Assessing the Nasalance of Native Mandarin Speakers in Mandarin and English

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Running Title: Nasalance in Native Mandarin Speakers

Acknowledgements: This research was supported by funding from the East Carolina University Cleft Palate Speech Imaging Laboratory.

Evaluating Nasalance Values among Bilingual Mandarin-English Speakers

Objective: The goals of this research are 1) to establish normative nasalance values for bilingual Mandarin-English speakers and compare values to those of previously reported monolingual Mandarin speakers, and 2) to examine if sex, age, dialect, and language proficiency affect levels of nasalance among Mandarin-English speakers in both English and Mandarin.

Design: All participants recorded the speech stimuli, constructed to include oral sentences, nasal sentences, oro-nasal sentences, and vowels /ɑ, i, u/ in Mandarin and English. Nasalance measurements were recorded using the Nasometer II 6450.

Participants and setting: A total of 45 (20 males and 25 females) native Mandarin-speakers between 20 and 54 years of age from mainland China participated in the study.

Results: Mean nasalance scores of the Mandarin oral sentence (M = 17.64, SD = 7.33), oro-nasal sentence (M = 54.62, SD = 7.81), and nasal sentence (M = 68.73, SD = 8.09) are reported. Mean nasalance scores of the English oral sentence (M = 20.02, SD = 7.83), oro-nasal sentence (M = 58.71, SD = 7.59), and nasal sentence (M = 65.27, SD = 7.45) are reported. A repeated measures ANOVA showed significant sex difference on nasalance scores for English stimuli (p = .031) and for Mandarin stimuli (p = .040). There was no significant effects of age, dialect, and language proficiency on Mandarin or English stimuli.

Conclusions: This is the first study to report normative values for Mandarin-English speakers using the Nasometer II. Values reported can be used for objective assessment of bilingual speakers.

Keywords: Mandarin, Chinese, English, nasalance, nasometer, resonance

INTRODUCTION

Mandarin is the most commonly spoken dialect of Chinese and has the largest population of native speakers in the world, with approximately 1.3 billion speakers (Lewis et al., 2016). Mandarin speakers reside in all parts of the world, but live predominantly in mainland China, where there are more than 40,000 new cases of cleft lip and/or palate each year (Kling et al., 2014). Cleft lip and palate impact speech in a variety of ways, with hypernasality and nasal air emission being the most prominent features among those with velopharyngeal dysfunction. The assessment of nasality relies on perceptual assessment by an experienced speech language pathologist, followed by objective instrumental measures to support perceptual observations. Nasalance is an acoustic correlate to the degree of perceived nasality in the speaker and is derived as the nasal energy divided by the total energy (oral and nasal combined) multiplied by 100 (Fletcher et al., 1974). Several devices utilized for measuring nasalance include the NasalView (Tiger Electronics Inc, Seattle, WA), the OroNasal system (Glottal Enterprises Inc, Syracuse, NY), and the Nasometer (KayPentax Corp, Lincoln Park, NJ). Studies comparing nasalance scores obtained by the three instruments concluded that the nasalance scores are not interchangeable and should not be compared directly (Bressmann, 2005; Bressmann et al., 2006). The Nasometer has been widely used as a clinical tool to quantify the level of nasality in speakers with a history of cleft palate.

Standardized speech stimuli for the Nasometer and subsequent nasalance data have been established in several languages and dialects, for example Australian English, Ugandan English, Irish-English, French, and Spanish (Rochet et al., 1998; Van Doorn and Purcell, 1998; Sweeney et al., 2004; Luyten et al., 2012; Perry et al., 2018). However, there are currently no clinical protocols comparable to those established in English for assessing nasality using the Nasometer for bilingual Mandarin-English speakers from China living in the United States (Kling et al., 2014). There are substantial phonological and phonetic differences between English and Mandarin that likely affect nasalance values on both language systems for bilingual speakers, thus warranting the development of standardized speech samples in Mandarin. Tsai et al. (2012) reported nasalance scores using the Nasometer II 6400 of ten native Mandarin speakers in Taiwan, 22 to 24 years old (6 male, 4 female) with English and Mandarin speech passages. Tsai et al. (2012) noted that native Mandarin speakers from Taiwan yielded lower nasalance scores for the English Zoo passage, Rainbow Passage, and English Nasal Sentences compared to English normative data. The results suggest that there is a difference in nasalance scores of native Mandarin speakers compared to normative data of native English speakers. However, speakers in the study by Tsai et al. (2012) reported, in some cases, being trilingual (speaking Mandarin, English, and one or more other languages) and thus nasalance values obtained may not be reflective of bilingual English-Mandarin speakers living in the United States.

Bilingual speakers have been observed to have phonetic assimilation with vowels and consonants in which learning of a sound in a second (L2) language is blocked by a similar sound in their primary (L1) language (Flege and Eefting, 1987; Yeni-Komshian et al., 2000; Flege, et al., 2003; Lee and Iverson, 2012). For example, bilingual English-French speakers may produce /p/ the same way for both the English aspirated /p/ and French unaspirated bilabial plosive. Doetzer (2008) examined bilingual Spanish-English speaking adults and observed a significantly lower nasalance score for Spanish stimuli compared to English stimuli. Findings suggest that native-like knowledge of L2 may decrease the variability in the amount of intra-speaker nasalance produced in the two languages, but the results do not provide data on whether second language fluency increases the likelihood of native-like nasalance values (Doetzer, 2008).

Because of these possible influences on bilingual speakers, it is likely that differences in nasalance would be evident between bilingual Mandarin speakers and monolingual Mandarin speakers.

Other factors, including age, sex, and dialect have been shown to influence nasality (e.g., Seaver et al., 1991; Leeper et al., 1992; Zajac et al., 1996; Corey et al., 1998; Park et al., 2014; Awan et al., 2015). Studies have consistently demonstrated age effects when comparing nasalance scores between children and adults (e.g., Park et al., 2014; El-Kassabi et al., 2015). When comparing across different languages, some studies report a significant influence of sex on nasalance while others report no significant difference (e.g., Seaver et al., 1991; Dalston and Seaver 1992; Okalidou et al., 2011; Lee and Browne, 2012; Park et al., 2014; El-Kassabi et al., 2015). Kim et al. (2016) found mean nasalance to be significantly higher among monolingual Mandarin speaking females compared to males.

Dialect variation within the same language have been found to result in articulatory changes that may affect nasalance. Studies have demonstrated dialectal influences on nasalance varies based on the geographical region (e.g., Seaver et al., 1991; Awan et al., 2015). Awan et al. (2015) reported that dialect variation based on geographical region accounted for 7-9% of the variation in nasalance. Adding to the complexity of studying Mandarin, there are over 200 dialects of Chinese, each presenting with complex and different phonological systems (Wurm et al., 1987). However, similarities exist between dialects that belong to similar geographical areas. Therefore, investigations examining dialects in China, typically use regional grouping methods to categorize dialects into seven regions, including Northern, Wu, Xiang, Gan, Hakka, Min, and Yue (Huang and Liao, 1983). Differences in pronunciation between dialects can cause differences in articulation habits. Kim et al. (2016) used the NasalView to compare monolingual speakers of four dialectal regions in China and observed significantly lower scores for the nasal and oro-nasal samples among speakers of the Guangzhou dialect, also known as Cantonese. In Cantonese, nasal sound /n/ is often substituted with lateral approximant /l/ sounds which could lead to lower nasalance scores (Bauer and Benedict, 1997; Wurm et al., 1987). Another potential phonetic variability in Cantonese that may contribute to varied nasalance is the dropping of the initial velar nasal during "ng" found in some speakers (Bauer and Benedict, 1997; Whitehill, 2001). Therefore, it is important to consider dialectal influence when reporting nasalance scores for Mandarin speakers.

Previous research indicate both language-inherent and speaker-acquired variation can affect nasalance values (Mayo and Mayo, 2011). It is therefore necessary to establish standardized, normative nasalance values for speakers in their native language to enable comparison of typical nasalance to abnormal oral-nasal balance. The goals of this research are 1) to establish normative nasalance values for bilingual Mandarin-English speakers and compare values to those of previously reported monolingual Mandarin speakers, and 2) to examine if sex, age, dialect, and language proficiency significantly affect levels of nasalance across the stimuli between languages.

METHODS

Participants

This study was approved by the Institutional Review Board at East Carolina University. A screening questionnaire was used to determine participation in the study based on inclusion and exclusionary criteria. To control for the effect of age on resonance (e.g., Park et al., 2014; El-Kassabi et al., 2015), participants in the present study were included if they were 18 years or older, literate, spoke Mandarin (L1) and English (L2), and were from mainland China but now living in the United States. This criteria for inclusion was judged to be necessary to control for known anatomical variations that could affect resonance, such as the cephalometric dimensions and nasal airway cross-sectional area, attributable to racial differences as described in Xue et al. (2006). Additional inclusionary criteria included no reported history of speech disorder, craniofacial anomalies, musculoskeletal disorders, neurological disorders, swallowing disorders, or hearing impairments. Because the stimuli were presented visually, participants were required to have adequate (aided or unaided) visual ability to see the stimuli and to be literate in both English and Mandarin. Participants who reported having a cold, nasal blockage, and/or congestion on the day of the study were excluded. This exclusionary criterion was used to remove the effect of nasal congestion on resonance as discussed in Watterson et al. (2008). An oral mechanism examination was administered on the date of the study to confirm normal oral structures and function.

Participants included 45 bilingual Mandarin-English speakers (20 male and 25 female) between 20 and 54 years of age (Mean = 34.9 years, SD = 8.7 years). The mean participant length of stay in the United States was 91 months but ranged from a low of two months to a high of 294 months, or 24.5 years. The Language Experience and Proficiency Questionnaire (LEAP-Q; Marian et al., 2007) was administered to determine English language proficiency. Marian et al. (2007) observed that L2 performance can be predicted by self-reported speaking proficiency while L2 language ability can be predicted by exposure to L2 environments. Therefore, two variables were used to determine English language proficiency: (1) current exposure to English and (2) preference for speaking English, noted in the remainder of this study as language proficiency. The English exposure and mean language preference were measured by self-reported percentage points, with 0% representing no exposure and no preference. Participants reported the percentage in response to the question, “What percentage of the time are you currently and on average exposed to English?" on the LEAP-Q. The mean language preference was the average of two percentages reported on the LEAP-Q: (1) When reading, what percentage would you choose to read in English? (2) When speaking, what percentage would you choose to read in English? The English exposure reported by participants in the present study was a mean of 44.5 % (SD = 24.4 %) with a range from 2-85 %. The mean language proficiency of all participants was 33.8 % (SD = 20.4 %) with a range from 0-85 %.

Mandarin is the most spoken dialect and considered the standard Chinese dialect used in the educational system. Because Kim et al. (2016) found that dialectal regions in China have a significant influence on nasalance scores, an additional question was added to the questionnaire to obtain information about Chinese dialects spoken by participants. The Mandarin dialects were obtained using participant self-report and recorded based on geographic region in China. Participants self-reported a 100% proficiency in their respective Mandarin dialects.

Nasometer Data Collection

The Nasometer II (model 6450, KayPentax Corp, Lincoln Park, NJ) was used to determine levels of nasalance. The Nasometer was calibrated before the study and the headgear was adjusted and placed according to manufacturer's instructions (KayPentax, 2007). The participants were asked to practice speaking with the device in place to ensure unobstructed speech production prior to data collection. The stimulus sets were presented in randomized order to control for fatigue or adjustment due to instrumentation. Mean nasalance values were calculated from recordings of each speaker's single repetition of stimulus set. Participants were asked to re-record the stimulus if the initial recording included unusual hesitations, abnormal delays, revisions, and/or production errors.

Speech Stimuli

The participants were instructed to repeat the speech stimuli following an auditory presentation of speech stimuli in modern standard Chinese (Mandarin) and Standard American English by a bilingual Mandarin-English female speaker. Mandarin and English vowels were elicited without the use of visual stimuli, in attempt to model how vowels are elicited in the clinical setting. Sentence-level stimuli were presented verbally and visually in Mandarin characters with Pin Yin script and English, as shown in Appendix A. The Mandarin vowels were elicited following the three Mandarin sentences and the English vowels were elicited following the three English sentences. Production of three Mandarin sentences, three Mandarin vowels, three English sentences, and three English vowels were recorded using the Nasometer.

The Mandarin speech materials in the study included the oral, oro-nasal, nasal sentence, and three Mandarin vowels /ɑ/, /i/ and /u/ from Kim et al. (2016). Kim et al. (2016) did not provide comparative English stimuli. Therefore, in the current study English speech stimuli were created to make comparisons between English and Mandarin nasalance scores. The stimuli were constructed to include oral sentences, nasal sentences, and oro-nasal sentences (Appendix A). Considerations about articulatory differences such as voicing, frequency of occurrence of phonemes, and length of stimuli were considered to ensure culturally and phonetically appropriate speech stimuli. Both the Mandarin and English oral sentence contained 16 non-nasal syllables with 100% high-pressure consonants and no nasal consonants. The English and Mandarin oro-nasal sentences contained 16 syllables, with approximately 50% nasal consonants. The Mandarin and English nasal sentences contained 16 nasal syllables with 0% high pressure consonants, resulting in approximately 100% nasal or low-pressure consonants. Types of vowels and consonants were considered during construction of speech stimuli (Table 1).

While the speech stimuli for English and Mandarin are not a direct match, they were constructed using language specific considerations. Kummer (2008) suggests that standardized passages such as the Zoo and Rainbow Passages are semantically and syntactically complex. The two passages contain words that are difficult to pronounce. This difficulty may result in speech production errors, articulatory substitutions, or deletions, and a decrease in the validity of the obtained nasalance scores. For example, a speaker's pause and insertion of "um" would be particularly problematic. Because of these concerns, a more efficient way to collect nasometric data would be to obtain information from less complex stimuli (MacKay and Kummer, 1994; Wozny et al., 1994; Watterson et al., 1999). Watterson et al. (1999) suggest that a minimum of six connected syllables are necessary to establish clinically reliable nasalance values. Similarly, in this study, we aimed to establish simple vowel and sentence-level stimuli in English and Mandarin to obtain normative nasalance values that could be used for speakers of Mandarin.

Data Analysis

The mean nasalance values were measured using the Nasometer II software. All data analyses were conducted in statistical software IBM SPSS version 24.0. The mean nasalance scores for the Mandarin stimuli collected in this study were compared to the mean scores reported in the study by Kim et al. (2016) using a one-sample t-test, with a significance level of 0.05. The effects of independent variables of age (continuous variable), sex, dialect, and English language proficiency on nasalance values were investigated using a multiple regression analysis. Further analysis with a repeated measures ANOVA was used to evaluate if the effect of sex-based differences can be attributed to the type of stimuli (oral, oro-nasal, nasal sentence). An independent samples t-test was used to evaluate the sex effects on vowel productions between both languages.

RESULTS

To investigate test-retest reliability of instrumentation and variation between individuals, 12 subjects were randomly selected to repeat recordings. Removal and repositioning of the headgear were done between repetitions so that reliability measures included reliability estimates of consistent placement of the nasometer. Across all stimuli, 80% of repeated scores were within 5 nasalance points of each other. A 5-point variation was used as criteria based on findings from Watterson and Lewis (2006) and Watterson et al. (2005), which reported that removal and repositioning of the headgear adds approximately 5 points of variability to the subject performance.

The primary goal of this study was to establish normative values for bilingual Mandarin-English speakers and compare normative values to values previously reported among monolingual Mandarin speakers. Mean nasalance scores for the Mandarin stimuli of bilingual speakers are as follows: Mandarin oral sentence (M = 17.64, SD = 7.33), oro-nasal sentence (M = 54.62, SD = 7.81), and nasal sentence (M = 68.73, SD = 8.09). Mean nasalance scores for the English stimuli of bilingual speakers are as follows: English oral sentence (M = 20.02, SD = 7.83), oro-nasal sentence (M = 58.71, SD = 7.59), and nasal sentence (M = 65.27, SD = 7.45).

The results of the one sample *t*-test (Table 2) showed significant difference in the Mandarin oral, $t(44) = -9.326$, $p < .001$, oro-nasal, $t(44) = 7.645$, $p < .001$, and nasal sentence stimuli, $t(44) = 12.132$, $p < .001$ between bilingual speakers in the present study compared to mean values for monolingual Mandarin speakers investigated by Kim et al. (2016). Nasal and oro-nasal sentences were produced with a greater amount of nasalance in the present study compared to mean values reported by Kim et al. (2016) for monolingual speakers. In contrast, oral sentences were produced with less nasalance in the present study. Comparison of vowels /i/

and /u/ produced by Mandarin bilinguals in our study showed a significant difference ($p < .05$) compared to the mean values spoken by Mandarin monolingual speakers in the comparison study (Kim et al., 2016). The vowel /ɑ/ was the only stimuli that showed no significant difference between bilingual (present study) and monolingual (Kim et al., 2016) Mandarin speakers, $t(44) = 1.089$, $p = .282$. Bilingual speakers from the present study produced the /i/ vowel with greater nasalance and /u/ with less nasalance compared to that of monolingual speakers in the study by Kim et al. (2016).

The second aim of this study was to evaluate the effect of sex, age, dialect, and language proficiency on nasalance scores. Given the sparse distribution of self-reported dialects spoken by participants in the present study, dialectal regions were organized into three major groups based on the suggested divisions of main Chinese dialects by Huang and Liao (1983) and Guo (2012). The three major groups are as follows: south (n = 19), east (n = 13) and other (n = 13). The dialects from the south included Yue (n = 1), Hunan (n = 3), Minnan (n = 2), Chaoshan (n = 1), Henan (n = 3), and Hubei dialects (n = 9). The dialects from the east included Shanghainese (n = 3), Anhui (n = 2), Jiangsu (n = 7), and Zhejiang dialects (n = 1). The other dialects included Tianjin (n = 1), Hebei (n = 2), and no reported dialect (n = 13).

The male participants showed lower mean nasalance scores compared to female participants for the sentence stimuli. Mean nasalance scores for the English stimuli of male participants are as follows: English oral sentence (M = 19.45, SD = 9.70), oro-nasal sentence (M = 55.95, SD = 8.67), and nasal sentence (M = 61.5, SD = 8.18). This can be compared to the mean nasalance scores for the English stimuli of female participants as follows: English oral sentence (M = 20.48, SD = 6.10), oro-nasal sentence (M = 60.92, SD = 5.88), and nasal sentence (M = 68.40, SD = 5.07). A repeated measures ANOVA showed a significant sex difference, F(1,

38) = 5.016, *p* =.031, in nasalance scores for English sentence stimuli spoken by bilingual speakers, in which females displayed a greater degree of nasalance compared to males. There was a significant interaction effect for stimulus type (oral, nasal, and oro-nasal sentences) and sex, $F(2,76) = 5.028$, $p = .009$. The interaction effect between stimulus type and sex are plotted on the graphs displayed in Figure 1. Males and females showed similar nasalance values for English and Mandarin oral sentences. Males showed lower nasalance scores for oro-nasal sentences and nasal sentences in both English and Mandarin when compared to females. There were no other significant main effects from age, language proficiency, or dialect ($p > .05$).

The repeated measures ANOVA assessing Mandarin sentence stimuli, similarly showed a significant sex difference, $F(1,38) = 4.499$, $p = .040$, in nasalance scores, in which females displayed a greater degree of nasalance compared to males with the exception of oral sentences. Mean nasalance scores for the Mandarin stimuli of male participants are as follows: Mandarin oral sentence (M = 17.75, SD = 8.95), oro-nasal sentence (M = 51.25, SD = 8.50), and nasal sentence (M = 64.60, SD = 8.72). This can be compared to the mean nasalance scores for the Mandarin stimuli of female participants as follows: Mandarin oral sentence (M = 17.56, SD = 5.92), oro-nasal sentence (M = 57.32, SD = 6.12), and nasal sentence (M = 72.04, SD = 5.84).

Also, there was a significant interaction for stimulus type and sex, $F(2, 76) = 10.909$, $p < .001$. There were no other significant interaction effects from age, language proficiency, or dialect ($p > .05$). An independent samples t-test was used to evaluate the sex effects on vowel productions between both languages. No significant sex effect was observed for the vowels /a/, $t(43) = -1.454$, $p = .153$, /u/, $t(43) = -1.025$, $p = .311$. However, there was a significant sex effect for the Mandarin vowel /i/, $t(43) = -2.664$, $p = .011$.

DISCUSSION

To the best of our knowledge, this is the first study to report normative nasalance values using the Nasometer among bilingual Mandarin-English speakers from mainland China living in the United States. English and Mandarin mean nasalance scores are presented for sentence-level and vowel productions. Compared to other studies of nasalance in native Mandarin speakers, values for oro-nasal and nasal sentences were slightly higher in the present study (Table 4). Dialectal, age, and instrumentation differences should be considered when comparing nasalance scores between these studies. Compared to nasalance values in the present study, Tsai et al. (2012) reported lower nasalance scores for the oral passages in Mandarin collected from ten bilingual Mandarin-English adult speakers from Taiwan. The study among children by Luo (1992) and Lim (2011) reported oral scores consistent with those in the present study. The difference between the Nasometer II 6450 used in this study and the Nasometer 6200 in Luo's study should be considered (De Boer and Bressmann, 2014), although Watterson, Lewis, and Brancamp (2005) observed no significant difference between Nasometer models. Variable stimuli used across the studies likely had the greatest impact on the differences in nasalance noted across stimuli. Mandarin stimuli in the present study were consistent with those reported by Kim et al. (2016).

Scores reported in the present study for the sentence stimuli were significantly different from scores reported in monolingual Mandarin speakers in the study by Kim et al. (2016). However, it is important to note that values reported by Kim et al. (2016) were obtained from the NasalView, whereas the present study used a Nasometer. Differences may be related to the varied instruments between comparison studies. Significant differences were also noted for vowel productions between bilingual speakers (present study) and monolingual Mandarin speakers (comparison study, Kim et al., 2016). However, trends for a greater or lower amount of nasalance were not consistent across stimuli. Specifically, some stimuli were produced with a greater amount of nasalance (/i/, oro-nasal sentences, nasal sentences) among bilingual speakers in the present study whereas other stimuli (oral sentences and /u/) were produced with less nasality compared to mean values reported by Kim et al. (2016). Differences between nasalance scores between the two speaker groups may be related to the effects of a L2 on the phonetic production and subsystem of the L1. Flege et al. (2003) observed that the phonetic subsystems of the L1 did influence production of the phonemes in the L2 in vowels produced by Italian-English bilingual speakers. Kuehn and Moon (1998) and Rochet and Yanmei (1992) observed that tongue position has a significant influence on vowel nasalance. This finding is not surprising as both oropharyngeal aperture (velopharyngeal port opening) and tongue constriction (oral cavity closing) are primary components of oral/nasal balance. It is possible that the differences between monolingual and bilingual Mandarin speakers can be attributed to these effects on the individuals' primary language, specifically the tongue position and resultant nasalance during vowel production. Future research is needed to examine this possible relationship.

Differences in nasalance scores between the two speaker groups (monolingual and bilingual) are likely related to, in part, the variations in the methods. Kim et al. (2016) used the NasalView while the present study utilized the Nasometer. The 4-6% variation between the Nasometer and NasalView should be considered when comparing scores. Bressmann (2005) reported that nasalance scores of sentences collected using the Nasometer and NasalView fell within 6% of each other. Additionally, Kim et al. (2016) used visually presented characters, whereas the present study elicited the vowel auditorily to the participant. The speaker whose voice was recorded for the stimuli was a bilingual Mandarin-English speaker and not a monolingual Mandarin speaker. Therefore, it is difficult to ascertain if the spoken vowels were more reflective of one's ability to repeat the sound they heard or if the vowels were reflective of the participant's typical production of that spoken Chinese vowel.

The second aim of this study was to evaluate the impact of sex, age, and dialect on nasalance among bilingual Mandarin-English speakers. Our results of higher nasalance scores among females compared to males is consistent with previous studies (e.g., Seaver et al., 1991; Park et al., 2014; Kim et al., 2016), including investigations of Mandarin (Kim et al., 2016). However, such sex effects of nasalance have not been observed in all studies using languages other than Mandarin (e.g., Dalston and Seaver 1992; Okalidou et al., 2011; Lee and Browne, 2012; El-Kassabi et al., 2015). The observed sex differences could be reflecting either a physiological difference, as males tend to generate higher levels of peak intraoral air pressure leading to decreased nasalance scores, or to as yet undescribed differences in gendered speech production (Zajac and Mayo, 1996).

The statistically significant interaction between sex and type of stimuli suggest that differences in nasalance depends on the type of stimulus and such differences are sex-specific. These sex-specific variations in nasalance by stimulus type may be attributed to sensitivity variations in frequency response of the Nasometer microphones, which interact differently within the frequency range of females compared to males (Zajac et al., 1996). This interaction may not be clinically applicable for children, as previous literature demonstrated no effect of sex on nasalance scores for children (Bettens et al., 2017).

Previous studies have indicated significant variation in nasalance between differing dialects (e.g., Awan et al., 2015; Kim et al., 2016). Kim et al. (2016) reported significantly different means for four cities in China—Beijing, Chongqing, Guangzhou, and Shanghai. The dialect background in the present study was grouped by larger geographical regions rather than cities. Therefore, greater variation is expected within each of the four dialect groups. In the current study, dialect did not influence the mean nasalance score for any of the speech materials, nor was there an interaction effect with sex or age. A more robust sample of data collected from a larger participant pool representative of each region would provide valuable data that could be used to evaluate the effect of native dialect on nasalance scores.

Clinical Implications

The mean nasalance scores in the present study can be a useful reference for preliminary normative nasalance scores of native Mandarin-speaking adults, as scores for the Nasometer II has not previously been reported. However, creation of a normative database would require a significant increase in sample size with consideration to regional dialect differences. Therefore, culturally and linguistically appropriate speech stimuli should be used with normative data reported for each specific population. The results of the second aim show that sex differences should be accounted for when reporting nasalance scores.

Given the observed age effect on nasalance when comparing children to adults (e.g., Park et al., 2014; El-Kassabi et al., 2015), values from the present study may not be directly applicable to the clinical pediatric population. Future research should investigate this suspected age effect and to produce normative values in a more clinically relevant age. Future research is necessary to determine if these sex differences are evident in children and whether the observed differences are more closely aligned with sex-based maturation or with the acquisition of gendered speech behaviors.

This study was limited by the small sample size and would benefit from a larger sample to establish normative data. Additionally, a larger sample would more accurately reflect the effect of native dialect on nasalance scores. Future research is needed to compare results from the present study with nasalance values obtained using more traditional stimuli (e.g., Zoo Passage). The vowels were elicited without visual representation for the English and Mandarin speech stimuli. The method of presentation by repetition may not accurately reflect speakers' typical production of vowel but rather the ability of the speaker to repeat what they heard. Future studies can compare differences in nasalance scores collected between reading and repetition of speech tasks using the same stimuli. The study reported nasalance scores from adults (ages 20-54), consequently, the nasalance scores may not be clinically relevant for children due to age differences. Consideration should be given to produce a simplified stimulus set using words and syllables, such as the Simplified Nasometric Assessment Procedures (SNAP Test), developed and standardized for children (Kummer, 1994). Further studies should report nasalance scores for Mandarin-English speaking children with the same speech stimuli.

CONCLUSION

Results from this study present normative nasalance values for bilingual Mandarin-English speakers living in the United States. Values for bilingual Mandarin-English speakers in the present study were significantly different for monolingual speakers reported by Kim et al. (2016), with the exception of one vowel production. This may be related to the presentation method for eliciting the vowel productions. Similar to other published studies, sex had a significant impact on nasalance scores with males showing lower nasalance values compared to females. Dialect, age, and language proficiency had no effect on the nasalance values obtained among the bilingual speakers in the present study.

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Table 1. Frequency of occurrence for Mandarin and English consonants and vowels included in the sentence speech stimuli are reported. The percentage of nasal consonants was calculated as the number of nasal consonants divided by the number of total consonants. The percentage of nasal phonemes was calculated as the number of nasal phonemes divided by the number of total phonemes. Classification of Standard Mandarin vowel position are consistent with vowels reported by Lee and Zee (2003) and Catford et al. (1974). Diphthongs were classified based on their initiating vowel (Dow, 1972). Mandarin high vowels include /i, e, u, ü, ɻ̩, o/, mid vowels include /ə/, low vowels include /ɑ/. English high vowels include /i, ɪ, u, ʊ/, mid vowels include /e, ɛ ʌ, ə, ɚ, o, ɔ/, low vowels include /æ, ɑ/.

	Nasal Consonants	Nasal Phonemes	High Vowels	Mid Vowels	Low Vowels
Oral Sentence					
Mandarin	0% (0/15)	0% (0/31)	43.8% (7/16)	25.0% (4/16)	31.3% (5/16)
English	0% (0/21)	0% (0/37)	43.8% (7/16)	43.8% (7/16)	12.5% (2/16)
Oro-nasal Sentence					
Mandarin	55.6% (10/18)	29.4% (10/34)	37.5% (6/16)	25.0% (4/16)	31.3% (5/16)
English	47.6% (10/21)	27.0% (10/37)	62.5% (10/16)	31.3% (5/16)	18.8% (3/16)
Nasal Sentence					
Mandarin	100% (21/21)	56.8% (21/37)	50.0% (8/16)	12.5% (2/16)	37.5% (6/16)
English	93.8% (15/16)	46.9% (15/32)	18.8% (3/16)	37.5% (6/16)	43.8% (7/16)

Table 2. Results of One Sample t-test for Comparison of Mean Nasalance Scores of Monolingual and Bilingual Mandarin Speakers

Speech Stimuli	**Mean (Standard Deviation)**				
	Monolingual Mandarin Speakers (Kim et al., 2016)	**Bilingual Mandarin-English Speakers**	**Mean difference**	***t-value***	***p-value***
Oral Sentence	27.84 (6.31)	17.64 (7.33)	20.74	4.067	0.154
Oro-nasal Sentence	45.72 (6.21)	54.62 (7.81)	48.17	10.825	0.059
Nasal Sentence	54.10 (6.02)	68.73 (8.09)	59.42	8.122	0.078
/a/ vowel	31.45 (8.06)	33.98 (15.57)	30.72	24.281	0.026*
/i/ vowel	37.21 (11.38)	47.18 (19.18)	40.20	8.063	0.079
/u/ vowel	26.24 (8.08)	15.51 (12.66)	18.89	3.518	0.176

*$p < 0.05$

Table 3. Results of Repeated Measures ANOVA for Effects of Sex, Age and Dialect on Nasalance Scores with Three Types of Stimuli (Oral, nasal, and oro-nasal sentences)

	Type III Sum of Squares	**df**	**Mean Square**	***F-value***	***p-value***
English Stimuli (Sphericity Assumed)					
Sex	655.092	1	655.082	5.016	< .001*
Dialect	34.072	3	11.357	.087	.031
Age	231.012	1	231.012	1.769	.967
Language proficiency	.685	1	.685	.005	.191
Stimulus type * sex	183.532	2	91.766	5.028	.009*
Stimulus type * dialect	69.183	6	11.531	.632	.704
Stimulus type * age	19.097	2	9.549	.523	.595
Stimulus type * language proficiency	33.457	2	16.729	.917	.404
Mandarin Stimuli (Sphericity Assumed)					
Sex	625.956	1	625.956	4.499	< .001*
Dialect	60.624	3	20.208	.145	.040
Age	140.469	1	140.469	1.010	.932
Language proficiency	9.334	1	9.334	.067	.321
Stimulus type * sex	320.095	2	160.048	10.909	.000*
Stimulus type * dialect	164.008	6	27.335	1.863	.098
Stimulus type * age	33.159	2	16.580	1.130	.328
Stimulus type * language proficiency	38.233	2	19.116	1.303	.278

*$p < 0.05$

Table 4. Comparison of Mandarin Chinese Nasalance Scores

Study	Instrument	Oral	Oro-nasal	Nasal
Pua et al.	Nasometer II 6450	17.64 (SD=7.33)	54.62 (SD=7.81)	68.73 (SD=7.45)
Tsai et al. (2012)	Nasometer II 6400	11.80 (SD=4.1)		53.80 (SD=7.4)
Kim et al. (2016)	NasalView	27.84 (SD=6.31)	45.72 (SD=6.21)	54.10 (SD=6.02)
Luo (1992)	Nasometer 6200	<50%		<70
Lim (2011)	Nasometer (unspecified)	16.08 (SD=2.57)	25.20 (SD=3.63)	55.44 (SD=4.17)

Abbreviation: SD, standard deviation

Figure 1. Comparison of Interaction between Sex for Mean Nasalance Scores with Three Types of Stimuli (Oral, nasal, and oro-nasal sentences)