COMPARISON OF NASALANCE VALUES OBTAINED FROM NASALITY VISUALIZATION SYSTEM AND NASOMETER II

[1]Madhu Sudarshan Reddy B., [2]Sheela S. & [3]Gopi Kishore Pebbili

Abstract

This study was designed to compare nasalance scores obtained with the Nasality visualization system (NVS) and Nasometer II (NM), and to evaluate test-retest reliability of nasalance scores on each of these instruments. Twenty two adult females, without any resonance or articulation disorders, in the age range of 17 to 25 years were considered for the study. Nasalance values were obtained using NVS and NM for the stimuli vowels (/a/, i// and /u/), syllables (/pa/, /ta/, /ka/, /ba/, /da/ and /ga/), eight oral and eight nasal sentences. Following familiarization task, the participants were instructed to read the stimuli with the headset/separator handle for the actual recording. Results indicated trends of increase in nasalance values with increase in vowel height, place of articulation moving backward in the oral tract, and voicing. Paired sample t test revealed significant difference between the nasalance measured by NVS and NM instruments across all the stimuli at $p < 0.05$ level of significance. Chronbach's alpha revealed good test retest reliability for both NVS and NM for most of the stimuli ($\alpha > 0.70$). From the findings of the study it may be concluded that nasalance values obtained from the Nasometer II and Nasal visualization system are not interchangeable and cannot be compared directly. The normative data, cutoff scores, sensitivity, specificity and other data of NM might not be applicable to nasalance values obtained from NVS and therefore, has to be established separately for NVS. Good test retest reliability obtained in the present study for NVS makes it a reliable nasalance measuring tool for clinical and research purposes. However, further studies investigating diagnostic efficacy using clinical population and correlations of perceptual analysis of nasalance might verify the validity of this instrument.

Keywords: *Nasalence, Velopharyngeal dysfunction*

Normal speech production depends, in part, on the ability to rapidly couple and decouple the nasal cavity from the oral cavity. Nasal speech sounds require oral nasal coupling, oral sounds require oral nasal decoupling. The process of coupling and decoupling the oral and nasal cavities for speech is called velopharyngeal valving. This valving is controlled by elevation of the velum and constriction of the pharyngeal walls. However, persons with structural anomalies such as cleft palate and with neuromuscular disorders such as dysarthria face difficulty in maintaining adequate velopharyngeal valving, also known as velopharyngeal dysfunction. Velopharyngeal dysfunction or presence of passages between oral and nasal chambers such as caused by cleft may result in excessive nasal resonance in the speech (hypernasality). Hyponasality is another condition characterized by reduced nasal resonance in speech. It may result from the conditions such as blocked nose associated with nasal congestion due to common cold or due to anatomical condition such as deviation of nasal septum. It is essential to have sensitive tools to assess these individuals with deviant nasality and to make appropriate treatment decisions. Nasalance is the proportion of nasal energy to the total acoustic energy in a speech signal. It allows the speech-language pathologist to substantiate the perceptual assessment and to provide a quantitative measure of perceived nasality. Nasalance measure acts as a supplement for the speech evaluation of individuals with resonance disorders resulting from cleft palate and other craniofacial disorders.

Spectrography has been applied extensively by a number of researchers (Curtis, 1942; Hattori et al., 1958; Fant, 1960; and Dickson, 1962) in studies designed to specify the acoustic characteristics of hypernasality. Oral-nasal sound pressure levels (SPL) have been studied by several researchers seeking correlates of perceived hypernasality. This technique uses microphones to record oral and nasal sound pressure levels. Weiss (1954) employed probe microphones to measure oral and nasal SPLs during speech. The first instrument to measure oral and nasal acoustic energy was first developed by Samuel Fletcher in 1970. This instrument is called TONAR, which is an acronym for Oral Nasal acoustic ratio (Fletcher

[1]Student, All India Institute of Speech and Hearing (AIISH), Mysore-06, Email: madhusudarshan@rocketmail.com, [2]Research officer, AIISH, Mysore-06, Email: sheela.mslp@gmail.com & [3]Lecturer in Speech Pathology, AIISH, Mysore-06, Email: gopiaslp@gmail.com

& Bishop 1970). The TONAR was later updated, revised and then renamed as TONAR II (Fletcher, 1976a, 1976b). Since its introduction, numerous investigations have been conducted to evaluate the validity and reliability of nasalance scores (e.g., Fletcher and Bishop, 1970; Fletcher, 1978; Dalston et al., 1991; Dalston and Seaver, 1992; Hardin et al., 1992; Karnell, 1995; Watterson et al., 1998, 1999; Lewis et al., 2000).

The TONAR did not employ acoustic filtering, however it was modified to include filtering based on the data from Fletcher and Bishop (1970); Fletcher, (1978), which suggested that filtering optimizes agreement between listener judgments of nasality and nasalance scores.

The Nasometer 6200 (Kay Elemetrics Corp., Lincoln Park, NJ) was developed by Fletcher, Adams, McCutcheon in 1987, and it is commonly used in the assessment of hypernasal speech (e.g., Kummer, 2001). It was a development of the TONAR II (S G Fletcher, Adams, & McCutcheon, 1989). The Nasometer 6200 comprises a headset with a sound-separator plate and two microphones. An analog preamplifier filters the signal with a bandwidth of 300 Hz around a 500 Hz center frequency. The filtered signal is then converted to DC voltage and fed to the application software for further analysis.

Nasometer II, Model 6450 (Kay Pentax), is the newest hardware/software version of the Nasometer 6200 developed in the year 2002. Although the Nasometer II is similar to the old Nasometer, it is also different in ways that may introduce variability in nasalance scores between the new machine and its predecessor. First, the new Nasometer II is a hybrid that uses both digital and analog circuitry, whereas the old Nasometer uses only analog circuitry. In both Nasometers, the oral and nasal acoustic waveforms are filtered as analog signals with a 300 Hz band-pass filter having a center frequency of 500 Hz. However, the Nasometer II converts the analog signals to digital signals after filtering, but before computing, the nasalance score. Second, the old Nasometer reports nasalance scores to the second decimal place, whereas the Nasometer II reports nasalance scores rounded to the nearest whole number.

The Oro Nasal system (Glottal Enterprises Inc., Syracuse, NY) is another instrument developed for the measurement of nasality. It uses a handheld circumvented facial mask with a soft sound-separation plate that is held against the patient's face. Two microphones positioned in the separate nasal and oral compartments of the mask record the patient's speech. These microphones are mounted inside the handle case, which also contains the preamplifier. The microphones are located at the end of two plastic tubes (about 1 cm in length and 2 mm in diameter) that hold the soft facial mask in place. Software and handling of the OroNasal system are comparable to those of the Nasometer and the Nasal View. Recordings are made in 16-bit quality with a sampling rate that can be set to either 11.25 or 22.5 kHz.

Glottal Enterprises Inc., (Syracuse, NY) in 2005 introduced Nasality Visualization System (NVS) which is an advanced version of the Oro Nasal system. It provides the nasalance measurement through Nasalance System (NAS) and Nasal air emission measurement through the Nasal Emission System (NEM). The instrument uses Rothenberg's dual-chamber circumvented airflow mask for recording and analyzing nasalance and nasal air emissions. NVS provides many user-friendly features such as USB operation, color-differentiated display that clearly separates vowels, unvoiced consonants and nasal consonants. *It has an additional feature to eliminate* nasal consonants from the average-nasalance computation. Further, this instrument uses a separator handle rather than head straps for the *measurement of nasalance.*

Orienting nasalance values for the Nasometer have been established for speaker groups of variable sizes and compositions for North American English (Seaver et al., 1991), Spanish-speaking females (Anderson, 1996), Australian English (Van Doorn and Purcell, 1998), Mid-West Japanese (Tachimura et al., 2000), German (Mu¨ller et al. 2000), Cantonese-speaking females (Whitehill, 2001), and young Flemish adults (Van Lierde et al., 2001). In a preliminary study by Awan (1998) with a total of 181 normal participants, measurements obtained with the Nasal View differed from measurements made with the Nasometer. Mean nasalance scores measured with the Nasal View were higher for non-nasal stimuli and lower for nasal stimuli in comparison to the Nasometer. Awan (1998) attributed this finding to the fact that the signal in the Nasal View is not band pass filtered, as it is in the Nasometer. The mean differences between repeated measurements were within a 2% to 3% range of nasalance for both instruments. However, Awan did not report whether the observed differences in nasalance magnitude as obtained with the Nasometer and the Nasal View were statistically significant. It should also be noted that Awan (1998) used a prototype version of the NasalView that was only capable of 8-bit s ignal encoding, as opposed to the current 16-bit version.

Lewis and Watterson (2003) compared nasalance scores from the Nasometer and the current Nasal View with 16-bit resolution for five test sentences that were loaded with different vowels (Lewis et al., 2000). The authors concluded that nasalance scores from the NasalView are qualitatively and quantitatively different from those of the Nasometer. The study by Bressmann (2005) has compared nasalance scores in normal participants for three systems Nasometer, the Nasal View, and the Oro Nasal System. Results indicated that Nasometer had the lowest nasalance scores for the non-nasal Zoo Passage. The Nasal View had the highest nasalance scores for the phonetically balanced Rainbow Passage. The OroNasal System had the lowest nasalance scores for the Nasal Sentences.

Subject test-retest variability has been evaluated previously in several studies using the old Nasometer (Seaver et al., 1991; Litzaw and Dalston, 1992; Kavanagh et al., 1994; Mayo et al., 1996; Van Doorn and Purcell, 1998). Seaver et al. (1991) evaluated test-retest variability in 40 subjects with normal speech by asking each subject to read each of three passages, three times in succession. The three passages were the Zoo Passage, the Rainbow Passage, and the Nasal Sentences. Cumulative frequency distributions showed that 97% of the nasalance scores for any single reading of the Zoo Passage were within three nasalance points of any other reading of that passage. For the Rainbow Passage, 91% were within three nasalance points, and for the Nasal Sentences, 94% were within three nasalance points. These data indicate minimal within-subject performance variability. Kavanagh et al. (1994) evaluated test-retest variability in nasalance scores after removing and replacing the Nasometer headgear. In this study, 52 adults with normal speech were asked to read each of the three standard passages three times, but between the second and third reading, the headgear was removed and replaced. Analysis of variance (ANOVA) showed no significant difference between any readings of the Zoo Passage or the Rainbow Passage, but there was a significant difference between the first and third readings of the Nasal Sentences. Cumulative frequency data were not reported.

To summarize, the instrumental means for assessing hypernasality and other resonance disorders have been gradually evolving and are gaining in popularity. As the evolution progress towards the replacement of old machines or invention of new machines, it will be critical for clinical purposes to find out normative data or to know exactly how the two machines compare. Can a clinician obtain a nasalance score from Nasality visualization system and compare it in a meaningful way with Nasometer II nasalance score? The answer to such questions will remain uncertain until the two machines are compared. According to Bressmann (2005) “The Nasometer is currently the most commonly used instrument for nasalance analysis and has been used for diagnosis and research with a wide variety of different languages and disorders” (p. 425).

However, the Nasality visualization system may be an affordable alternate for clinicians and institutions with added advantages of user friendliness. Hence, it is essential to investigate whether these two instruments provide comparable results. Further, since the Nasality visualization system being the newly introduced system, there is no normative or clinical data available. The present study was taken up to answer the research questions (1) does nasalance scores obtained from the Nasality visualization system are comparable to those obtained from the Nasometer II (2) does the obtained difference, if any, be statistically or clinically significant, and (3) whether the two instruments provide similar test-retest reliability?

Aim of the study

The aim of the study was to obtain nasalance values obtained from Nasality visualization system and Nasometer instruments for Vowels, voiced and unvoiced stop consonants in various place of articulation in the context of vowel /a/, sentences (oral and nasal) and to compare the nasalence across the above stimuli; and to establish the test-retest reliability of the measures obtained from Nasality visualization system and Nasometer.

Method

Participants

Twenty two adult females in the age range of 17 to 25 years were considered for the study. All the participants were native speakers of Kannada language. All the participants had reported no history of structural and functional abnormality of the oral mechanism or nasal obstruction or hearing problem. It was ensured that the participants were not suffering from common cold or any other upper respiratory tract infections on the day of testing.

Instrumentation

Nasometer (model 6400 II, Kay Pentax, New Jersey) and Nasal visualization system (Glottal Enterprises) was used to obtain nasalance scores. Nasometer II was calibrated each day prior to the data collection based on the guidelines provided by the manufacturer. Although there is no such calibration function for Nasality visualization system, the input connection and recording level was checked for separator handle based on manufacturer's guidelines. This was performed each day prior to the data collection.

Material

Stimuli in Kannada language consisting of vowels, syllables (CV) and sentences were considered for the study. Vowels /a/, /i/, /u/; syllables with /p/, /t/, /k/, /b/, /d/, /g/ phonemes in the contexts of /a/,/i/,/u/ and sentences including eight oral sentences, eight nasal sentences were considered. Each participant was made to produce a total of 37 stimuli (3vowels x 18 syllables x 16 sentences).

Recording Procedures

All the recordings were made in the quiet chamber, with the participants seated in a comfortable chair. The recordings were obtained from the two instruments on three separate days. While recording with the Nasometer, separator was placed below the subject's nose and above the upper lip and the headset position was adjusted so that the two microphones of the separator will receive the oral and nasal components. For the Nasality visualization system a separator-style measurement handle was used and the position of the handle was adjusted in accordance with the manufacturer's specifications. Five minutes time was provided to each of the participants to get familiarized with the test stimuli. Following familiarization task, the participants were instructed to read the stimuli with the headset/separator handle for the actual recording. They were instructed to start with production of vowels, followed by repetition of CV syllables 3 times each (e.g., pa-pa-pa), finally the oral and nasal sentences at a normal rate, comfortable loudness and pitch. The order of recording on each of the instruments was counter balanced. Second recordings were made in the same session for two instruments to check the test-retest reliability. For Nasometer-II, the headgear was not replaced prior to the second recording.

Measurement of nasalance

Single mean nasalance percentage or nasalance score, was computed by either the nasality visualization system or the Nasometer software. For vowels and sentences the mean nasalance score was analyzed, whereas for CV syllables the mean nasalance score of 3 repeated stimuli (e.g., pa-pa-pa) was taken into consideration. The score for the nasalance were copied to a data sheet by the experimenter and retained for analysis. Thus, the data consists of 74 nasalance scores for each participant (37 using the Nasometer and 37 using the nasality visualization system).

Nasalance scores for each subject were transferred to a data file for statistical analyses. Mean Nasalance scores (%) for the Nasality visualization system and Nasometer II were entered in their original form (to two decimal places). The completed data file was then rechecked against the individual subject data sheets for accuracy of data entry.

Statistical analysis

Statistical Package for Social Sciences (SPSS) version 18.0 (SPSS Inc., Chicago, IL) was used to perform all the statistical analysis. Descriptive statistical measures mean and standard deviation of mean nasalance scores for the all the stimuli were calculated separately for both the instruments. Paired samples t test was performed separately for all the stimuli to verify whether the difference in nasalance scores between the instruments were statistically significant. Within subject repeated measures design was considered for the study. The instrument either Nasometer II or Nasality visualization system and the stimuli (four types) served as the independent variables and the mean nasalance score served as the dependent variable.

Results

1.a. Comparison of nasalance scores with respect to vowels: The mean and standard deviation of nasalance for vowel /a/ was 25.04 (±11.53) and 36.18 (±12.82) respectively with Nasality visualization system and Nasometer instruments. The mean and standard deviation of nasalance for vowel /i/ was 37.09 (±16.91) and 49.68 (±16.53) respectively with Nasality visualization system and Nasometer instruments. The mean and standard deviation of nasalance for vowel /u/ was 18.22 (±12.24) and 23.59 (±14.85) respectively with Nasality visualization system and Nasometer instruments. These results are depicted in figure 1. The nasalance values for the vowels /a/, /i/, and /u/ revealed a trend in which the vowel /i/ had the highest nasalance value followed by vowel /a/ and vowel /u/ had the least nasalance value. This trend was commonly observed with both Nasality visualization system and Nasometer instruments.

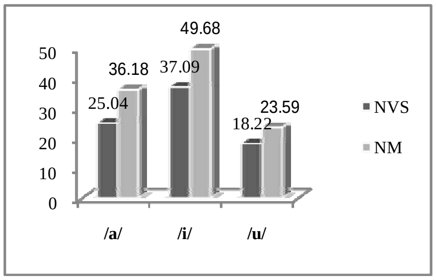

Figure 1: *Mean of nasalance values for vowels /a/, /i/, /u/ with Nasality visualization system (NVS) and Nasometer (NM).*

The mean of the nasalance values for vowels /a/, /i/, and /u/ with Nasality visualization system were lower than that of obtained from Nasometer. This difference is statistically significant at the level of P <0.05 for vowels /a/ and /i/, however, it was not found to be significant for vowel /u/ (Table-1).

Table 1: Statistical significance (p) of difference between nasalance of vowels /a/, /i/, and /u/ obtained with Nasality visualization system (NVS) and Nasometer (NM)

	T	df	Sig. (2-tailed)
NVS /a/ Vs NM /a/	- 4.20	21	0.001
NVS /i/ Vs NM /i/	- 3.75	21	0.001
NVS /u/ Vs NM /u/	- 1.61	21	0.121

1.b. Comparison of nasalance scores with respect to place of articulation and voicing of stop consonants in the context of vowel /a/: The mean and standard deviation of nasalance for /p/ was 12.77 (±8.57) and 17.27 (±8.52) respectively with Nasality visualization system and Nasometer instruments. The mean and standard deviation of nasalance for /t/ was 18.18 (±10.72) and 20.82 (±8.95) respectively with Nasality visualization system and Nasometer instruments. The mean and standard deviation of nasalance for /k/ was 18.14 (±10.96) and 20.23 (±9.99) respectively with Nasality visualization system and Nasometer instruments. The mean and standard deviation of nasalance for /b/ was 30.45 (±12.67) and 27.59 (±13.09) respectively with Nasality visualization system and Nasometer instruments. The mean and standard deviation of nasalance for /d/ was 34.64 (±13.55) and 31.27 (±11.98) respectively with Nasality visualization system and Nasometer instruments. The mean and standard deviation of nasalance for /g/ was 32.64 (±12.93) and 31.41 (±11.50) respectively with Nasality visualization system and Nasometer instruments. These results are depicted in figure 2.

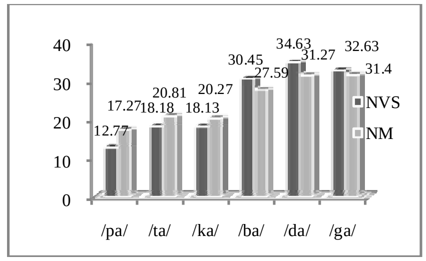

Figure 2: *Mean of nasalance scores for stop consonants with respect to place of articulation and voicing obtained with Nasality visualization system and Nasometer.*

From figure 2 it can be observed that the nasalance values had increased as the place of articulation of the stop consonant moved from bilabial to alveolar or bilabial to velar. This pattern was also observed with voiced stop consonants. Compared to the unvoiced consonants, the voiced consonants (with same place of articulation) obtained higher nasalance values. This trend was commonly observed with both Nasality visualization system and Nasometer instruments. The mean difference of the nasalance values from Nasality visualization system and Nasometer instruments was found statistically significant for /pa/ at p < 0.05 levels. None of the other voiced/unvoiced stop consonants revealed a statistically significant difference between the nasalance values from two instruments. These values are presented in the table 2.

Table 2: Statistical significance (p) of difference between nasalance of unvoiced and voiced stop consonants obtained with Nasality visualization system (NVS) and Nasometer (NM)

	t	df	Sig. (2-tailed)
NVS /pa/ Vs NM /pa/	- 2.41	21	0.02
NVS /ta/ Vs NM /ta/	- 1.42	21	0.16
NVS /ka/ Vs NM /ka/	- 0.91	21	0.37
NVS /ba/ Vs NM /ba/	1.08	21	0.28
NVS /da/ Vs NM /da/	1.16	21	0.25
NVS /ga/ Vs NM /ga/	0.41	21	0.68

1.c. Comparison of nasalance scores with respect to sentences (oral and nasal): The mean and standard deviation of nasalance for oral sentences was 24.80 (±7.88) and 28.27 (±7.87) respectively with Nasality visualization system and Nasometer instruments. The mean and standard deviation of nasalance for nasal sentences was 54.09 (±6.02) and 59.06 (±5.06) respectively with Nasality visualization system and Nasometer instruments. These values are depicted in figure 3. The nasalance values for the nasal sentences were observed to be higher than the oral sentences. This trend was commonly observed with both Nasality visualization system and Nasometer instruments. These results are depicted in figure 3. Paired sample *t* test did not reveal statistic1ally significant difference between the Nasality visualization system and Nasometer for both oral (t = -2.699, p = 0.01) and nasal sentences (t = -3.709, p = 0.001)

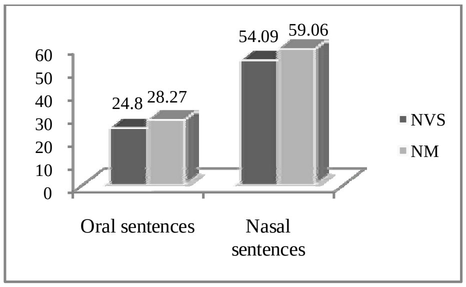

Figure 3: *Mean of nasalance values for oral and nasal sentences obtained with Nasality visualization system (NVS) and Nasometer (NM).*

1.d. Comparison of nasalance scores with respect to all the stimuli: Mean and standard deviations of nasalance score (%) using Nasality visualization system for the stimuli vowels, syllables, oral, nasal sentences were 26.78, 27.35, 24.80, 54.09 respectively. Using Nasometer II, mean nasalance score (%) for vowels, syllables, and oral, nasal sentences were 36.48, 29.85, 28.27, 59.06 respectively. Figure 4 reveals the means and standard deviations for both Nasality visualization system and Nasometer II. Paired sample *t* test revealed significant difference between the nasalance measured by Nasality visualization system and Nasometer instruments across all the stimuli at $p < 0.05$ level of significance (table 3).

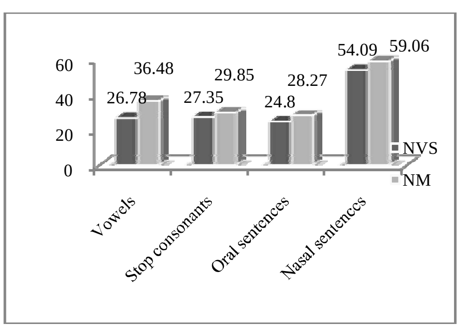

Figure 4: *Statistical significance (p) of difference between nasalance for all the stimuli obtained with Nasality visualization system (NVS) and Nasometer (NM).*

Table 3: Statistical significance (p) of difference between nasalance for all the stimuli obtained with Nasality visualization system (NVS) and Nasometer (NM).

	t	df	Sig. (2-tailed)
NVS-NM (Vowels)	-3.807	21	0.001
NVS-NM (Stop consonants)	-1.656	21	0.113
NVS-NM (Oral Sentences)	-2.699	21	0.013
NVS-NM (Nasal Sentences)	-3.709	21	0.001

2. **Test-retest reliability of the two instruments Nasality visualization system and Nasometer:** Chronbach's alpha for Nasality visualization system indicated acceptable reliability for the vowels (Chronbach's alpha 0.78), good for syllables (Chronbach's alpha 0.87), excellent for nasal sentences (Chronbach's alpha 0.99) but unacceptable for oral sentences (Chronbach's alpha 0.37). Nasometer results indicated excellent Reliability for the vowels (Chronbach's alpha 0.99), acceptable for syllables (Chronbach's alpha 0.76), good for nasal sentences (Chronbach's alpha 0.89), but poor for oral sentences (Chronbach's alpha 0.68). The Chronbach's alpha values for all the stimuli are shown in table 4.

Table 4: *Chronbach's alpha values for Nasality visualization system (NVS) and Nasometer II (NM) across the stimuli.*

	Chronbach's alpha (α) with NVS	Chronbach's alpha(α) With NM
Vowels	0.719*	0.991*
syllables	0.878*	0.769*
Oral sentences	0.370	0.683
Nasal sentences	0.994*	0.896*

* Chronbach's alpha (α) > 0.7 indicate acceptable reliability

Discussion

The purpose of present investigation was to compare nasalance scores for Nasality visualization system and Nasometer II. In the present study the mean nasalance scores were compared between Nasometer II (6400) which is an advanced version of Nasometer (6200) and Nasality visualization system which an advanced version of OroNasal system. Since there is no availability of published studies comparing nasalance scores obtained from Nasality visualization system and Nasometer II, results of the study cannot be compared directly with that of existing literature. The discussion here will be confined to the comparison of trends in nasality with vowel type, place of articulation and voicing of stop consonants and sentence type (oral/nasal) between two instruments.

The results indicated significant difference across vowels with the high nasalance value for the high front vowel /i/ followed by /a/ and /u/ with both Nasality visualization system and Nasometer. These results are in agreement with the previous studies (Mackay & Kummer, 1994; Lewis et al., 2000; Neumann & Dalston, 2001; Gopi Sankar & Pushpavathi, 2008). These authors reported that stimuli weighted with high vowels, especially the high front vowel /i/, produce higher nasalance scores than low vowels on the Nasometer. Gopi Sankar and Pushpavathi (2008) attributed this finding to the articulatory postures assumed during the production of these vowels. The low mid vowel /a/ is an open vowel which creates relatively little resistance to airflow out of the mouth. Therefore the maximum energy is transmitted through the oral cavity. But high vowels /i/ and /u/ impose relatively high resistance to airflow. However, during the production of the /u/ the tongue is placed in close proximity to the velum. This placement may tend to dampen the velar oscillations and thereby reduce acoustic transfer to nasal chamber. Kendrick (2004) provided a physiological explanation for higher nasalance value on vowel /i/. He reported a strong effect of horizontal position of the tongue on the nasalance of vowels.

The mean of the nasalance values for vowels /a/, /i/, and /u/ with Nasality visualization system were significantly lower than that of obtained from Nasometer. This may be attributed to the difference in filter characteristics between two instruments. The Nasometer measures sound intensity in a 300-Hz band around a centre frequency of 500 Hz. Thus, most acoustic energy measured by the Nasometer would be associated with vowels and primarily just the first formant of vowels (Lewis and Watterson, 2003). Whereas the Nasality visualization system features the calculation of nasalance from the amplitudes of the nasal and oral voice components at the voice fundamental frequency, Fo. Therefore the resulting 'Fo Nasalance' is less dependent on the particular vowel sound being spoken. Whereas the Nasometer uses a nasalance ratio derived from sound pressure energy in the first formant (the F1 Nasalance) as proposed by Fletcher and Daly (1976) and implemented in his TONAR 2 and in the Kay Elemetrics Nasometer (User Manual, Nasality tutor, Glottal Enterprises, Inc. 2008).

The results of the present study indicated a trend of increase in nasalance values as the place of articulation moved from bilabials to alveolars and bilabials to velars for stop consonants. This trend was observed with both Nasality visualization system and Nasometer instruments. These findings are in agreement with the study by Gopi Sankar and Pushpavathi (2008). These authors using Nasometer II instrument reported higher nasalance values for /k/compared to /t/ and /p/. That is, the nasalance value increased as the place of articulation moved backward in the oral tract. None of the other studies had used the nasalance scores obtained using syllables for comparing the instruments.

Comparison of the nasalance scores obtained using both oral and nasal sentences revealed significant difference between two instruments at $p<0.05$ level of significance. When the instruments were compared for nasalance values across all the stimuli i.e. vowels (average of /a/, i// and /u/), syllables (average of /pa/, /ta/, /ka/, /ba/, /da/ and /ga/), the Nasometer II revealed higher nasalance values than the Nasality visualization system. This finding may be attributed to the difference in the filter settings of the two instruments. However, the nasalance for stop consonants in the context of vowel /a/ was not found to be differing between the instruments.

Chronbach's alpha reveals good test retest reliability using the Nasality visualization system for three stimuli at a value of $\alpha > 0.70$. However test retest reliability for oral sentences was found to be unacceptable with Chronbach's alpha less than 0.37. Similar results were obtained with Nasometer II, in which test retest reliability was found to be poor for oral sentences with Chronbach's alpha less than 0.70. These results are in agreement with the earlier studies by Awan (1998), Seaver et al. (1991), Bressmann (2005) and Neuman and Dalston (2001) who also reported high test retest reliability for nasalance values obtained from Nasometer. In the present study Nasometer as well as Nasality visualization system revealed acceptable test retest reliability for most of the stimuli. Hence, from these findings it may be concluded that both the instruments Nasometer and Nasality visualization system are comparable at least with respect to the test retest reliability.

Conclusions

The Nasometer II revealed higher nasalance values than the Nasality visualization system with statistically significant difference for the most of the stimuli. Therefore, the Nasalance values from the Nasometer II and Nasal visualization system are not interchangeable and cannot be compared directly. The normative data, cutoff scores, sensitivity, specificity and other data of Nasometer might not be applicable to nasalance values obtained from Nasality visualization system. Hence it is essential to consider the establishment of normative and diagnostic efficacy data for Nasality visualization system in future research. The Nasality visualization system provided good test retest reliability which is comparable to that of Nasometer. This finding reveals Nasality visualization system as reliable equipment for nasalance measurement. However, these findings have to be verified with the clinical data. Further, the nasalance values are clinically useful only when it bears a definable and systematic relationship to the listener perception of nasality in patients. Therefore further studies considering listener's perceptual evaluation and using clinical population are essential to compare the clinical utility of Nasality visualization system. If future studies reveal good validity for Nasality visualization system, considering its user friendly hardware, and relatively economical price, may make it an effective alternate for the existing nasalance measuring equipment.

Acknowledgements

The authors would like to thank the Director, All India Institute of Speech & Hearing, Mysore, for the support and permitting to carry out this study. The authors also thank the participants of the study and finally would like to thank Mr. Gnanvel, Junior Research Fellow, AIISH for his help in data collection.

References

Anderson, R. T. (1996). Nasometric values for normal Spanish-speaking females: Preliminary report. *Cleft Palate Craniofacial Journal*, 33, 333–336.

Awan, S. N. (1996). Development of a low-cost nasalance acquisition system. In Powell, T, ed. *Pathologies of Speech and Language: Contributions of Clinical Phonetics and Linguistics.* New Orleans, LA: International Clinical Linguistics and Phonetics Association, 211–217.

Awan, S. N.(1998). Analysis of nasalance: NasalView. In: Ziegler W, Deger K, eds. *Clinical Phonetics and Linguistics.* London: Whurr-Publishers; 518– 525.

Bressmann, T., Sader, R., Whitehill, T. L., Awan, S. N, Zeilhofer, H. F, Horch, H. H. (2005). Nasalance distance and nasalance ratio: two new measures. *Cleft Palate Craniofacial Journal*, 37, 248–256.

Dalston, R., Warren, D. W., & Dalston. E. (1991). Use of nasometry as a diagnostic tool for identifying patients with velopharyngeal impairment. *Cleft Palate Craniofacial Journal*, 28, 184–188.

Gildersleeve-Neuman, C. E., & Dalston, R. M. (2001). Nasalance scores in noncleft individuals why not zero? *Cleft Palate Craniofacial Journal,* 38, 106–111.

Gopi Sankar, R. & Pushpavathi, M. (2008). Effect of vowels on consonants in nasalance. *Journal of all India institute of speech and hearing, 27,* 3-7.

Fairbanks, G. (1960). *Voice and Articulation Drillbook*, 2nd Ed. New York: Harper and Bros.

Fletcher, S. G. (1978). *Diagnosing Speech Disorders From Cleft Palate.* New York, Grune and Stratton.

Fletcher, S. (1970). Theory and instrumentation for quantitative measurement of nasality. *Cleft Palate journal*, 13, 601–609.

Fletcher, S. G. & Bishop, M. E. (1970). Measurement of nasality with TONAR. *Cleft Palate Journal.*7, 610-621.

Fletcher, S.G., Daly, D.A. (1976). Nasalance in the Utterances of Hearing Impaired Speakers. *Journal of Communication Disorders 9*, 63-73.

Jayakumar, T. (2005). Unpublished research at AIISH, University of Mysore.

Kay Elemetrics Corp. (2003). *Nasometer II Model 6400/6402 Installation, Operations, and Maintenance Manual.*Lincoln Park, NJ: Kay Elemetrics Corp.

Kummer, A. W. (2001). *Cleft Palate and Craniofacial Anomalies.* San Diego: Singular.

Lewis, K. E., Watterson, T., Quint, T. (2000). The effect of vowels on nasalance scores. *Cleft Palate Craniofacacial Journal,* 37, 584–589.

Lewis, K. E., & Watterson, T. (2003). Comparison of nasalance scores obtained from the Nasometer and the NasalView. *Cleft Palate Craniofacacial Journal,* 40, 40–45.

MacKay, I.R., & Kummer, A. W. (1994). *Simplified Nasometric Assessment Procedures.* Lincoln Park, NJ: Kay Elemetrics Corp.

Seaver, E. J., Dalston, R. M., Leeper, H. A., & Adams L. (1991). A study of nasometric values for normal nasal resonance. *Journal of Speech Hearing Research,* 34, 715–721.

Sangeetha, M & Pushpavathi, M. (2008). Nasalence Value for Rainbow Passage: Normative Data for Non- Native Speakers, *Journal of All India Institute of Speech and Hearing,* 27, 22-28.

Tachimura, T., Mori, C., Hirata, S. I., Wada, T. (2000). Nasalance score variation in normal adult Japanese speakers of Mid-West Japanese dialect. *Cleft Palate Craniofacial Journal.* 37, 463–467

Van Lierde, K. M., Wuyts, F.L., De Bodt M, & Van Cauwenberge, P. (2001). Nasometric values for normal nasal resonance in the speech of young Flemish adults. *Cleft Palate Craniofacial Journal,* 38, 112–118.

Van Doorn, J., & Purcell, A.,(1998). Nasalance levels in the speech of normal Australian children. *Cleft Palate Craniofacial Journal,* 35, 287–292.

Watterson, T., Lewis, K., & Deutsch, C., (1998). Nasalance and nasality in low pressure and high pressure speech. *Cleft Palate Craniofacial Journal,* 35, 293–298.

Watterson, T., Lewis, K. E., & Foley-Homan, N. (1999). Effect of stimulus length on nasalance scores. *Cleft Palate Craniofacial Journal,* 36, 243–247.

Whitehill, T. L. (2001) Nasalance measures in Cantonese-speaking women. *Cleft Palate Craniofacial Journal,* 38, 119–125.