Average Nasalance Score	14.40	13.40	33.40	26.90	63.10	53.50
Difference in Nasalance Scores	1.0		6.50		9.60	

The result of within-subject MANOVA was presented in Table 7. The language and type of the tasks were two independent factors. The nasalance scores for Spanish tasks were significantly higher than those for their English counterparts when speakers tested were the same. The Levene's Test of Equality of Error Variance demonstrated no violation of equal variance across groups (p > .05).

Table 7

MANOVA results for within-subject comparison

Multivariate Tests[c]									
Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Language	Pillai's Trace	.933	126.0	1	9	.000	.933	126.000	1.000
	Wilks' Lambda	.067	126.0	1	9	.000	.933	126.000	1.000
	Hotelling's Trace	14.000	126.0	1	9	.000	.933	126.000	1.000
	Roy's Largest Root	14.000	126.0	1	9	.000	.933	126.000	1.000
Tasks	Pillai's Trace	.987	313.0	2	8	.000	.987	626.083	1.000
	Wilks' Lambda	.013	313.0	2	8	.000	.987	626.083	1.000
	Hotelling's Trace	78.260	313.0	2	8	.000	.987	626.083	1.000
	Roy's Largest Root	78.260	313.0	2	8	.000	.987	626.083	1.000
Language * Tasks	Pillai's Trace	.938	60.149[a]	2	8	.000	.938	120.298	1.000
	Wilks' Lambda	.062	60.149[a]	2	8	.000	.938	120.298	1.000
	Hotelling's Trace	15.037	60.149[a]	2	8	.000	.938	120.298	1.000
	Roy's Largest Root	15.037	60.149[a]	2	8	.000	.938	120.298	1.000

a. Exact statistic

b. Computed using alpha = .05

c. Design: Intercept

Within Subjects Design: Language + Tasks + Language * Tasks

Discussion

This study investigated the validity and limitations of standardized nasometric assessment on typically developing bilingual Spanish/English adults. Previous research had indicated thatthe use of English stimuli with non-native speakers may yield an inaccurate picture of the speakers' voice resonance (Hirschberg et al. 2006; Whitehill, 2001; Van Lierde, 2001; Tachimura et al. 2000). In particular, a study of Castillian (Peninsular) Spanish-speaking children indicated that their scores might appear abnormally high when judged by English norms (Santos-Terron, et al., 1991). On the other hand, several studies with native Spanish-speakers have indicated that commonly used English stimuli—the non-nasal Zoo Passage, the oro-nasal Rainbow Passage, and the five Nasal Sentences—are accurate with Spanish-speaking populations (Nichols, 1999; Anderson, 1996). However, these studies generally mixed data taken from Spanish speakers with English speakers' data recorded in previous studies. This introduced numerous uncontrolled variables related to recording methods and participant characteristics, including speaker characteristics, listener judgments, stimulus presentation, and recording circumstances.

This design allows for two comparisons. When a single speaker's nasalance scores for English stimuli are compared to those for similarly constructed Spanish stimuli, anatomical difference of the vocal tract between speakers is not a contributing factor to nasalance score difference as in previous studies. Since the comparison was carried out on the same speaker, recorded on the same day under identical circumstances, any divergences would presumably be due to language-specific differences in resonance, in the temporal pattern of the velopharyngeal motions during speech, or in the phonology of the stimuli. The bilingual-speaking group scores for Spanish stimuli can be compared to those collected by Anderson (1996) and Nichols (1999) to provide information about the reliability and usefulness of the Spanish stimuli. If the bilingual group scores for the English stimuli differ significantly from the native-speaking group scores, this may indicate that native-language is a factor to be considered even in people whose English is adequate for assessment in that language.

Spanish was selected as the non-English language for this study because of the rapidly growing Spanish-speaking population in the United States, where Spanish speakers are the largest ethnic and linguistic minority. According to the 2000 U.S. Census, there are 28,101,052 Spanish speakers in the United States. They make up 10% of the population and significantly exceed all other language groups (MLA Language Map). Nevertheless, there is a disappointing lack of research related to the speech and language needs of this and other non-English populations. In a review of fifty years of voice research, Agin (as cited in Kayser, 1995) noted that there were very few studies with participants from culturally or linguistically diverse (CLD) backgrounds and cautioned that a 'disorder' in one population may not exist in another population. Glattke (cited in Kayser, 1995) examined over 200 speech, language, and hearing research articles from 1992-1994 and found that none addressed CLD communication disorders. Concerning speech disorders in particular, Kayser (1995) identified a high rate of vocal pathologies among Mexican and Puerto Rican students, but could not speculate as to the cause or extent of this incidence. She noted that epidemiology statistics related to the Latino population were particularly lacking because, in the United States, Latinos have frequently been classified as Caucasian (1995, p. 303). Information from this study can be used as preliminary research toward creating nasalance norms for Spanish-speaking populations.

Nasalance Scores for English Tasks

Average nasalance scores obtained on reading English tasks in the present study showed the consistent pattern: regardless of gender or native language, scores on the non-nasal Zoo Passage were lower than those on the oro-nasal Rainbow Passage; the Nasal Sentences produced the highest nasalance scores. The average nasalance score of native-Spanish speaking adults for the English oro-nasal paragraph is 54.7; for the English oral paragraph, the average score is 14.4. The average nasalance score for native Spanish-speaking adults recording the English Sentence set was 63.1. The bilingual speakers' scores for all English stimuli were slightly higher than those of their monolingual counterparts, confirming the findings of Santos-Terron et al. (1991). However, their differences were not significant. Therefore, the native language of the highly fluent monolingual or bilingual English speakers did not seem to affect their nasalance scores. Moreover, for the purposes of assessment or diagnosis, the standard English norms could be accurately applied to the bilingual group.

Language factor

The within-subject comparison of the bilingual participants' scores with the English stimuli and their scores with the Spanish stimuli eliminates variations between speakers. Each bilingual participant's Spanish score is compared with his/her English score. Within-Subject MANOVA found no significant difference between individual scores on the non-nasal paragraphs. The most notable difference—between the English Nasal Sentences and the Spanish Oraciones Nasales—can be attributed to differences in the stimuli. The proportion of nasal consonants to other phonemes is 50% in the English sentences and only 36% in the Spanish sentences. The English sentences also have a higher number of shifts between nasal consonants and oral consonants or vowels. The English and Spanish oro-nasal paragraphs, on the other hand, produce smaller but still significant differences. This difference cannot be attributed to an imbalance in the stimuli: nasal consonants make up 26% of the total consonants (11.3% of all phonemes) in the Spanish oro-nasal paragraph and 23% of the total consonants (15% of all phonemes) in the English oro-nasal paragraph. Any influence that this slight discrepancy might have is probably negated by the fact that the English oro-nasal paragraph has 5 more nasal-to-oral phonemes shifts than the shorter Spanish oro-nasal paragraph. That is, a larger percentage of the Spanish phonemes are nasal, but the English paragraph also may require more velopharyngeal agility.

Conclusion

This provides further evidence that there may, indeed, be a subtle language-specific difference between English and Spanish even when the speakers are identical in other capacities. Furthermore, the fact that this distinction is only apparent in the oro-nasal paragraph implies that the language-specific difference is most evident in contexts that require frequent velopharyngeal shifts from the closed position needed for vowels and non-nasal consonants to the opened position required for nasal consonants. While highly-fluent speakers may be able to use the established stimuli interchangeably, less fluent or more accented speakers may require tasks that are more phonemically balanced to produce the same results.

Suggestions for Future Research

The limitations of this study provide suggestions for future research. Despite the use of a variety of recruitment methods over the course of a year, the sample size remains small. Recruiting bilingual native Spanish speakers, and male participants of either language background, proved difficult with the time and resources at hand. At least one previous study (Anderson, 1996) also reports difficulty recruiting male Spanish speakers. A larger sample size would doubtlessly have provided more concrete information about the effect of native language on nasalance score. Future studies could investigate whether gender continues to be more of an influence than native language within larger populations.

Additionally, this study recruited highly fluent bilinguals from a variety of Spanish language backgrounds. The intent was to reduce the effects of any difficulty with English pronunciation or influence by a particular dialect. However, bilingual Spanish/ English speakers who are very familiar with English and who live in a mostly English-speaking area may be less likely to show Spanish-specific patterns of nasalance or velopharyngeal timing than bilingual speakers who are less familiar with English. A larger study of participants' who have less English experiences might determine the presence of language-specific velopharyngeal patterns more definitively. Moreover, pronunciation and vocabulary in Spanish are highly variable across national and regional borders (Guirao & García Jurado, 1990). Nichols's (1999) study determined that the nasalance scores of Mexican speaking groups varied significantly depending on their native city; similar results have been found for English speakers (Dalston et al., 1993). Consequently, an investigation of Spanish dialect-groups might show that particular dialects use different velopharyngeal patterns, an effect that would not be noticed in a smaller study that did not control for dialect. Finally, since English and Spanish are phonologically relatively similar, a study with more divergent language groups might yield interesting results.

The participants in this study were judged to be perceptually normal; effort was taken to exclude participants with abnormal voice resonance or velopharyngeal structure. As a result, any of the results determined using this sample, even if confirmed in larger samples, may not hold true for disordered populations. Comparative studies with disordered populations would be needed to determine if native language or gender, or any combination, influences the scores of bilingual speakers who have atypical voice resonance or velopharyngeal closure.

Appendix A

English Stimuli

Nasal Sentences (English Nasal Sentences)

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

Rainbow Passage (English Oro-nasal Paragraph)

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. 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.

Zoo Passage (English Oral Paragraph)

Look at this book with us. It’s a story about a zoo. That is where the 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 the birds so they’re able to fly.

Appendix B

Spanish Stimuli

Oraciones Nasales (Spanish Nasal Sentences)

La niña se sentó en mi mesa.

Caminaba en la montaña.

La china es anaranjada.

Mi amigo rentó la maquina.

El niño canta mientras come.

La Oveja (Spanish Oro-nasal Paragraph)

La oveja es un animal hervívoro. Se alimenta de yerba. Habita en todos los climas. Es un animal manso y resistente. Se mueve constantemente, pero es dócil a la voz del pastor y se deja guiar por los perros. Todo es útil en la oveja. La lana sirve para fabricar vestidos, mantas y alfombras. La piel se usa para abrigos y objetos de adorno. Su carne es sabrosa y con su leche se hace quesos.

Texto el Bosque (Spanish Oral Paragraph)

La batalla se paro por la falta de agua. El río que rodeaba el castillo estaba casi seco. Se hizo la fogata, alta, rojiza, para dar calor a los soldados. La chispa saltó y se aceró al bosque y todo él fue devorado por el fuego.

Appendix C

Table 8

Nasalance Scores for English Stimuli, by Language Group and Gender

Native Language	Nasalance Scores					
	Female			Male		
	English Oral Paragraph	English Nasal Paragraph	English Sentences	English Oral Paragraph	English Nasal Paragraph	English Sentences
English (n = 10)	15	34.714	64.428	13	31.750	60.5
Spanish/ English (n = 10)	10.428	29.714	57.857	11.333	30.333	58

Appendix D

Phonological Analysis of Stimuli

Spanish Oro-nasal Paragraph (La Oveja)

Table 9

Phoneme Frequency in Spanish Oro-nasal Paragraph: Oral Stops, Fricatives, & Affricates

Phoneme	/p/	/b/	/t/	/d/	/k/	/g/	/f/	/v/	/θ/	/ð/	/s/	/z/	/dz/	/ʃ/	/tʃ/
Frequency	7	11	13	4	6	2	2	4	0	5	38	0	0	0	1

Table 10

Phoneme Frequency in Spanish Oro-nasal Paragraph: Oral Liquids & Glides

Phoneme	/l/	/w/	/r/	/j/
Frequency	18	1	11	0

Table 11

Phoneme Frequency in Spanish Oro-nasal Paragraph: Vowels

Phoneme	/a/	/ɛ/	/o/	/i/	/u/	/e/
Frequency	40	17	24	21	7	16

Table 12

Phoneme Frequency in Spanish Oro-nasal Paragraph: Nasal Consonants

Phoneme	/m/	/n/	/ñ/
Frequency	8	17	0

English Oro-Nasal Paragraph (Rainbow Passage)

Table 13

Phoneme Frequency in English Oro-nasal Paragraph: Oral Stops, Fricatives, & Affricates

Phoneme	/p/	/b/	/t/	/d/	/k/	/g/	/f/	/v/	/θ/	/ð/	/s/	/z/	/dz/	/ʃ/	/tʃ/	/h/
Frequency	7	8	17	15	8	2	5	7	3	11	8	13	1	0	2	5

Table 14

Phoneme Frequency in English Oro-nasal Paragraph: Oral Liquids & Glides

Phoneme	/l/	/w/	/r/	/j/
Frequency	13	5	13	4

Table 15

Phoneme Frequency in English Oro-nasal Paragraph: Vowels

Phoneme	/a/	/ɛ/	/o/	/i/	/u/	/e/	/I/	/ai/
Frequency	14	11	6	8	3	10	17	4

Table 16

Phoneme Frequency in English Oro-nasal Paragraph: Nasal Consonants

Phoneme	/m/	/n/	/ŋ/
Frequency	5	25	5

Spanish Non-Nasal Paragraph (Texto El Bosque)

Table 17

Phoneme Frequency in Non-nasal Paragraph: Oral Stops, Fricatives, & Affricates

Phoneme	/p/	/b/	/t/	/d/	/k/	/g/	/f/	/v/	/θ/	/ð/	/s/	/z/	/dz/	/ʃ/	/tƒ/	/dz/
Frequency	5	4	8	3	7	3	4	1	0	5	0	0	0	0	1	0

Table 18

Phoneme Frequency in Spanish Non-nasal Paragraph: Oral Liquids & Glides

Phoneme	/l/	/w/	/r/	/j/
Frequency	15	3	11	2

Table 19

Phoneme Frequency in Spanish Non-nasal Paragraph: Vowels

Phoneme	/a/	/ɛ/	/o/	/i/	/u/	/e/
Frequency	34	7	22	8	1	10

Table 20

Phoneme Frequency in Spanish Non-nasal Paragraph: Nasal Consonants

Phoneme	/m/	/n/	/ñ/
Frequency	0	0	0

English Non-Nasal Paragraph (Zoo Passage)

Table 21

Phoneme Frequency in English Non-nasal Paragraph: Oral Stops, Fricatives, & Affricates

Phoneme	/p/	/b/	/t/	/d/	/k/	/g/	/f/	/v/	/θ/	/ð/	/s/	/z/	/dz/	/ʃ/	/tʃ/	/dz/	/h/
Frequency	3	6	19	11	8	1	5	4	2	12	8	12	1	0	1	1	6

Table 22

Phoneme Frequency in English Non-nasal Paragraph: Oral Liquids & Glides

Phoneme	/l/	/w/	/r/	/j/
Frequency	9	8	14	3

Table 23

Phoneme Frequency in English Non-nasal Paragraph: Vowels

Phoneme	/a/	/ɛ/	/o/	/i/	/u/	/e/	/I/	/aI/
Frequency	6	7	5	13	8	8	8	1

Table 24

Phoneme Frequency in English Non-nasal Paragraph: Nasal Consonants

Phoneme	/m/	/n/	/ŋ/
Frequency	0	0	0

Spanish Nasal Sentences (Oraciones Nasales)

Table 25

Phoneme Frequency in Spanish Nasal Sentences: Oral Stops, Fricatives, & Affricates

Sentence	Phoneme Frequency															
	/p/	/b/	/t/	/d/	/k/	/g/	/f/	/v/	/θ/	/ð/	/s/	/z/	/dz/	/ʃ/	/tf/	/dz/
1.	0	0	1	0	0	0	0	0	0	0	3	0	0	0	0	0
2.	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0
3.	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0
4.	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
5.	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0
Total	0	1	4	1	4	1	0	0	0	1	4	0	0	0	1	0

Table 26

Phoneme Frequency in Spanish Nasal Sentences: Oral Liquids & Glides

Sentence	Phoneme Frequency			
	/l/	/w/	/r/	/j/
1.	1	0	0	0
2.	1	0	0	0
3.	1	0	1	0
4.	1	0	1	0
5.	0	0	1	0
Total	4	0	3	0

Table 27

Phoneme Frequency in Spanish Nasal Sentences: Vowels

Sentence	Phoneme Frequency					
	/a/	/ɛ/	/o/	/i/	/u/	/e/
1.	3	3	1	2	0	1
2.	6	1	1	1	0	0
3.	7	1		1	0	0
4.	4	1	2	3	0	0
5.	3	2	2	2	0	1
Total	23	8	6	9	0	2

Table 28

Phoneme Frequency in Spanish Nasal Sentences: Nasal Consonants

Sentence	Phoneme Frequency		
	/m/	/n/	/ɲ/
1.	2	3	1
2.	2	3	1
3.	0	3	0
4.	3	2	0
5.	2	3	1
Total	9	14	3

English Nasal Sentences

Table 29

Phoneme Frequency in English Nasal Sentences: Oral Stops, Fricatives, & Affricates

Sentence	Phoneme Frequency															
	/p/	/b/	/t/	/d/	/k/	/g/	/f/	/v/	/θ/	/ð/	/s/	/z/	/dz/	/ʃ/	/tf/	/dz/
1.	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1
2.	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1
3.	0	0	0	3	0	2	0	0	0	0	0	1	0	0	1	1
4.	1	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0
5.	0	1	0	2	1	0	0	1	0	0	0	0	0	0	0	0
Total	1	2	2	6	3	2	0	1	1	0	1	1	0	0	1	3

Table 30

Phoneme Frequency in English Nasal Sentences: Oral Liquids & Glides

Sentence	Phoneme Frequency			
	/l/	/w/	/r/	/j/
1.	1	0	0	1
2.	0	1	1	1
3.	0	0	0	0
4.	2	1	0	0
5.	1	0	0	1
Total	4	2	1	3

Table 31

Phoneme Frequency in English Nasal Sentences: Vowels

Sentence	Phoneme Frequency									
	/a/	/ɛ/	/o/	/i/	/u/	/e/	/I/	/aI/	/ʌ/	/au/
1.	4	0	0	0	0	1	0	0	2	0
2.	2	3	0	0	0	1	1	0	0	0
3.	2	0	0	0	0	1	0	1	0	0
4.	2	2	1	1	0	1	0	0	1	0
5.	2	0	0	0	0	2	1	0	1	1
Total	12	5	1	1	0	6	2	1	4	1

Table 32

Phoneme Frequency in English Nasal Sentences: Nasal Consonants

Sentence	Phoneme Frequency		
	/m/	/n/	/ɲ/
1.	6	1	0
2.	2	5	1
3.	2	3	0
4.	0	6	0
5.	4	3	1

Total	14	18	2

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