EFFECT OF VOCAL TRAINING ON NASALANCE IN INDIVIDUALS WITH VARYING FUNDAMENTAL FREQUENCY AND INTENSITY

Vijaitha V Soonan

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Master of Science (Speech Language Pathology),

University of Mysore, Mysore

ALL INDIA INSTITUTE OF SPEECH AND HEARING

MANASAGANGOTHRI, MYSORE-570006

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CERTIFICATE

This is to certify that this dissertation entitled ***"Effect of Vocal Training on Nasalance in Individuals with varying Fundamental Frequency and Intensity"*** is a bonafide work submitted in part fulfilment for the degree of Master of Science (Speech Language Pathology) of the student Registration No.: 11SLP031. This has been carried out the under guidance of a faculty of this institute and has not been submitted earlier to any other university for the award of any diploma or degree.

Mysore
May, 2013

Dr. S.R. Savithri,
Director,
All India Institute of Speech and Hearing,
Naimisham Campus
Manasagangothri, Mysore – 570006

CERTIFICATE

This is to certify that this dissertation entitled ***"Effect of Vocal Training on Nasalance in Individuals with varying Fundamental Frequency and Intensity"*** has been prepared under my supervision and guidance. It is also certified that this dissertation has not been submitted earlier to any other university for the award of any diploma or degree.

Mysore
May, 2013

Dr. Jayakumar. T
Lecturer
Department of Speech Language Sciences,
All India Institute of Speech and Hearing,
Naimisham Campus
Manasagangothri, Mysore – 570006.

DECLARATION

This is to certify that this master's dissertation entitled ***"Effect of Vocal Training on Nasalance in Individuals with varying Fundamental Frequency and Intensity"*** is the result of my own study under the guidance of **Dr. Jayakumar. T**, Lecturer in Speech Language Sciences, Department of Speech-Language Sciences, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier to any other university for the award of any diploma or degree.

Mysore
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Register No. 11SLP031

DEDICATED TO

MY

BELOVED

DADDY

&

MOMMY

With lots of Love...

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TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

Human spoken language makes use of the ability of a person in a given society to dynamically modulate his/her voice. Production of voice depends on many systems. This includes respiratory, phonatory, articulatory and resonatory systems which in fact have sub systems also. When we analyze each of the system, respiratory system serves as the power supplier in which the lungs provides the air supply, which is the main source for voice production through the branchial arches and the trachea. Breathing in everyday life is a subconscious bodily function which occurs naturally, however the singer must have control of the intake and exhalation of breath to achieve maximum results from their voice. The effort from the respiratory system is high in singing than for what is required for speech. Titze (1994), for singers, he identified four breathing stages which has to be under the conscious control of singers until it becomes reflexial action during singing. The four stages are, a breathe-in period (inhalation), a setting up controls period (suspension), a controlled exhalation period (phonation), and a recovery period. There are many differences between a speaking utterance and the singing. Both the speech and singing have its own intensity and frequency values, but the range of these frequency and intensity values are considerably narrower for speech than it is for singing.

The phonatory system, the larynx, which is the human voice box, produces the laryngeal tone by the adductory and abductory mechanisms of the vocal folds. This laryngeal tone is modified and made audible by the resonators and articulators. The dynamics of the singing voice has many abrupt pitch changes which are in contrast to the speaking utterance, where the pitch change is slow and smooth. Unlike speech, in singing, the vowels have a greater percentage of the total phonation time and there is less co-articulation observed with the surrounding consonants. All this together makes the singing more resonant than the speech.

There are seven areas that may be listed as possible vocal resonators. In sequence from the lowest within the body to the highest, these areas are the chest, the tracheal tree, the larynx itself, the pharynx, the oral cavity, the nasal cavity, and the sinuses. Research has shown that the larynx, the pharynx, the nasal cavity and the oral cavity are the main resonators of vocal sound which gives the maximum sonority to the voice. The main resonating space, from above the vocal folds to the lips is known as the vocal tract. Many voice users experience sensations in the sinuses that may be misconstrued as resonance. However, these sensations are caused by the result of sympathetic vibrations, rather than a cause, of efficient vocal resonance. Because there are a large number of resonators from the subglottal level till the opening of the oral cavity, coupling of resonators are not uncommon, (Birch, 2002; Roy, 2005; Fowler, 2004). There are two identified resonance in the process of singing, the chest resonance and the head resonance, McCoy (2004). Physiologically, in the chest resonance, the thyroarytenoid muscles are more active (Thyroarytenoid- Dominant Production) and the moment there is a transition occurs to the head voice, the cricothyroid muscle becomes active (Cricothyroid- Dominant Production). This mean to say, for singing in the lower registers or lower pitches, the resonance used is primarily chest resonance and for singing in the upper registers or higher pitches, the resonance used is head resonance.

Miller (1993) suggests that as a singer increases the scale or the pitch, there is a change in resonance and the timbre, which could be due to the changes in the laryngeal muscles. A tone lacking in resonance is termed as ineffective, devoid of carrying power, diffuse and unfocused; while a resonant tone, no matter how soft dynamically, has carrying power and is focused in its vibration. Vocal resonance is "the process by which the basic product of phonation is enhanced in timbre and/or intensity by the air-filled cavities through which it passes on its way to the outside air (McKinney, 1994). Various terms related to the resonation process include amplification, enrichment, enlargement, improvement, intensification, and prolongation. These mentioned terms are meant to produce a better sound quality for the utterances produced either by a singer or a speaker. To simplify, one achieves a comparatively better voice quality or a beautiful tone by bringing a resonant voice.

The basic component of music is said to be the sound. Musicologists referred this sound as ‘nada’ which gives rise to ‘shrutis’. ‘Shrutis’ gives rise to ‘swaras’ and ‘swaras’ makes different ‘ragas’ (Vijaya, 1994). Indian classical music got divided after fourteenth century, where now it has two main genres, Hindustani and Carnatic. Hindustani music more refers to music of Northern India and Carnatic Music more refers to the music of Southern India. The two genres have the same basic pillars of the music, the *ragas* and the *talas*. *Ragas* are the melodic form of the music while *talas,* refers to the rhythm of the music.

There are seven *swaras* lies in one octave, or in other words, an octave consists of seven *swaras*. These seven notes of the Indian musical scale include sa, ri, ga, ma, pa, dha, and ni.

A raga can be said as the composition of a minimum of a four to a maximum of seven *swaras*. In Carnatic music, there are several ragas, where *swaras* move in an ascending and a descending order. In the ascending order, the frequencies of the swaras are increasing from the lowest to the highest note. In the descending order, the frequencies of the swaras are decreaing from the highest note to the lowest note. The ascending order is also called as 'arohana' and the descending order is known as 'avarohana'. Every raga will have an arohana and avarohana, as the composition for that particular raga. In Carnatic music there are *complete ragas* or *Melakarta ragas* which have seven *swaras* and several other *Janya ragas*, which has only four to five *swaras*. Once the composition of raga is occurred, the speed in which the raga has to be sung is determined. The generation of ragas can be at different tempos, that is to say, slow, medium and fast where the frequency of the notes in each raga are inter related and a singer is expected to maintain this frequency ratio in all the tempos (Sriram, 1990). In order to gain proficiency and to achieve a good voice, a singer must pass the rigors of practice and thereby bringing out all the deep nuances abounding in the Indian Classical systems of music.

The power of the music is immeasurable to bring out different emotions and enormous impact on the human mind. The ragas have the ability to produce or evoke different emotions to the listeners. For example, if one raga gives the sad feeling, the other can provide a feeling of pleasure. The ragas 'Hamsadhwani', 'Kalyani', 'Shankarabharanam', 'Mohanam' gives the feeling of joy and happiness. The efficiency and the effectiveness of the singer play a major role in evoking the emotions. The professional singers face additional challenges in mastering the techniques behind this.

Hence, most of the time, the professional singers are the one who spend immense time for practices. The demand for the professional singers in the field of music is increasing. The singers have to shape their voice according to the listener's ears and also have to focus in better voice. This makes a professional singer more dedicated and practice oriented to shape their tone appealing to the listeners. The professional singers have to be effectively and qualitatively trained to bring the appealing nature to the singing.

Singers and voice teachers spend enormous time to teach the concept of supported voice quality to their students. This is most of the time confusing to the teachers as well as the students. Griffin (1995) found that certain singers perceive the concept of supported voice quality as ring, vocal formant and focused. Good quality in voice has been described using the terms loud, bright, projective etc. These qualities can only be achieved through competent training. However, the concept of how to shape these peculiarities in a music student and bring these qualities in singing is still different for different musicians and music teachers.

The unresolved question in the field of vocal science is that whether professional singers or the classically trained singers use nasal resonance to increase sonority, or the bright quality of the voice (Fowler, 2004). However, the perceived nasality during singing or speaking is considered to be noisy or unacceptable. Where as one group, the professional singers and the trained classical and Carnatic singers use their nasal resonance to brighten their vocal timbre. The high vocal demands among the group of singers make them use their nasal resonance to a greater extend making their voice more effortless and melodious.

Brown and Behnke (1883) stated that, “the soft palate rises with the ascending scale, the arch between the pillars of the fauces becomes narrower and higher, and the uvula diminishes in size” (Monahan, 1978). An alternation in pitch and intensity may vary the resonance (Van Lierde, 2010). An operative singer needs to have an independent control over pitch and loudness and an excellent training is inevitable to perform good singing activity.

Perna (2008) found that in the voice of tenors, there is an area of confusion with the nasality and the perceived brilliance of the voice. Miller (1993) stated that a singer should not confuse the sympathetic vibrations which happened due to a forward focus, with the actual nasality coming from an opening of the velopharyngeal port. He also talks about the responsibilities of the voice teachers in having a well active knowledge of how to handle or bring the nasality into use in singing. Holbrook Curtis (1896) believed that the nasal resonance could reduce the muscle tension in the laryngeal muscles. McCoy (2004) commented that some singers are trained to effectively use their nasality to encourage the first formant to release its hold on the second harmonic. He also claims nasality may help in navigating the transitions between the registers, but it is a must determinant to the sound quality. This led researchers focused to study the oral-nasal coupling in singing (Birch, 2002; Roy, 2005; Fowler, 2004). Birch, Gumoes, Stavad, Prytz, Bjokner, Sundberg (2002) investigated the velopharyngeal opening in western operatic singers and found that all the singers had an opening of the velum when they go from the lowest registers to the highest registers.

The role of nasal resonance in classically trained and professional singers in building astonishing voice has been widely studied. Vennard (1964) has used the expression ‘nasal resonance’ to designate as a desirable property of the vocal tone, particularly in singers. This term is justified with the help of the fact that the vibratory sensations in the face frequently accompany good voice production. Majority of the music teachers use humming prior to singing for the purpose of inducing desired property to their tones. A German pedagogue proposed that, to produce a beautiful vocal tone, a quantity of air sound must travel through the nose. This opinion agrees with the McCoy (2004) who claimed nasality is must determinant of sound quality. Some singers and teachers of singing believe that the nasal passages and sinuses of the head are the source of the "ring" (a concentration of acoustic energy at around 3,000 Hz) that has been described as an important characteristic in good voice quality (Helmholtz, 1954). Vennard (1967) identified this ring voice quality as fifth formant (singer’s formant) and he found it as important in singing occurs between 2500Hz and 3200Hz. The ring voice quality generated by the resonance effects alone, it calls no vocal effort: the singer achieves audibility without having to generate extra air pressure. Russel (1931) in the x-ray data taken for professional singers found that, the open nasal port in singing during non nasal phonemes did not affect the quality adversely. This explains the fact that there is a nasal resonance used in singing by the singers to bring in a good voice quality. To accomplish this, a long tradition in vocal training is the use of nasal murmur (/ma, mi, mu/) which involves the velopharyngeal opening, and humming prior to singing suggests that an open velum is beneficial in singing (Vennard, 1964; Birch, 2002; Austin, 1997). Keeping these different facts in mind, the manner and the extent of velar adjustments has to be done in order to produce an aesthetically pleasing vocal qualities are to be trained competently. So now it is evident and clear that, there must be an effect of vocal training which plays the role of using the nasal resonance to tune a marvelous melody.

Nafisi (2010) demonstrated a training session to her music students to teach sensation related gestures, where the students are taught to keep their both hands at the cheek bone level with a rounded palm to represent the elevated soft palate and with the fingers forward pointing to make the students sing with a forward focus. Birch (2002) found that, there is a classical use of murmur, that is to initiate vowel phonation as in /ma/, /mi/ and /mu/ or the techniques such as ‘resonant hum’, ‘nasal vowel repetition’ or singing into the mask are commonly used to bring a forward focus during classical singing. Presumably, these techniques may alter the resonatory characteristics to produce a vibratory pattern at the mid face. To make the voice obey the musical impulses is comparatively very hard task and needs an intensive training which is one of the voice requirements of an efficient singer.

The music teachers spend considerably longer time to explain the physiology of the nasal resonance in singing. They believe the perception of nasality in singing to be ineffective and inefficient, but the use of nasal resonance is taught to the students using the terms forward focus, vibrant, round etc. Carnatic singing, which is a wide musical system, commonly associated with the southern part of Indian subcontinent is believed to be a divine and the tradition of singing and practicing classical music is established throughout the nation. The music, which originated and derived from the Vedas consists of a wide range of oral and nasal consonants also, still the music has never been heard as unacceptable or nasal and noisy. So, how much experienced or trained a singer should be to color and brighten their voice when the velum is open or whether professional singer can better able to control the degree of velum movement?

Need of the study

Majority of the studies reveals there is increased velopharyngeal opening with increasing pitch or in the upper registers, and it is negatively correlated with the perceived nasality in the singers (Birch, Gumoes, Stavad, Prytz, Bjokner, Sundberg, 2002; Fowler, 2004; Carlo and Autesserre, 1987).

Research in singers shows that even though the velum is opened when they sing especially at the higher registers and with increased intensity, there voice is not perceived as nasalized, rather the sound quality was more attractive. In the comparison studies of singers and non singers, the sound of non singers were perceived as nasalized at higher registers. The singers seem to have control over their voice when they raise their pitch and vocal intensity, which in turn controls their nasality. Due to this, the voice of singers do not perceive nasalized. The initial murmur of /ma/, /mi/ and /mu/ before singing is an example suggesting velopharyngeal opening is beneficial in singing, on the other hand if nasality is perceived, it is considered as noisy or unacceptable in singing. Many studies had evaluated the velum behavior and its movement while singing, but not so much researches were conducted to find the correlation between the open velum and the perceived quality of the voice. It is also important to find out that, whether the listeners perceiving nasality in singers with the velum being opened when they increase their pitch and vocal intensity. The studies done on the velum movement and the perceptual correlations were in the western operatic singers. There are not many studies conducted in Carnatic singers. Also a very few of the studies described the effect of training and the experience in controlling the nasalance with increasing the pitch and the vocal intensity. Hence, it is necessary to study the influence of vocal training in Carnatic singers which is in fact helping them to control their nasality, and also their ability to use the nasal resonance effectively.

The present study, compare the nasalance values between two groups, the professional singers and the non singers using frequency and intensity variation, which will give the effect of vocal training.

Aim of the study

The present study aims to investigate the effect of vocal training on nasalance with variation in Fundamental Frequency (F0) and Intensity in professional singers and non singers.

Objectives of the study

- To find the effect of vocal training on nasalance with variation in F0 and Intensity.
- To find the effect of vocal training on perceived nasality with variation in F0 and Intensity.
- To find the correlation between perceptual and objective measurements of nasality.

CHAPTER II

REVIEW OF LITERATURE

Singing is not an isolated art. Singing is an act, in which the production of the musical sound is accompanied with the voice, which can augment the regular speech act by giving the tonality and rhythm adding to it. Singing again can be formal or informal, in such a way that, anyone who speaks can sing because singing is a form of sustained speech. The purpose of singing may be different in each individual. It can range from singing for a pleasure or comfort, an educational purpose, for rituals, or to make profits. The song performance can be either alone or with the accompaniment of musical instruments. The music instruments often used in Carnatic classical singing includes venu, gottuvadaym, harmonium, veena, mridangam, kanjira, ghatam, violin, keyboard etc. When singers sing along with the instruments their vocal efforts are increasing.

They have to raise their voice in order to be projective from the musical background instruments with having an independent control over pitch and loudness. Because of this, singers have to take extreme care to maintain their scale or pitch of singing whenever they attempt to sing with greater effort. This situation is more challenging and to handle this kinds of issues are only possible with the help of an effective training. The group singing is also not uncommon as in choirs, of singers with different voice ranges, or with an ensemble with the instrumentalists as in a rock group. Excellence in singing without a vocal fatigue is one of the qualities of professional singers and this may require time, dedication, instruction and training in singing and regular and qualitative practices. If the training and practices are done on a regular basis then the voice is said to be more clear and strong. A professional singer needs to take training and practices throughout their career.

The human voice is produced by vibration of vocal cords which is amplified by cavities of mouth, throat, and nose in the vocal tract. Excellent singing depends on the singer's ability to establish optimum conditions of vocal resonance.

The type of resonant voice quality where the resonance occurs through the nose is referred as nasality. There are no specific muscles in the nasal cavity to adjust the shape of the cavity and hence the sound passing through the cavity is considerably affected by the swelling or shrinking of the mucous membrane.

To explain physiologically, the lowering of the velum (soft palate) allows air to pass through the nasal cavity to bring nasality in the produced utterances. The velopharyngeal port serves to vary the degree of acoustic coupling between the nasal and oral cavities. The velum can be raised to prevent the oral and nasal coupling or it can be dropped to allow a coupling. During the time of lowering also, the major source of output is the oral cavity only, but the sound quality gets a nasal characteristic. The coupling allows certain degree of nasality which is acceptable, but severe nasality is not considered pleasing. She also commented, if no sound flows through the nose, then the perceived sound is possibly an "unacceptable white tone", (Gregg, 1998 & 1999).

The nasal tract has its own resonant frequencies and nasal formants as the oral tract. With the coupling the amplitude of the resonant formant frequencies are reduced and the bandwidth and the frequency increases, House and Stevens (1956). The first formant frequency for the nasal consonant usually occurs at around 300Hz and their anti formants at around 600 Hz. The main characteristic of the spectral properties of the nasal sounds is at around 200Hz to 2500Hz, thus giving more energy concentration on the low frequency regions and little energy to the anti formants (Lieberman and Blumstein, 1988).

Indian classical music is elaborative, vivid and expressive. The octaves are divided into twelve semitones, of which the 'arohana' and 'avarohana' of each raga is derived from the seven notes 'sa', 'ri', 'ga', 'ma', 'pa', 'dha', 'ni', 'sa', in the ascending order and descending order respectively. These seven notes are similar to the Western music's 'do', 're', 'mi', 'fa', 'so', 'la', 'ti', 'do'. The melody of the music depends upon the 'raga' and the rhythm of the music depends upon the 'tala'. The basic component of the music is the sound or nada (musical term).

'Swara' refers to any musical note or interval. 'Swaras' are seven in number. The scale which is chosen within a particular octave is referred to as "shruthi'. Vocal registers are referred as 'sthayi' in musical terms. In an ascending scale of pitch, musicologists consider five registers. They are 'Anu mandara sthayi', 'Mandara sthayi', 'Madhya sthayi', 'Tara sthayi' and 'Ati tara sthayi'. Among these five registers, the middle three registers are widely used. Mandara sthayi corresponds to the chest register, the Madhya sthayi corresponds to the middle register or the neck register and the tara sthayi corresponds to the head register (Vijaya, 1994). The seven notes or the swaras cannot be sung in all the three registers due to physiological constraints or limitations. The singer chose his/her comfortable sthayi or register in which he/she can reach the lower and higher extrimities. With the help of a shruthi box or a tampuru, the Madhya sthayi is decided and soon after the other two registers are automatically defined. The south Indian music which is the Carnatic music is more rhythmically based and structured than the Hindusthani music.

An efficient vocal training and exercises are mandatory to become a vocal athlete. In the present days, there are more number of people who have been trained with various vocal lessons and techniques, and the playback singing gives a wide scope for the expanding singer's population to use their voice effectively. All the singers do not become professional singers, and those who are capable of meeting the increasing demands of the listeners makes the professional singing group. And it includes the efficient and qualitative use of the resonant system which only can develop through a suitable and sufficient training. Professional singers not just sing for their pleasure or satisfaction. They come under the category of 'Elite voice users' where they take singing as their career, in which, their livelihood depends on it. This varies from a music teacher to a stage performer where the singer will have to perform in music bands and troops. They should be able to perform the programs energetic without any voice fatigue regardless of the duration of the music programs. In order to achieve this there must be a good amount of practice behind it. An effective practice is build from the adequate training the person had received. The physiology of singing is entirely different from that of speaking and the singers should have an independent control over pitch and loudness unlike non singers, which makes them efficient. Singers have to cover a wide range of frequencies (low to high), the effective use of subglottic pressure, and controlled manipulations over the resonators. A child with an inborn talent of singing will not be able to do all the above mentioned characteristics without an effective training. Without an adequate training, an attempt to singing like an expert itself can be an abusive behavior and will lead to voice problems. Once good amount of training is received, the next focus of a singer or a music teacher is to build up a good quality to the voice.

Fowler (2004) investigated and compared the nasalance between 36 trained female singers and 36 female non singers by sustaining phonation of /i/, /ae/, /u/, and /a/ for six seconds across three frequency levels. The oro nasal nasality system for measuring nasalance was used. To analyze the intensity and the vocal jitter, Marantz PMD221 audio cassette recorder with an electret condenser microphone connected was attached to the oral vents of the oro nasal mask. Using a digital sound level meter (Radio-Shack 33-2055), intensity calibration tones was monitored. The averages of the comfortable lower and higher pitches of the subjects were selected as the low and high pitch in the study. The mid frequency was selected as the middle point of the low and the high pitch. Non singers groups had more nasalance mean scores in the production of front vowels than the singers. On the other hand, non singers produced slightly lesser mean nasalance scores in the production of back vowels. The singers and the non singers groups displayed less nasalance scores with ascending frequencies. There were no significant difference between the trained singers and the non singers. The difference seen across the back and front vowels were not statistically significant.

Jennings & Kuehn (2008) studied the effect of frequency range, the vowel, the dynamic loudness level and the gender on nasalance in amateur singers and classically trained singers. 21 amateur singers (11 women and 10 men) and 25 singers participated in the study. The singers group consisted of seven sopranos, four mezzo sopranos, three tenors and seven baritones. To obtain the values Nasometer II 6400 by KayPENTAX (Version 2.7, Lincoln Park, NJ) was used. The cardinal vowels /a, e, i, o, u/ were asked to sing in an ascending/descending five-tone scalar passage (warm-ups used in voice lessons). The recordings of the procedures were done in low, mid, and high frequency ranges. The amateur singers had significantly higher nasalance scores than classically trained singers in all ranges and on all vowels except /o/. Within the vowels, the vowel /i/ had the highest nasalance scores. The difference between the nasalance scores between the other two vowels /a/ and /o/ were not statistically significant. Frequency range had a significant effect on nasalance with the highest nasalance score being for the low and mid and high frequency respectively. Authors could not find a statistically significant difference on nasalance scores between the genders in any of the parameters. There was an interaction between gender and vowel and also with frequency range even though it was not statistically significant. As the frequency range increased, the mean nasalance scores for men were increased. For female singers, the mean nasalance scores decreased with increase in frequency. Dynamic loudness level had a significant effect on nasalance for all subject groups except for female majors in the middle and high frequency ranges. The vowel, /i/, received significantly higher nasalance than all of the other vowels. Even though some of the non singers in this study were not able to reach the highest pitch scales, they had nasality more in the lower scales. Hence, the results of the study show that dynamic loudness level, vowel, and level of training in classical singing have a significant effect on nasality.

Perna (2008) aimed to examine whether nasality is present in the singing voice of professional operatic tenors especially in the passagio of chest and head voice. Register from the lowest pitches to the primary register transition is termed as the chest voice. The fundamental frequency extension beyond the primary register transition is termed as the

Full head voice and the passagio is the transition between the registers. Eight professional operatic tenors participated in this study. The acoustic signals were captured and analyzed using Voce-Vista Pro software and it combines power spectrum, spectrographic, audio signal, and electro glottographic signals in real time display. The tenors were asked to sing the words /pinti/, /puntu/ and /panta/ in three different pitches B3 flat, F4 and B4 flat. The results revealed that the tenors sing /i/ vowel with most nasality and /u/ vowel with least nasality. When the tenors started to sing with the head voice resonance, the percentage of nasalance noted was less.

Stemple & Bush (2010) evaluated the perceptual quality of belt voice in 20 musical theatres majors who were all efficient in the singing style belting. Six short excerpts from the belting repertoire and two specified vocalizes were chosen for rating. In order for the perceptual judgment, seven parameters were given. They were loudness, vibrato, ring, timbre, focus, nasality, and registration breaks. To establish the elite and average student belter, the four highest and lowest average scores were used. The perceptual ratings of vibrato and ring were highly correlated to the elite student belter. They correlate well with perceived loudness.

Griffin, Woo, Colton, Casper, & Brewer (1995) analyzed the physiological characteristics of supported singing voice. The aim of his study was to develop a definition to the supported singing voice, which arises due to the difficulty faced by the music and voice teachers in teaching the concept of supported singing voice to their students. The existing literature on this concepts were, the voice which has greater breath support and sustaining capacity can be termed as supported singing voice. The study focused on the physiological characteristics of the singing voice and aerodynamic measurements were carried out along with that the subjects were given questionnaires to be filled to know their concept of supported singing voice. The terms used by the singing teachers and professionals were classified under three main headings, they are, ‘quality’, ‘manageability’ and ‘carrying power’. Under manageability and carrying power, most of the subjects described the breath support, the ability to change and regulate pitch changes with minimum perturbations and the ease of singing a wide range etc to describe the supported singing voice. Under the heading quality, the most of the singers have used the terms, ‘vibrato’, ‘ring’, ‘warm voice’, ‘central core of sound’, ‘clear’, ‘focused’, ‘energized’, ‘consistent’, ‘full bodied’, ‘ ringing tone’ etc. and these terms were again and again used by different singers revealing the importance of nasal resonance in singing. The postulated definition for the supported singing voice was, “The supported singing voice is distinguished by its spectral characteristics and high SPL, and singers produce it by increasing peak airflow and subglottic pressure and making changes in glottal and/or laryngeal configuration”.

Ranjini (2010) aimed to find out the effect of vocal training on the voice of Carnatic classical singers. The study consisted of two groups of participants, 20 female trained singers and 20 beginning singers. Nine parameters were considered for the study. Maximum Phonation Duration, habitual frequency, frequency of base note, singing frequency range, speaking frequency range, maximum frequency range in phonation, number of vibratos, singer’s formant, skewness and kurtosis. Trained singers had more respiratory support and efficiency. Their frequency range was wider when compared to the beginning singers. There was a difference between trained singers and beginning singers in certain parameters which was influenced by the effect of vocal training.

Many questions were raised regarding the use of nasal resonance in professional and trained singing. They have a pleasing, pleasant, energetic voice when compared to untrained singers, while on the other side, less nasalance scores below the normative mean value of the nasalance scores. This ambiguous situation in the field of vocal science paved the way for conducting studies which includes the visualization of velum activity during singing. The velum is the soft and flexible structure which moves alternatively to give oral and nasal resonance for oral and nasal consonants respectively. If visualization of the velum is made possible, then more vivid picture behind the bright tone and the effect of vocal training could be better studied.

Volo, Farnetani, & Troup (1986) observed that velopharyngeal opening may be dependent up on the style of an individual. They had taken the xeroradiographic images of two professionally trained baritone subjects. The singers were instructed to sing all the Italian vowels /a,e,i,o,u/ starting on ‘‘do’’ moving to ‘‘sol’’ and back to ‘‘do’’ in a key of their choosing. Later they sang a two octave arppegio on all the Italian vowels. From the xeroradiographic images the authors found a complete closure of the velopharyngeal for both singers in slower sustained singing, whereas the more florid arpeggios did not.

Carlo & Autesserre (1987) investigated the movement of velum in six professional singers with the phonation of /a/, /i/, /u/ and /ae/ using endoscopy and xero radiography. The study focused upon two questions, first ‘why the velum was in a specific position in the upper register’ and ‘how singers could think that the velum is raised when it is actually in a relatively low position?’ A physiological and perceptually explanation were given regarding the particular position of the velum. Physiologically, pharyngeal tightening in the upper register occurs due to tension of the muscles. In order to avoid the excessive contraction of velar and pharyngeal muscles, singer will adjust the velum in a particular position without letting the velopharyngeal contact occur through the simultaneous action of levator palate and the palate pharyngeus muscle. Perceptually the same voice was rated and those which was sung with a raised velum was rated as flat, crushed, and dull while, those sung with a lowered velum was rated as beautiful, round, and powerful. The authors answered the second question with the help of exo and endo-buccal endoscopy where they found that, in the upper register, the transverse tension of the velum and the stretching of the posterior faucial pillars is being accompanied by the hyper retraction of the uvula. This substantial raising of the uvular area makes singers feel as though they are raising their entire velum.

Troup, Welch & Tronchoni (1989) obtained xerographic images from nine professional sopranos in three singing ranges. The scales of singing were E3 (165 Hz), E4 (330 Hz), E5 (660 Hz), C6 (1000 Hz), and E6 (1320 Hz). The velar patterns varied within the singers. Two singers exhibited an open velopharynx in all the scales, one singer had closed velum across all the scales, and a mixture of closed and open positions were found in the other singers. He concluded saying, as the pitch increases, the oro nasal coupling decreases in his subjects. He also commented certain factors on which the velum is depended. The language, education, style, pitch and the anatomy of the individual influences the velar closure.

Yanagisawa (1991) studied nine professional singers to find out the participation of soft palate in pitch raising. Six voice qualities like, speech, falsetto, cry/sob, twang, belting and opera were given to the singers and they were asked to find their limits of vocal range. Velolaryngeal endoscopy technique was used to find out the supraglottal activity. The results showed that with higher frequencies, the larynx was raised in all the subjects and the soft palate is lifted up and the velopharyngeal port narrowed considerably.

Austin (1997) studied movement of velum during speech and singing in four highly trained classical singers. Speech samples and cardinal vowels at three different pitches were the stimuli for speech and singing task respectively. The area of the velopharyngeal port was monitored with a photo detector as described by Dalston (1982). The duration of velum opening was longer and the degree of opening reduced as the subject goes higher pitch range. One another thing which was evident from the photo detector was, the velopharyngeal port showed a binary behaviour, that is, whenever it assumed the shape of opening, it did not opened to a maximal value, but either opened, or closed.

Many researchers made use of the flow measurements also to have an in depth study of the singing voice. The air from the lungs through larynx has two pathways to the external atmosphere, the oral and the nasal tracts. When the velum is closed or raised, the air goes via the oral tract, and goes through the nasal tract when the velum is opened or lowered. Flow measurements are those which measure the amount of air coming out of either of these cavities, oral or nasal.

Gramming, Nord, Sundberg, & Elliot (1993) investigated the use of the velopharyngeal port in singing. They applied three different analysis techniques, flexible nasofiberoscope, recordings of oral and nasal flow and experiments on a vocal tract model. Four professional singers were selected, two sopranos (F1 and F2), one bass

(Ml), and one baritone (M2). Of these, F1 was an internationally renowned opera singer, F2 an advanced student, also with considerable experience of solo singing, MI an experienced professional opera singer, and M2 a highly experienced singing teacher. The protocol consisted of a number of speaking and singing tasks which included stops, nasals, and vowels: speech samples involving velar activity [punta], singing tasks such as ascending/ descending fifth-wide scales. Soprano F1 showed no evidence of velar opening during the production of scales. Soprano F2 showed a nasal DC (constant) airflow in all tasks indicating a constant velopharyngeal opening. The bass singer M1 also revealed nasal leakage in most of the tasks. Baritone M2 showed no evidence of nasal DC airflow for any of the tasks. Nasofiberoscopic data reveals a small orifice in the velopharyngeal port only at the higher pitch. For the other subjects, the two results correlated. The vertical position of the velum found to change with pitch suggesting velum plays a role of articulator in singing to shape their vocal tract to arrive at the target formant frequencies. In this study, inter individual variability in using velopharynx in singing is evident. Here, soprano F1 was the teacher of Soprano F2, still they exhibited velopharyngeal opening, revealing an imperfect vocal technique which is used in singing.

Birch, Gumoes, Stavad, Prytz, Bjokner, & Sundberg (2002) analysed velopharyngeal opening in 17 professional operatic singers, 3 high sopranos, 3 sopranos, 2 mezzo-sopranos, 3 tenors, 2 baritones, 2 bass-baritones, and 2 basses singing the vowels [a, i, u] as in the stimulus /panta/, /pinti/, and /puntu/ at middle degree of vocal loudness in an ascending scale of seven pitches throughout their pitch range. Three methods were used in the study, nasofiberoscopy for the visualization of the nasopharynx. A divided flow mask was used to measure the oral and nasal airflow. The third method was to compare the level of fundamental in the nasal and oral airflow signals. In airflow measures, in some singers, oral airflow decreased with increasing pitch and they could not find significant nasality probably due to the leakage of the airflow through the mask. Nasofiberoscopic results did not correlated with the airflow measures completely as it showed a velopharyngeal opening. An open velopharynx was observed in high soprano 3, soprano 1, tenor1, while no DC (constant) nasal airflow was measured. This study gives us the information that at higher pitches, singers use their velopharyngeal opening to tune their vocal timbre or to colour their vocal tone and it is evident they have an opened velum while singing at higher pitches.

Roy, Merrill, & David (2005) investigated the status of the velopharyngeal (VP) port during classical singing. They used aeromechanical instrumentation, nasal airflow (ml/s), oral pressure (cm H_2O), and VP orifice area estimates (cm) were studied in 10 classically trained sopranos during singing and speaking. Each participant sang and spoke 3 nonsense words /hampa/, /himpi/, and /humpu/ at 3 loudness levels (loud vs. comfortable vs. soft) and 3 pitches (high vs. comfortable vs. low. In general, nasal airflow, oral pressure, and velopharyngeal area estimates were significantly greater for singing as compared to speech, and nasal airflow was observed during non-nasal sounds in all participants. Anticipatory nasal airflow was observed in 9 of 10 participants for singing and speaking and was significantly greater during the first vowel in /hampa/ versus /himpi/ and /humpu/.

York & McFarlane (1994) had evaluated the effect of vocal loudness on the measurement of nasalance. The participants were 30 young females (21-49 years) with no history of communication disorders. The Zoo passage and the nasal sentences were used as the stimuli. The nasometer was used for the objective measurements of nasalance. The subjects were asked to read the passage in three different intensity levels, the usual conversational voice, soft voice and loud voice. Results revealed that, there was no significant difference observed in the nasalance across different loudness conditions. Researchers concluded saying that, the vocal loudness remained stable with regard to vocal loudness in females with no communication disorders.

Van Lierde, Borsel, Cardinael, Reeckmans & Bonte (2010) studied the impact of pitch and intensity modulation on nasalance scores in subjects with and without cleft palate. The non cleft group consisted of 50 healthy adult (25 men and 25 women) age ranged from 18 to 29 years with a mean age of 22 years. None of the subjects had craniofacial anomalies or velopharyngeal impairment. The cleft group consisted of twenty two children with cleft palate and mild to moderate hypernasality. None of them had cognitive dulling, neurological disorders, or cleft palate associated with syndromes. The subject task was to read the nasometric passages, one oro nasal passage and an oral passage. All subjects were asked to read the two passages at a habitual pitch and loudness followed by reading the same passages at a decreased loudness, without whispering and increased loudness without shouting at an increased pitch and decreased pitch respectively. The Nasometer (model 6200, Kay Elemetrics), a microcomputer- based system manufactured by Kay Elemetrics, was used for recording the nasalance values during each reading task. The results showed lower nasalance scores for the non cleft group in the condition of high intensity and low pitch for both the oral and oro nasal passages, where as for the cleft group, the nasalance scores were low for both the oral and oro nasal passages read at the low pitch. The lower nasalance scores in the non cleft group were attributed to the high intensity values. When subjects spoke with a higher intensity, which would have reduced the nasalance scores, as it increase the oral resonance due to greater degree of oral openness. In the cleft group, lowering of pitch significantly reduced the hypernasality which is due to the increased subglottal pressure as it is used as a compensatory mechanism to reduce hyper nasality. The contraction of both the thyro-arytenoid and the crico-arytenoid muscles together contributed to the elevated subglottic pressure.

Sadjadi, Ali, Farhad, Amiri & Keyhani (2010) aimed to determine the effect of vocal loudness on the nasalance scores of the vowels in normal adults. Also to identify the relationship of these two factors which is the effect of loudness and nasalance. They recruited18 to 28 year old, 65 normal Persian speaking individuals as the participants. To measure the levels of the vocal nasality, the Nasal view software system from the Dr. Speech software suite was used. From the nasalance values of the parameters computed the statistical parameters of average, mean, minimum, and maximum were obtained. Three loudness levels were considered for the study, low, normal and loud. The low level was similar to the low speech, but not the whisper. For the loud level, the intensity should not exceed the maximum recording level of the Nasal view system which is 100 dB. The six Persian vowels (a, æ, e, o, u, i) in low, normal, and loud levels were used as the stimuli for the study. The results revealed was, in the low voice, the vowel /i/ had the highest nasalance scores which decreased with the increase in the intensity. And in the loud voice the vowel /o/ had the lowest nasalance scores. In this study both for the males and females, the average nasality of the vowels decreased with increase in the vocal intensity. As the vocal loudness increases, the velum is raised more to allow more air to pass through the oral cavity. In individuals with no velopharyngeal dysfunctions, the velopharyngeal sphincter works more accurately causing the closure of the passage from the pharynx to the nose as the vocal intensity increases, which in turn results in lower nasality.

CHAPTER III

METHOD

Participants

Two groups of adult participants were considered for the present study. The first group had 15 female professional singers with an age range of 20 to 50 years. The second group had 25 female non singers with an age range of 20 to 50 years. The participants of the two groups were age matched. All the participants in the first group had received a minimum of 10 years of Carnatic classical training and majority of them had set their career as singing. Individuals who have not yet received any kind of formal vocal training and those who had no exposure to church choirs singing have been selected in the second group. The participant's background information such as the medical history was collected. The inclusion criteria for the participants were

- Participants whose native language is Kannada were included in the study.
- All the participants had no complaint regarding the hearing ability.
- Participants who do not display any kind of respiratory infections, allergies, vocal abusive behaviours, vocal fatigue, asthma, any kind of voice problems were included in the study.
- Participants who do not have any kind of neurological or speech and language problems were included.
- Participants must be non smokers.

Stimuli and Procedure

The two groups, the professional singers and the non-singers were evaluated under two different conditions.

- Condition I: Sustained phonation of the vowels /a/, /i/ and /u/ for 10 seconds in three frequencies (low, middle, high) were recorded for singers and non singers. In this condition, each participant have to sustain the phonation for the vowels /a/, /i/ and /u/ for 10 seconds with an ascending pitch in three different frequencies (low, middle and high) along with an increase in vocal intensity.

- Condition II: Oral and nasal non words were given for the singing task. In this condition, the participants had to sing /pa:va/, /pi:va/, /pu:va/, as oral stimuli and /ma:va/, /mi:va/ and /mu:va/ as nasal stimuli with ascending pitch in three different frequencies (low, middle and high) along with an increase in vocal intensity.

Prior to the actual recording, a practice session of 10 minutes was given. During the practice session, a model was provided with audio and video. For vowels the model pitches were 240 Hz, 360 Hz, and 482Hz for low, middle and high pitch respectively. For the oral non words, the pitches given were 245Hz, 373Hz, and 497Hz and for the nasal non words the pitches given were 250Hz, 376Hz, and 501Hz. All the participants were able to match the pitch with 90% and above accuracy (APPENDIX). Pitch and intensity variation was taken together. It was found that, as the pitch increases, the intensity was also increasing. The non singers who were not able to match the model by 90% were eliminated from the study.

Condition I			Condition II					
Vowels			Non words					
Low pitch	Mid pitch	High pitch	Low pitch		Mid pitch		High pitch	
/a/	/a/	/a/	/pava/*	/mava/#	/pava/*	/mava/#	/pava/*	/mava/#
/i/	/i/	/i/	/piva/*	/miva/#	/piva/*	/miva/#	/piva/*	/miva/#
/u/	/u/	/u/	/puva/*	/muva/#	/puva/*	/muva/#	/puva/*	/muva/#

(* - Oral non words; # - Nasal non words)

Table 3.1: List of stimuli for condition 1 and II

Test environment

All the recordings were done in a sound treated room using Nasometer II (6400) and the digital audio recorder.

Instrumentation

The Nasometer II (6400), which is a micro-computer based system, manufactured by Kay Elemetrics (1983) was used to record the nasalance. The instrument consists of a headset which contains a sound separator which rests on the subject's upper lip, with microphones on the either side. The microphone detects the oral and nasal component of the utterances. The customized electronic modules, individually filters and digitizes the signal from each microphones. This software gives us the nasalance score of the signal by using the formula nasal: nasal plus oral acoustic energy in terms of percentage (nasalance) which is multiplied by 100.

$$\text{Nasalance} = \text{Nasal} / (\text{Nasal} + \text{Oral}) \times 100$$

Procedure

(i) Nasalance measurements

The Nasometer was setup in a suitable sound treated quiet recording room. Based on the instructions provided in the manual, the instrument was calibrated prior to the recording. Participants were seated comfortably and recorded individually. They were asked to practice the singing task prior to the recording using the appropriate video models. The headset was placed with the sound separator rests on their upper lip in a comfortable manner without inducing pain. The participants were asked to phonate the vowel /a/, /i/, and /u/ in the low, middle and high pitch with an increase in the intensity as provided in the model. The participants were instructed to follow the same pitch which was provided in the video models. Each vowel was recorded separately in the three frequencies. The oral and the nasal non words were recorded after completing the vowels. Recordings were done in the same way of the vowels. Each set of recording had three frequencies. For example, the set of oral non word /pava/ was recorded in three frequencies which make the one set of data. A total of 9 sets of data were obtained.

The signal captured was being continuously monitored to ensure there is no breaks occurred in between. If the participants had made any error in between, a retrial was given to capture the appropriate signals and those data was included as the data.

From the data obtained, the mean nasalance scores were measured using the nasometer in the phonation and the singing conditions. In the phonation task, the steady portion of the vowel was taken for the measurement. In the singing task, the steady portion of the vowel which follows the initial consonant (/p/ and /m/) was considered for the measurement. Only the mean nasalance score was considered for the study.

(ii) Perceptual measurements

The two tasks, the phonation and singing tasks were given to five qualified Speech Language Pathologists for the evaluation of perceptual measurement of nasality in different conditions (increasing F0 and intensity). Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V) was the rating scale used to perceptually rate the nasality. Only the nasality parameter was rated in a 100 point scale.

Statistical analysis

(i) Nasalance measurements

Statistical analysis of the nasalance measurement was done using the SPSS, 17.0 software. Mixed ANOVA with two way repeated measures ANOVA (parametric) was performed to find the significant interactions and differences in the vowels, oral non words, and nasal non words for both the groups. The repeated measure ANOVA was done to find the significant differences in the two groups separately.

(i) Perceptual measurement

The average perceptual nasality was calculated from the ratings of five SLP's for the vowel /a/, oral non word /pava/ and the nasal non word /mava/ at three different pitches, low, mid and high pitch. The mean of the perceptual nasality for each stimulus in different pitches was taken for both the groups. Paired 't' test was used to test the perceptual nasality within the groups. The vowel /a/, the oral non word /pava/ and the nasal non word /mava/ were analyzed across pitch. Pearson correlation coefficient was used to obtain the correlation between the nasalance and perceptual measurements.

CHAPTER IV

RESULTS

In the present study, there were two groups of participants, with the group of professional singers having 15 members and the group of non singers groups having 25 members. The aim of the study was to find the effect of the vocal training on nasalance and perceived nasality with variation in fundamental frequency (F0) and intensity in professional singers and non singers, also to find the correlation between perceived nasality and objective measurements of nasality. The results of the study are sub grouped under three main headings

I. Nasalance measure
II. Perceptual measure
III. Correlation between perceptual and nasalance measurements

I. Nasalance Analysis

Descriptive statistical analysis was done for vowels, oral non words and nasal non words separately. Table 4.1 shows the mean and (standard deviation) SD for vowels in singers and non singers.

The mean scores of the nasalance were higher in singers compare to the non singers except at high pitch in all the vowels. Vowel /i/ had high nasalance in both the groups.

	Stimulus	Nasalance	
		Mean & SD of Singers	**Mean & SD of Non Singers**
Vowel /a/	Low pitch /a/	34.33(21.21)	31.28(12.12)
	Mid pitch /a/	37.33(19.41)	36.28(15.55)
	High pitch /a/	30.73(16.67)	42.68(14.38)
Vowel /i/	Low pitch /i/	51.60(28.40)	44.36(17.61)
	Mid pitch /i/	52.93(25.25)	43.60(17.64)
	High pitch /i/	44.33(24.92)	49.24(18.75)
Vowel /u/	Low pitch /u/	29.53(20.15)	23.48(9.64)
	Mid pitch /u/	35.93(19.30)	24.44(13.17)
	High pitch /u/	31.06(19.97)	32.88(15.34)

Table 4.1: Mean and SD of nasalance in singers and non singers in vowels.

Table 4.2 shows the mean and SD for oral non words in singers and non singers. The mean scores of the nasalance were higher in singers compare to non singers except at high pitch in all the vowels. Vowel /i/ had high nasalance in both the groups.

	Stimulus	Nasalance	
		Mean & SD of Singers	**Mean & SD of Non Singers**
Oral non word /pava/	Low pitch /pava/	28.20(21.91)	26.28(12.37)
	Mid pitch /pava/	30.93(19.10)	28.04(13.60)
	High pitch /pava/	29.13(16.67)	36.20(16.47)
Oral non word /piva/	Low pitch /piva/	42.13(23.63)	34.64(16.48)
	Mid pitch /piva/	46.13(23.40)	39.76(19.10)
	High pitch /piva/	40.33(22.85)	47.04(18.28)
Oral non word /puva/	Low pitch /puva/	22.33(15.89)	19.24(13.04)
	Mid pitch /puva/	31.86(17.77)	20.76(14.32)
	High pitch /puva/	25.60(15.86)	33.96(16.91)

Table 4.2: Mean and SD of nasalance in singers and non singers in oral non words.

Table 4.3 shows the mean and SD for nasal non words singers and non singers. Unlike vowels and oral non words, the nasal non words did not show any clear trend as the pitch varies in both the group. However the nasalance value was high for /miva/ than the other nasal non words.

	Stimulus	Nasalance: Mean & SD of Singers	Nasalance: Mean & SD of Non Singers
Nasal non word /mava/	Low pitch /mava/	49.33(14.91)	54.96(14.24)
	Mid pitch /mava/	51.13(14.62)	58.00(15.10)
	High pitch /mava/	41.86(12.40)	62.24(17.64)
Nasal non word /miva/	Low pitch /miva/	79.53(10.93)	74.40(10.38)
	Mid pitch /miva/	74.80(9.82)	74.96(9.58)
	High pitch /miva/	64.86(13.38)	76.40(13.41)
Nasal non word /muva/	Low pitch /muva/	61.20(15.63)	57.96(15.67)
	Mid pitch /muva/	56.46(15.02)	58.36(16.96)
	High pitch /muva/	45.20(13.35)	60.44(21.30)

Table 4.3: Mean and SD of nasalance in singers and non singers in nasal non words.

Mixed ANOVA with two way repeated measure ANOVA was done to find the significant difference between the singers and non singers. To find the significant difference within the group, ie., within the singers and non singers two way repeated measure ANOVA was performed.

In order to find the difference in each parameter separately ie., pitch and vowel or pitch and oral non words or pitch and nasal non words, Repeated Measure ANOVA was done.

The statistical analysis was done separately for the vowels, oral non words and nasal non words. Hence the results will be discussed in three separate sections for each. In the first section, the nasalance of the three dependent variables (the three vowels /a/, /i/ and /u/) are given across three different pitches and between the vowels.

(i) Nasalance in the Vowels

The Table 4.4 shows the significant differences observed in mixed ANOVA with two way repeated ANOVA.

Parameter	df, E	F value	p- value
Pitch* Groups	2,76	9.04	0.000
Vowel	2,76	34.26	0.000
Pitch* Vowel	4,152	3.13	0.016

Table 4.4: Result of mixed ANOVA for vowels in both the groups.

The result shows a significant difference between vowels. It also showed significant interaction between pitch and groups (pitch*groups) and pitch and vowel (pitch*vowel). This shows the singers and non singers behaves differently as the pitch changes, similarly nasalance of the vowels are different across the pitch. Hence repeated measure ANOVA was done for the singers and non singers separately to find the difference in nasalance with change in pitch.

(a) In singers

Repeated measure ANOVA was used for vowels across pitches to find which vowel was significantly different across the pitch. The results showed that the vowel /i/ was the only vowel which showed a significantly difference in the nasalance across the different pitches. Table 4.5 shows the results of repeated measure ANOVA for the vowel /i/ across the different pitches in singers.

Parameter	df, E	F value	p- value
Pitch	2, 28	3.71	0.037

Table 4.5: Results of repeated measure ANOVA for the vowel /i/ across the different pitches in singers.

Hence, the pairwise comparison was done across pitch in the vowel /i/. There was only a significant difference observed between the mid and high pitch for the vowel /i/.

(b) In non singers

Repeated measure ANOVA was used for vowels across pitches. The vowels were compared across different pitches, to find which vowel was significantly different across the pitch. The results showed that the vowels /a/ and /u/ were significantly different across the different pitches in non singers. Table 4.6 shows the results of repeated measure ANOVA in the vowels /a/ and /u/ across the different pitches in non singers.

Parameter	df, E	F value	p- value
Vowel /a/ across pitch	2, 48	13.76	0.000
Vowel /u/ across pitch	2, 48	7.80	0.001

Table 4.6: Results of repeated measure ANOVA in the vowel /a/ and /u/ across pitch in non singers.

Hence, the pairwise comparison was done across pitch in the vowel /a/ and /u/.

In the vowel /a/, nasalance scores between mid Vs high pitch and low Vs high showed a significant difference.

In the vowel /u/ also, nasalance scores between and mid Vs high pitch and low Vs high pitch showed a significant difference.

As the mixed ANOVA showed significant difference for vowels (Table 4.4), mixed ANOVA with repeated measure ANOVA was performed across the three vowels keeping the pitch as constant. (Taking all the vowels in low or mid or high pitch)

The results showed a significant difference in the nasalance of vowels at all the three different pitches. This means, the nasalance of the vowels /a/, /i/ and /u/ were significantly different in the low pitch, mid pitch and high pitch for singers and non singers. Table 4.7 shows the result of mixed ANOVA with repeated measure ANOVA for vowels across the three different pitches in singers and non singers.

Parameter	df, E	F value	p- value
Vowels at low pitch	2, 76	44.67	0.000
Vowels at mid pitch	2, 76	20.43	0.000
Vowels at high pitch	2, 76	21.29	0.000

Table 4.7: Results of mixed ANOVA with repeated measure ANOVA for vowels across the three different pitches in singers and non singers.

The pairwise comparisons of the vowels were done. The following results were observed.

- In low pitch, there is a significant difference in nasalance between vowel /a/ Vs vowel /i/; vowel /i/ Vs vowel /u/ and vowel /a/ Vs vowel /u/.
- In mid pitch, there is significant difference in nasalance between vowel /a/ Vs vowel /i/ and vowel /i/ Vs vowel /u/.
- In the high pitch also, there is significant difference in nasalance between vowel /a/ Vs vowel /i/ and also between vowel /i/ Vs vowel /u/.

There was no significant difference in the nasalance for the vowels across the singers and non singers, hence there is no need of analyzing vowels separately across the singers and the non singers.

(ii) Nasalance in the oral non words

Table 4.8 shows the results of mixed ANOVA for singers and non singers. Table 4.2 shows the mean and SD of oral non words.

Parameters	**df, E**	**F value**	**p- value**
Pitch	2,76	5.58	0.005
Pitch* Groups	2,76	7.19	0.001
Vowel	2,76	37.06	0.000

Table 4.8: Results of mixed ANOVA for singers and non singers.

The result shows, significant difference between the vowels and between the pitch. It also showed a significant interaction between pitch and groups (pitch*groups). This shows the singers and the non singers behave different as the pitch changes. Hence repeated measure ANOVA was performed at each oral non word keeping vowel as constant in singers and non singers separately.

(a) In singers

The results of repeated measure ANOVA shows no significant difference in the nasalance scores of the oral non words across the three different pitches in singers.

(b) In non singers

Table 4.9 shows the results of repeated measure ANOVA of oral non words at low, mid and high pitch in non singers. There is a significant difference observed for the three oral non words across the three different pitches.

Parameters	df, E	F value	p- value
/pava/ across pitch	2, 48	10.01	0.000
/piva/ across pitch	2, 48	6.16	0.004
/puva/ across pitch	2, 48	6.16	0.004

Table 4.9: Results of repeated measure ANOVA of oral non words across pitch in non singers.

Hence, the pairwise comparison was done for the oral non words across the different pitches. The following results were observed.

- In /pava/, the nasalance scores between low Vs high pitch and mid Vs high pitch showed significant difference.
- In /piva/ the nasalance scores between low Vs high pitch and mid Vs high pitch showed significant difference.

- In /puva/ also, the nasalance scores between low Vs high pitch and mid Vs high pitch showed significant difference.

(iii) Nasalance in the nasal non words

Mixed ANOVA with two way repeated measure ANOVA was carried out for the analysis of nasal non words also. Mean and SD for the nasal non words are given (Table: 4.3). The results of mixed ANOVA with two way repeated measure ANOVA for nasal non words is shown in Table 4.10

Parameters	df, E	F value	p- value
Pitch	2, 76	4.86	0.010
Vowel	2, 76s	111.66	0.000
Pitch*Vowel	4, 152	5.19	0.001
Pitch*Groups	2, 76	16.24	0.000
Vowel*Groups	2, 76	4.43	0.015

Table 4.10: Results of mixed ANOVA with two way repeated measure ANOVA for nasal non words.

Results shows there are significant interaction between in pitch and groups. This means as the pitch changes, the nasalance value is changing differently for singers and non singers. Similarly there is an interaction between vowel and group is noticed. There was also a significant difference observed across the three vowels. This means the nasalance scores were different in /a/, /i/, and /u/ in singers and non singers. Hence the pairwise comparison was done for both the pitch and vowels in singers and non singers.

In pitch, the nasalance scores between mid Vs high pitch and low Vs high pitch showed a significant difference in both the groups.

In vowels, the mean scores of nasalance between the vowel /a/ Vs vowel /i/, vowel /i/ Vs vowel /u/ and vowel /a/ Vs vowel /u/ showed a significant difference for singers and non singers.

There was a significant interaction between pitch and vowels. This means the nasalance of each nasal non word were significantly different across the pitch. Mixed ANOVA with repeated measure ANOVA was done across the nasal non words at constant pitches (taking all the nasal non words in low, mid and high pitch) and at constant nasal non words (taking one nasal non word across pitch). The result of mixed ANOVA is showed in Table 4.11 and 4.12 respectively.

Constant pitch taken	**Parameter**	**df, E**	**F value**	**p- value**
Nasal non words in low pitch	Vowel	2, 76	120.18	0.000
	Vowel*groups	2, 76	6.11	0.003
Nasal non words in mid pitch	Vowel	2, 76	64.67	0.000
Nasal non words in high pitch	Vowel	2, 76	66.77	0.000

Table 4.11: Results of mixed ANOVA of nasal non words at low, mid and high pitch in singers & non singers.

Constant vowel taken	**Parameter**	**df, E**	**F value**	**p- value**
/miva/ across pitch	Pitch	2, 76	07.77	0.001
/muva/ across pitch	Pitch	2, 76	5.00	0.009

Table 4.12: Results of mixed ANOVA of /miva/ and /muva/ across pitch in singers & non singers.

Result showed that the nasal non words were significantly different across the three different pitches. This means, the nasalance of the nasal non words are significantly different between the low, mid and the high pitch. Hence, the pairwise comparison was done to see which nasal non word is significantly different at each pitch. The following results were observed.

- In low pitch, the nasalance scores between the vowel /a/ Vs vowel /i/; vowel /i/ Vs vowel /u/ and vowel /a/ Vs vowel /u/ showed significant difference.
- In mid pitch, the nasalance scores between vowel /a/ Vs vowel /i/ and vowel /i/ Vs vowel /u/ showed significant differences.
- In high pitch also, the nasalance scores between vowel /a/ Vs vowel /i/ and vowel /i/ Vs vowel /u/ showed significant differences.

Table 4.12 showed that, the mean nasalance scores of nasal non words /miva/ and /muva/ had significant difference across the low, mid and high pitch.

Results of mixed ANOVA (Table 4.10) have also showed a significant interaction between pitch and groups (pitch*groups) and also interaction between vowel and groups (vowel*groups). Hence repeated measure ANOVA was done to analyze singers and non singers separately across pitch and vowels. The results are given separately for singers and non singers.

(a) In singers

Repeated measure ANOVA was performed in the nasal non words in singers. Here the dependent variable taken was the nasal non words to see the significant difference across each pitch separately as low /mava/, low /miva/ and low /muva/ etc. The same procedure was carried out for mid and high pitch. Table 4.13 shows the results of repeated measure ANOVA of nasal non words in low, mid and high pitch in singers.

Constant pitch taken	Parameter	df, E	F value	p- value
Nasal non words at low pitch	Vowel	2, 28	73.66	0.000
Nasal non words at mid pitch	Vowel	2, 28	28.82	0.000
Nasal non words at high pitch	Vowel	2, 76	47.19	0.000

Table 4.13: Results of repeated measure ANOVA of nasal non words in low, mid and high pitch in singers.

The results showed, that the nasalance between the nasal non words were significantly different at each pitch. That means the nasalance between /mava/, /miva/ and /muva/ were significantly different on low pitch, mid pitch and high pitch. Hence the pairwise comparison was done in each pitch to see which nasal non words were significantly different.

- In low pitch, the nasalance between each nasal non word had significant difference. That mean, the nasalance between /mava/ Vs /miva/, /miva/ Vs /muva/, and /mava/ Vs /muva/ varied significantly.
- In mid pitch, the nasalance between /mava/ Vs /miva/ and /miva/ Vs /muva/ varied significantly.
- In high pitch also, the nasalance between /mava/ Vs /miva/ and /miva/ Vs /muva/ varied significantly.

Since mixed ANOVA had showed significant interaction between pitch and groups, repeated measure was done separately for singers across pitch in each nasal non word as /mava/ at low, mid and high pitch, /miva/ in low, mid and high pitch, and /muva/ in low, mid and high pitch. Table 4.14 shows the results of repeated measure ANOVA of nasal non words across pitches in singers.

Constant vowel taken	Parameter	df, E	F value	p- value
/mava/ across pitch	Pitch	2, 28	10.84	0.000
/miva/ across pitch	Pitch	2, 28	23.55	0.000
/muva/ across pitch	Pitch	2, 28	14.28	0.000

Table 4.14: Results of repeated measure ANOVA of nasal non words across pitches in singers.

Results showed that the nasalance of the each nasal non word, varied significantly across the three different pitches. That means, the nasalance of /mava/ at low pitch is different from that of at mid pitch and high pitch. The same results are observed for /miva/ and /muva/.

(b) In non singers

Repeated measure ANOVA was performed in the nasal non words in non singers. Here the dependent variable taken was the nasal non words to see the significant across each pitch separately as low /mava/, low /miva/ and low /muva/ etc. The same procedure was carried out for mid and high pitch. Table 4.15 shows the results of repeated measure ANOVA of nasal non words in low, mid and high pitch in non singers.

Constant pitch taken	Parameter	df, E	F value	p- value
Nasal non words at low pitch	Vowel	2, 48	51.99	0.000
Nasal non words at mid pitch	Vowel	2, 48	36.51	0.000
Nasal non words at high pitch	Vowel	2, 48	27.43	0.000

Table 4.15: Results of repeated measure ANOVA of nasal non words in low, mid and high pitch in non singers.

The results showed, that the nasalance between the nasal non words were significantly different at each pitch. That means the nasalance between /mava/, /miva/ and /muva/ were significantly different on low pitch, mid pitch and high pitch. Hence, the pairwise comparison was done in each pitch to see which nasal non words were significantly different. The following results were observed.

- In low pitch, the nasalance between each nasal non word had significant difference. That mean, the nasalance between /mava/ Vs /miva/, /miva/ Vs /muva/ varied significantly.
- In mid pitch, the nasalance between /mava/ Vs /miva/ and /miva/ Vs /muva/ varied significantly.
- In high pitch also, the nasalance between /mava/ Vs /miva/ and /miva/ Vs /muva/ varied significantly.

Since Mixed ANOVA had showed significant interaction between pitch and groups, repeated measure was done separately for non singers also across pitch in each nasal non word as /mava/ at low, mid and high pitch, /miva/ in low, mid and high pitch, and /muva/ in low, mid and high pitch. Table 4.16 shows the results of repeated measure ANOVA of nasal non words across pitches in non singers.

Constant vowel taken	**Parameter**	**df, E**	**F value**	**p- value**
/mava/ across pitch	Pitch	2, 48	6.53	0.003

Table 4.16: Results of repeated measure ANOVA of nasal non words across pitches in non singers.

Results showed that the nasalance of the nasal non word /mava/, varied significantly across the three different pitches. That means, the nasalance of /mava/ at low pitch is different from that of at mid pitch and high pitch.

II. Perceptual analysis

Descriptive statistics was done to obtain the mean and standard deviation of the perceived nasality in singers and nasality. Table 4.17 shows mean and SD of singers and non singers for perceptual analysis.

	Stimulus	Nasalance	
		Mean & SD of Singers	**Mean & SD of Non Singers**
Vowels	Low /a/	9.97(3.40)	10.42(3.16)
	Mid /a/	12.51(4.19)	13.01(3.15)
	High /a/	15.22(5.03)	15.34(3.18)
Oral non words	Low /pava/	11.82(2.30)	12.53(3.12)
	Mid /pava/	13.68(2.66)	15.69(2.66)
	High /pava/	16.62(3.29)	19.06(3.14)
Nasal non words	Low /mava/	19.26(2.47)	21.63(3.83)
	Mid /mava/	22.97(3.98)	24.73(4.27)
	High /mava/	25.62(3.32)	29.46(3.83)

Table: 4.17: Mean and SD of singers and non singers for perceptual analysis.

The mean of the perceived nasality was more in non singers than in singers in all parameters. Hence paired 't' test was done to see the significant difference between each parameter. Results of paired 't' test for singers and non singers are given in Table 4.18 and 4.19 respectively.

	Low Vs Mid	Mid Vs High	Low Vs High
/a/	+	+	+
/pava/	+	+	+
/mava/	+	+	+

Table 4.18: Results of paired ‘t’ test in singers (+ = p<0.05)

	Low Vs Mid	Mid Vs High	Low Vs High
/a/	+	+	+
/pava/	+	+	+
/mava/	+	+	+

Table 4.19: Results of paired ‘t’ test in non singers (+ = p<0.05)

Results showed that there is a significant difference for vowels, oral non words, and nasal non words present across the pitch in singers and non singers.

III. Comparison of perceptual Analysis of Nasality with the objective analysis of Nasalance

Pearson test of correlation was used to find the correlation between the perceived nasality and the objective analysis of the nasality. Table 4.20 shows the correlation coefficient between the perceived nasality and the nasalance in both the groups.

Parameter	Correlation coefficient in singers	Correlation coefficient in non singers
Low /a/	0.19	0.101
Mid /a/	0.27	0.082
High /a/	0.23	0.011
Low /pava/	0.19	0.089
Mid /pava/	0.020	0.093
High /pava/	0.091	0.22
Low /mava/	0.25	0.031
Mid /mava/	0.081	0.070
High /mava/	0.009	0.325

Table 4.20: Correlation coefficient between the perceived nasality and the nasalance.

Results showed that there is no correlation observed between the nasalance of perceptual measures and the objective measurements in both the groups.

Summary of the results

The aim of the study was to find out the effect of the vocal training on nasalance and perceived nasality with variation in fundamental frequency (F0) and intensity in professional singers and non singers, and to find out the correlation between perception and objective measurements of nasality.

Mixed ANOVA with two way repeated measures ANOVA was done to see the significant difference in the vowels, oral non words and nasal non words.

Descriptive analysis was done to obtain the mean and standard deviation for both the groups. In vowels and oral non words, the mean nasalance scores of singers were higher than non singers except high pitch. However, in nasal non words, no such trend was observed. But the nasalance score of singers at high pitch was less than non singers. Vowel /i/ had high nasalance compare to other two vowels in both the groups. Similar result was found in oral and nasal non words.

In vowels there was a significant interaction between pitch and groups also between pitch and vowel. Repeated measure ANOVA showed that the vowel /i/ significantly varied between the mid and high pitch in singers. In non singers, the vowels /a/ and /u/ showed significant difference between mid Vs high pitch and low Vs high pitch. There was a significant difference observed in the vowel alone. Mixed ANOVA with repeated measure ANOVA showed that, all the vowels were significant across the pitches.

In oral non words, there was a significant interaction between the pitch and groups. Repeated measure ANOVA in singers did not show any significant difference, but in non singers, the oral non words were significantly different across the pitches.

In nasal non words, there was a significant interaction present between pitch and groups, vowel and groups, and pitch and vowel. Repeated measure ANOVA in singers showed that, each nasal non word was significantly different at each pitch and across pitches. In non singers showed that, the nasal non words were significantly different at each pitch, and only /mava/ showed a significant difference across the pitches. The nasal non words were significantly different at each pitch and across pitches.

In the perceptual analysis, the mean nasalance of the non singers were higher than singers. Paired ‘t’ test showed a significant difference in the vowels, oral non words, and nasal non words across the pitch for both the groups.

Pearson test of correlation showed no correlation between the perceptual measurements and the objective measurements in both the groups.

CHAPTER V

DISCUSSION

The aim of the present study was to determine whether, the professional singers who were trained in Carnatic classical singing differed in nasalance (degree of nasality and perceived nasality) from non singers across a change in the fundamental frequency levels and vocal intensity. The effects of vocal training in controlling the nasality with variations in the frequency levels and in the vocal intensities are primarily focused. For this purpose, 15 professional singers and 25 non singers (total of 40 females) participated in the study. The nasalance was compared between the professional singers and the non singers in vowels (/a/, /i/, and /u/), in oral non words (/pava/, /piva/, /puva/), and in nasal non words (/mava/, /miva/, /muva/).

Since the intensity increases with increase in pitch, there was no separate task for pitch and intensity. Both the variations were accomplished together. All the participants were told to match the pitch with the model provided. The analysis was done for both the groups together initially, and then for both the groups separately. The vowels, oral non words and nasal non words were separately analyzed. Following this, perceptual measurements were done. Finally, the objective measurement (nasalance) and the perceptual measurement (perceived nasality) were correlated.

I. Nasalance Analysis

Nasalance analysis was done separately for the vowels, oral non words and the nasal non words.

(i) Nasalance in the vowels

Mixed ANOVA showed a significant interaction in nasalance between pitch and groups. This shows that the difference occurred in the nasalance with variation in the frequency is not same for the singers and non singers in the vowels. There was a group difference present in the nasalance scores of the vowels. Hence the analysis of the pitch had to be done separately for singers and non singers.

(a) In Singers

The three vowels were compared across the three different pitches and the results found was the nasalance scores of the vowel /i/ varied significantly between the mid and high pitch (Table 4.5). It was observed that the mean scores of nasalance decreased with the high pitch (Table 4.1). A study by Austin (1997) found out that, as the pitch of the singers goes high, the time of the velopharynx opened was reduced. And it is quite possible that the nasalance will be less, when the velopharynx is closed as it is measured by the air passing out of the nasal cavity. Yanagisawa (1991) found that with ascending frequencies, the soft palate is lifted up and the velopharynx is narrowed in singers. The effect of loudness on nasalance was discussed by Sadjaji (2010) and he found out that in normal individuals (both males and females), the nasality had decreased with an increase in vocal intensity. This finding supports the present study, where the mean scores of the nasalance of the vowel /i/ was less at high pitch when compared to the mid pitch. The vocal intensity would be the maximum at the high pitch, since an amount of intensity increases with increase in the pitch. On the other hand, in a study done by Birch et al (2002) stated that the tenors (category of western operatic professional singers) sang the vowel /i/ with an open velopharynx at the higher scales. This could probably due to the fact that tenors use nasalance to make slight timbral changes as they ascend with the pitch (Perna, 2008). However, Tanner, (2005) found that, singers allow fairly large amount of nasal airflow through a relatively small gap in the velopharyngeal port.

The difference in the mean scores of nasalance of the vowel /i/ between mid pitch and high pitch reveals that, the singers had adjusted the soft palate configuration effectively at high pitch to restrict the excess passage of air through the nasal cavity. Even though Austin (1997) found less time duration of velopharyngeal opening at higher scales, the singers are trained to use the small velopharyngeal opening effectively to make use of the nasal resonance. The high nasalance scores of the vowel /i/ in the mid pitch reveal that the singers use a nasal resonance in singing, but they are adapted to control the nasalance with the increase in pitch.

(b) In Non Singers

Repeated measure ANOVA showed that in the non singers, the nasalance scores of the vowels /a/ and /u/ were significantly different across the pitch (Table 4.7). And it was also observed that for both the vowels, the difference in the mean scores of nasalance was significant between mid Vs high pitch and low Vs high pitch. There was no significant difference in nasalance was found for the vowel /i/. Fowler (2004) found that in untrained singers, the pattern of nasalance observed between the front vowel (/i/) and the back vowels (/a/ and /u/) was different. There was increased nasalance for the vowel /i/ than the vowels /a/ and /u/. Jennings and Kuehn (2008) observed that in the upper frequency ranges the vowel /a/ receives the highest nasalance than the vowel /i/ and /u/.

They also found that, the untrained singers received highest scores of nasalance in all the frequency ranges for all the vowels she experimented (/a/, /i/, /u/, /o/) except /o/. This correlated with the present findings of the study where the non singers had increased nasalance on the vowels /a/ and /u/ in the mid pitch and high pitch. This could be due to an inefficient velar adjustment. As the intensity increases with increasing frequency, the non singers tend to have more nasal airflow at higher pitches. The singers are able to control their nasality by using variable velar patterns which in turn shape their nasal resonance (Gramming, 1993).

(Table 4.4) shows a significant difference for the vowels, mixed ANOVA with repeated measure ANOVA was done to see the significant difference in each vowel. In all the three pitches, the mean scores of nasalance showed a significant difference between the vowels with the highest nasalance observed for the vowel /i/, followed by the vowel /a/ and the vowel /u/ in all the pitches. The results well correlated with the findings of Jennings (2008), who found the highest nasalance for the vowel /i/ which is followed by /a/ and /u/ in untrained singers. And also the nasalance values of the untrained singers in the vowels were all higher than that of singers. Lewis (2000) and Von Berg (2002) also found the same results in the vowels. They also found that the back vowels /o/ and /u/ received the minimum nasalance among all the vowels (/a/, /i/, /o/, /u/) which were sung in scales. These results were also consistent with the study done by Puspavathi and Gopi Sankar (2008). The increased oral impedance to the high vowels makes them more nasal than the back vowels.

The possible conclusion for the difference between the mean scores of the singers and non singers would be the effect of sufficient vocal training where the singers are being taught to eliminate nasality directly or indirectly (by controlling velopharyngeal opening or the amount of air flow through the VP opening) in their singing which helps them to control their nasality than the novice singers. Because perceptually nasality in singing is considered ineffective, and hence the nasal airflow in the singers are utilized for producing the sympathetic vibrations which will result in a resonance rather than nasality.

(i) Nasalance in the oral non words

In the oral non words, Mixed ANOVA showed a significant interaction across the pitch and groups (Table 4.8). That means the mean scores of nasalance between the low, mid and high pitch was significantly different and the degree of difference was not same for the singers and non singers. Hence, repeated measure ANOVA was done to see the difference in the nasalance scores across the pitch in singers and non singers separately.

(a) In Singers

The oral non words /pava/, /piva/ and /puva/ did not varied significantly across the three pitches. Lubker and Fritzell (1970) found that tighter velopharyngeal closure is required for voiceless consonants, since they are produced with greater intra-oral pressure, and the vowels which were analyzed in the oral non words all followed a voiceless consonant. However the finding of Tanner (2005) disagrees with this current result. He found increased nasal air flow during the time of maximum intra oral pressure. Traditionally the voiceless consonants are considered to obtain tight velopharyngeal closure. The present study could not find a significant difference in the nasalance scores in the oral non word across pitches. This suggests the singers had used a consistent velar configuration across the different pitches. The mean scores of oral non words in high pitch shows a reduction in the nasalance scores even though it is not statistically significant. This correlates with the finding of Yanagisawa (1991). The present study do not comment about the velopharyngeal opening, instead agrees with Tanner (2005) that singers use nasal airflow to improve resonance and quality of singing.

(b) In Non Singers

In non singers, the nasalance scores of all the oral non words showed a significant difference across the pitches. The pairwise comparison showed the nasalance scores of all the three oral non words were significantly different between mid Vs high and low Vs high pitch. There was no significant difference found between low and mid pitch. Van Leirde (2010) found that lowering of pitch decreased the nasalance scores in cleft and non cleft individuals. This is consistent with this study, where the mean nasalance scores were less at low pitch and it increased at high pitch. Jennings (2008) found that the untrained singers have higher nasalance with increase in frequency ranges when compared with the classically trained singers. This particular difference was attributed to the appropriate training and the inherent vocal abilities of the singers. This could be the reason for the increase in nasality found in non singers as the pitch increased from low to high in the present study.

(ii) Nasalance in the nasal non words

Results of mixed ANOVA (Table 4.10) performed in the nasal non words showed a significant difference in pitch and in vowels. The pairwise comparison of pitch shows that, there was a significant difference between mid Vs high and low Vs high pitch for both the groups even though singers showed less mean nasalance scores when compared to non singers. Lowest nasalance scores in high pitch were observed for singers, and highest nasalance scores were observed in high pitch for non singers. Tanner (2005) found that the carryover nasal air flow value from the preceding consonant /m/ is 40% greater for singing Vs speaking. He also found out that the nasal air flow values of /m/ in singing reached statistical significance. A part of vowels which occur adjacent to a nasal consonant is nasalized which is termed as co-articulatory nasalization (Pruthi, 2007). Phonemically /m/ is a nasal consonant which requires maximum velopharyngeal opening irrespective of either singing or speaking conditions. The vowels which are following the consonant get the quality of that consonant. In the present study, both the singers and non singers had exhibited a velopharyngeal opening which results in the nasalance scores are not surprising. For the analysis of nasalance in the nasal non words, the steady portion of the vowel followed the nasal consonant was taken. Hence it is possible to get the high nasalance values in the nasal non words. The low mean nasalance scores in singers reveal that, even in the nasal context, the singers are able to control their velar movement which in turn controls nasalance.

In the present study, unlike the vowels and oral non words, except a few values, the nasalance scores in singers are less than non singers. DeLeo, LeBorgne, Lee, Stemple, Bush (2010) observed high correlation between the experience in singing with the vibrato and ring of the voice quality. It suggests that singers do use their nasal resonance to brighten their voice, but are also adapted to regulate the amount of air that has to be passed through the nasal cavity as the pitch increases. As quoted by Brown and

Behnke (1883), ‘singers raise their soft palate with an ascending pitch’, but this phenomenon becomes effortless with increased experience in the field of singing.

Table 4.10 shows there is an interaction between pitch and vowels. The results showed that in all the pitches the nasal non words showed significant differences, and the nasal non words /miva/ and /muva/ had significant difference across the pitches (Table 4.11 and Table 4.12). The vowel /i/ had the maximum nasalance among all the three nasal non words in all the pitches. This is consistent with the findings of Jennings and Kuehn (2008), Lewis (2000), Von Berg (2002), Puspavathi and Gopi Sankar (2008). The decreased oral intensity and increased nasal intensity is the causation of increased nasalance scores in high front vowels (Fairbanks, House, Stevens 1950; Stevens and House, 1961; Counihan and Pierce, 1965; Hirano, Takeuchi, and Hiroto 1966). In the present study found increased nasalance in the vowel /i/ in accordance with the previous findings.

Since there is a significant interaction present between pitch and groups (pitch*groups) and vowel and groups (vowel*groups) (Table 4.10), the analysis was done separately for singers and non singers.

(a) In singers

Results showed that, in nasal non words there was a significant difference observed across vowels and across pitch in singers. The difference in nasality across vowel is the influence of vowels on the nasality scores as discussed previously by several authors (Fairbanks, House, Stevens 1950; Stevens and House, 1961; Counihan and Pierce, 1965; Hirano, Takeuchi, and Hiroto 1966; Jennings and Kuehn 2008). The nasal non word vowel effect was same as it was observed for the isolated vowels, and oral non words. On the other hand in nasal non words, a consistent decrease in the nasalance scores with high pitch was observed for singers. Austin (1997) found that in singers, the velopharyngeal opening was completely eliminated in the medium and higher singing ranges, even though the phonetic environment required the use of nasal consonants. Tanner (2005) found that classically trained singers experience a regular velopharyngeal opening during their singing even in non nasal contexts also. This was attributed to the forward focus used by classically trained singers which will increase their resonance effect and create least amount of vocal fold impact stress (Chen et al., 2003; Roy et al., 2003; Stemple, 2000; Verdolini, 2000; Verdolini, Druker, Palmer, & Samawi, 1998; Verdolini- Marston, Burke, Lessac, Glaze, & Caldwell, 1995). Even though the singers had nasal airflow continuously regardless of the phonetic environment, none of the singers had crossed the cut off value of nasalance for velopharyngeal inadequacy in the previous findings.

(b) In non singers

The significant difference in the nasalance scores between the vowels observed in non singers was due to the same reasons which were discussed earlier. Across different pitches, only the nasal non word /mava/ varied significantly. The nasalance value of /mava/ in low pitch was significantly less from the nasalance value obtained in high pitch. As the non singer increases the pitch, the nasalance values also increased. This finding was the same for non singers in the oral non words also and it is consistent with the finding of Jennings and Keuhn (2008). The increase in the intensity at the higher scales also contributed to the increased nasalance scores in high pitch. The phonetic environment and the co-articulatory nasalization had well influenced the untrained velum in non singers.

II. Perceptual Analysis

The second objective of the present study was to find out the effect of vocal training on perceived nasality with varying fundamental frequency and intensity. The mean scores of the perceptual rating revealed lower nasalance scores for singers and higher nasalance scores for non singers. Gregg (1998, 1999) stated that the oro nasal coupling allows air passage through the nose, but severe nasality is not considered pleasing to the listeners. She also commented that, if no sound flows through the nose, then that is also unacceptable. The huge reduction of the nasalance scores perceptually in the present study could be because of the effective vocal training which the singers had received. Unlike non singers, singers know the use of nasal airflow effectively without showing it perceptually. Paired 't' test revealed a significant difference in the vowels across all the pitches. The listeners felt the nasality is increasing along with the pitch (Table 4.17).

III. Comparison of perceptual analysis of nasality with the objective analysis of nasalance.

Final objective of the present study was to find the correlation of perceptual and objective measurements of nasality. The Pearson's correlation coefficient showed no correlation between perceived nasality and objective measurements. Birch (2002) found no correlation between the nasal airflow and the perceived nasality in singers. He stated that the degree of perceived nasal quality is not related to the existence of a velopharyngeal opening. The x-ray studies taken during singing of a famous operatic singer (tenor) Enrico Caruso, showed a completely closed velopharyngeal port. This indicates no nasality. But in fact Caruso was the greatest tenor of the twentieth century for his aesthetically pleasing and brilliant voice, which was perceptually rated as nasal (Perna, 2008). That means the perceived nasality and the x-ray study are negatively correlated. The present study finds the objective measurements and the perceived nasality as two unrelated parameters.

The present study aimed to find out the effect of vocal training on nasalance with variation in the fundamental frequency and in the intensity. A group of professional singers and a group of non singers were the participants of the study. A significant difference in nasalance measurements were observed with change in pitch and intensity in singers and non singers. The findings lay open the importance and the effect of vocal training on nasalance measurement. A series of research had been conducted in the past years to find out the effects of vocal training on nasalance (Fowler, 2004; Barichello 2003; Jennings, 2008; Ranjini, 2010, Morris, 1995; Birch, 2002; Gramming, 1993; Tanner, 2005) etc. Certain research could not find a significant difference between the professional singers and the non singers. However, the present study could find a significant difference in the nasalance measurement of singers and non singers in few of the conditions. The nasalance of the singers did not exceed the nasalance of non singers. The difference in the nasalance scores across the pitches discloses that, the singers use a variable velar pattern. Volo & Farrero (1986) commented about the style of singing which can have an influence the velar movement. In the present study, the more experienced singers, sang the vowels, oral non words and nasal non words in a more

Carnatic classical style of singing. They had an easy and smooth kind of phonation, where the target pitch was approached gradually. However, the initial part was not steady. A direct attack to the target pitch was not observed. They start from a lower pitch and reach the target within no time. This could also have an impact on the nasalance scores between singers. The effect of vowels on nasalance scores was consistent for singers and non singers. An apparent reduction in the nasalance scores at high pitch was evident for singers which convey the activity at the velar level to regulate the nasalance.
The results showed both the parameters (nasalance and perceived nasality) are unrelated. Birch et al. (2002) also found the same results.

The present study also agrees that the singers do use nasal resonance while singing and the ability to use the resonant system effectively are acquired through an effective vocal training. Factors like determining the amount of air that has to be passed through the nasal cavity, or at which pitch or scales the resonance should be given; such things are only known to a trained or professional singers.

CHAPTER VI

SUMMARY & CONCLUSIONS

Resonance can be termed as the vibrations which can create tone through and within the mouth, throat, and nasal passages. When singing is accompanied with adequate nasal resonance, it gives the maximum benefit to the singer. The use of nasal cavity on the process of singing has been widely studied. It is documented that, nasality is caused due to the oro nasal coupling. Speech comprises nasal and non nasal phonemes and the velopharynx has to be activated during conversation. Several studies found that during singing, singers make use of the nasal airflow. Nasalance measurements, nasal air flow studies, velopharynx visualization studies (x-rays, endoscopy), perceptual ratings of nasality were the means to measure the nasal resonance. The variation in nasalance with change in frequency and intensity became evident from the previous investigations.

Much research in western operatic male and female singers is documented regarding the use of velopharyngeal opening to use the nasal airflow. The vocal technique behind this is least explained. Hence, the effect of vocal training in singers to regulate the velum became noticeable. Carnatic music which took its origination from Vedas is very admirable and impressive in Indian music. Hence it was interesting to study the resonance in Carnatic singing. The effect of training in bringing such voice is measurable through the above mentioned measurements.

The present study focused to find the effect of vocal training on nasalance and perceived nasality with varying fundamental frequency and intensity in Indian Carnatic singers and the comparison between the objective and perceptual measurements. The participants of the study were 15 professional singers in the first group (in Carnatic classical singing) and 25 non singers in the second group. Professional singers had a minimum of ten years of experience in the field if Carnatic classical singing, and the non singers had not received any kind of formal training.

There were three stimuli; the vowels (/a/, /i/ & /u/), oral non words (/pava/, /piva/ & /puva/) and nasal non words (/mava/, /miva/ & /muva/) were used in the study. The participants were asked to sing the stimuli in three different pitches (low, mid, high) as how it was demonstrated in the model pitch. A practice session was given prior to the recording. Intensity was not given as a separate model with the presumption of intensity will increase with increase in pitch. The steady portion of the vowel was analyzed and the mean nasalance scores were obtained.

The Nasometer II 6400 was used for the measurement of nasalance. For the perceptual measurements, CAPE-V was used and it was rated by five SLP's. All the recordings were done in sound treated room.

Descriptive analyses showed the mean nasalance scores of vowels and oral non words were higher for singers at low and mid pitch except in nasal non words. Mixed ANOVA with repeated measure ANOVA was done to find the significant interactions and differences in both the groups. When a parameter was significantly different, pairwise comparisons were also made using repeated measures ANOVA.

In vowels, there was an interaction present between pitch and groups and pitch and vowels. Repeated measures ANOVA showed the differences within each group. Vowel /i/ was significantly different between mid and high pitch in singers. In non singers, the vowels /a/ and /u/ showed significant difference between mid Vs high pitch and low Vs high pitch. There was a significant difference observed in the vowel alone. Mixed ANOVA with repeated measure ANOVA showed that, all the vowels were significant across the pitches.

In oral non words, there was a significant interaction present between pitch and groups. The results of repeated measure ANOVA showed no significant difference in the nasalance scores across the three different pitches in singers. But in non singers, the oral non words were significantly different across pitch.

In nasal non words, there was a significant interaction observed between pitch and groups, vowel and groups and between pitch and vowel. Repeated measure ANOVA in singers showed that, each nasal non word was significantly different at each pitch and across pitches also. In non singers, there was a significant difference at each pitch, and only /mava/ showed a significant difference across the pitches. All the nasal non words were significantly different at each pitch and across pitches.

The mean and standard deviation of the perceived nasality was obtained by averaging the ratings made by 5 SLP's of the vowel /a/, oral non word /pava/, and nasal non word /mava/. Paired 't' test was used to find the significant difference in vowels, oral non words and nasal non words across pitch. Pearson correlation test of coefficient was used to find the correlation between the objective and perceptual measurements.

The study could find a difference in the nasalance scores in a few conditions between singers and non singers. The present study is in concordance with the previous findings (Birch, Gumoes, Stavad, Prytz, Bjokner & Sundberg, 2002; Tanner, Merril &

David, 2005; Jennings & Kuehn, 2008). The increased air flow and nasalance scores in singers revealed that singers use the nasal airflow to improve their resonance in the form of sympathetic vibrations in the nasal cavity. The decreased perceived nasality in singers disclose the fact, even though the singers use nasal airflow, they do not allow the listener to perceive it. They regulate and modify the velum and airflow in such a way that, the listeners could only perceive the brilliance in their voice quality and not the nasality. Singers showed less variation of nasalance across pitch compared to non singers. This suggests that singers are able to control the nasalance across the pitch with minimal change. The study could not find a correlation between nasalance and perceived nasality. The singers had higher nasalance than non singers in few conditions and the mean of perceived nasality as less for singers. However, a statistically significant correlation was not present.

All these findings support the efficiency of a singer which he/she procures through an immense vocal training. The present study can explicitly conclude that Carnatic singers use more nasal resonance during singing. However, the perceived nasality is less for singers compared to non singers.

Clinical implications

The results of the present study could add more information in the field of singing, especially on the physiology behind Indian Carnatic singers. An insight of the relation between nasalance and perceived nasality in singers are also explained.

Limitations of the study

The current study had certain limitations.

- The rate of singing was not controlled in the study.
- The intensity control was not taken separately.
- The habitual pitch was not measured for both the groups
- The SLP's found difficulty to rate the perceived nasality in a 100 point scale.

Future Directions

- The current study did not include any velopharyngeal visualization system which could have provided a better realization at the velopharyngeal level. Visualization systems, nasalance and acoustic measurements can be together compared.
- The age, gender, experience and style of the singers are considerable factors for further evaluations.
- The effect of the length of stimuli on nasalance in singers can be further explored.
- Correlation between the perceived nasality and objective measurements also need to be further evaluated, at larger scales.
- Single subject design can be used instead of group design, since the individual variation is more.

REFERENCE

Arushi, C. (2001). Relationship between the Fundamental Frequency of Voice and Adhara Shruthi in Carnatic Vocal Music. Unpublished dissertation: University of Mysore.

Austin, F. Stephen. (1997). Movement of Velum in During Speech and Singing in Classically Trained Singers. Journal of Voice, 11 (2), 212-221.

Awan, S. N. (1991). Phonetographic Profiles and F0-SPL Characteristics of Untrained versus Trained Vocal Groups. *Journal of Voice,* 5, 41-50.

Barrichello, V. M. O., Heuer, R. J., Dean, C. M. & Sataloff (2003). Comparison of Singer's Formant, Speaker's Ring, and LTA Spectrum among Classical Singers and Untrained Normal Speakers. *Journal of Voice*, 15, 344-350.

Birch, P., Gumoes, B., Stavad, H., Prytz, S., Bjokner, & Sundberg, J. (2002). Velum behaviour in Professional Classic Operatic Singing. *Journal of Voice,* 16 (1), 61–71.

Brown, L., & Behnke, E. (1883). Voice, Song, and Speech. A Practical Guide for Singers, Speakers, London, Sampson Low.

Bunch, M., (1995). Dynamics of Singing Voice (*III* edition). *Disorders of Human Communication Disorders.*

Chaya, Devi. (2003). Singers Formant in Indian Classical Singers Carnatic Vs. Hindusthani. Unpublished Dissertation: University of Mysore.

Chen, S. H., Hsiao, T., Huang, C. C., Hsiao, L., Chung, Y., Chiang, S. (2003). Outcome of Resonance Voice Therapy for Teachers with Voice Disorders. Paper presented at the annual convention of the American Speech-Language-Hearing Association, Chicago.

Cleveland, T. F., Stone, R. E., Sundberg, J., & Iwarson, J. (1997). Estimated Subglottal Pressure in Six Professional Country Singers. *Journal of Voice,* 11, 403-409.

Counihan, D. T., Pierce, B. R. (1965). Measurement of Cleft Palate Nasality. *Final Report*, Research Grant No. NB04216–02.

Dalston, R. M. (1982). Photodetector Assessment of Velopharyngeal Activity. *Cleft Palate Journal*, 19, 1-8.

DeLeo, LeBorgne, W., Lee, L., Stemple, J. C., Bush, H. (2010). Perceptual Findings on the Broadway Belt Voice. *Journal of Voice,* 24 (6), 678-89.

Donald, G. Miller. (2000). Registers in Singing. Ph. D. dissertation, Rijks universiteit, Groningen, 58.

Fairbanks, G., House, A. S., Stevens, E. L. (1950). An Experimental Study of Vowel Intensities. *Journal of Acoustic Society of America,* 22, 457–459.

Fowler, L, P. (2004). Comparison of Nasalance between Trained Singers and Non Singers. *The Florida State University. DigiNole Commons*. (unpublished dissertation)

Ghosh, K. (2007). Comparison of Acoustic Characteristics in Female Trained (Carnatic Style) Singers, Untrained Singers and Non-Singers. Unpublished Dissertation: University of Mysore.

Gramming, P., Nord, L., Sundberg, J., & Elliot, N. (1993). Does the Nose Resonate During Singing? *Speech Transmission Laboratory- Quarterly Progress and Status Report,* 34 (4), 35-42.

Gregg, Jean. Westerman. (1998). "What About Humming with the 'Ring?" *Journal of Singing,* 54 (4), 55-57.

Gregg, Jean. Westerman. (1999). "On the Velopharyngeal Port." *Journal of Singing,* 56 (1), 43-46.

Griffin, B., Peak, W., Raymond, C., Casper, J., & David, B. (1995). Physiological Characteristics of the Supported Singing Voice. A Preliminary Study. *Journal of Voice,* 9 (1), 45-56.

Helmholtz, Z. (1954). On the Sensation of Tone, Dover, Newyork.

Hirano, M., Takeuchi, Y., Hiroto, I. (1966). Intranasal Sound Pressure during Utterance of Speech Sounds. *Folia Phoniatr*, 18, 369–381.

Holbrook, H. Curtis. (1896). Voice Building and Tone Placing, Newyork.

House, S & Stevens, K. N. (1956). Analog Studies of the Nasalization of Vowels. *The Journal of Speech and Hearing Disorders*, 21 (2), 218- 232.

Jayakumar, T. (2005). Normative Score for Nasometer in Kannada. Dissertation: University of Mysore.

Jennings, J. J., & David, P. Kuehn. (2008). The Effects of Frequency Range, Vowel, Dynamic Loudness Level, and Gender on Nasalance in Amateur and Classically Trained Singers. *Journal of Voice*, 22 (1), 75–89.

Kent, R. D., & Read, C. (2002). The Acoustic Analysis of Speech (2nd ed.). Albany, NY: Thomson Learning.

Lee, G. S., Wang, C. P., (2009). Evaluation of Hyper Nasality in Vowels using Voice Low Tone to High Tone Ratio. *Cleft Palate Craniofacial Journal,* 46 (1), 47-52.

Lewis, K. E., Watterson, T. L., & Quint, T. (2000). The Effect of Vowels on Nasalance Scores. *Cleft Palate Craniofacial Journal.* 37, 584–589.

Lieberman, P., & Blumstein, S. (1988). Speech Physiology, Speech Perception and Acoustic Phonetics. *Cambridge University Press*.

Lintz, L. B., Sherman, D. (1961, December). Phonetic Elements and Perception of Nasality. *Journal of Speech and Hearing Research,* 4.

Lubker, J. F., B. Fritzell., & Lindquist, J. (1970). Velopharyngeal Function: An Electromyagraphic Study. Speech Transmission Laboratory Quarterly Progress and Status Report (Stockholm, Sweden: Royal Institute of Technology) STL-QPSR 4/1970, 9-20.

McCrea, R. Christopher., & Morris, J. Richard. (2005, May 18). Effects of Vocal Training and Phonatory Task on Voice Onset Time. *Journal of Voice*, 21 (1), 54-63.

McKinney, James. (1994). The Diagnosis and Correction of Vocal Faults, Nashville, TN: Genovex Music Group.

Miller R. (1996). The Velopharyngeal (palatopharyngeal) Port during Singing. *Journal of Singing*, 53, 27–29.

Miller, R. (1993). Training Tenor Voices. United States, Schirmer Books.

Moll, K. L., & Daniloff, R. G. (1971). Investigation of the Timing of Velar Movements during Speech. *Journal of the Acoustical Society of America,* 50, 678–684.

Monahan, B. J. (1978). *The Art of Singing; A Compendium of Thoughts on Singing Published between 1777 and 1927.* New Jersey: The Scarecrow Press.

Morris, R.J., Brown, W.S., Hicks, D. M., & Howell, E. (1995). Phonational Profiles of Male Trained Singers and Non-Singers. *Journal of Voice* 9, 142-148.

Nafisi, J. (2010). Gesture as a Tool of Communication in the Teaching of Singing. *Australian Journal of Music Education,* 2, 103-16.

Ohman, S. (1967). Peripheral Motor Commands in Labial Articulation, STL-QPSR 4, 30-63.

Ohman, S., Persson., & Leanderson, R. (1967). Speech Production at the Neuromuscular Level, S TL -QPSR 2 - 3, 15 - 19.

Perna, Nicholas. K. (2008). Effects of Nasalance on the Acoustics of the Tenor Passaggio and Head Voice. *University of Miami.* Doctoral Thesis, 88.

Pruthi, T., & Espy-Wilson, C.Y. (2007, August). Acoustic Parameters for the Automatic Detection of Vowel Nasalization, in *Interspeech.*

Pushpavathi, M., & Gopi Sankar, R. (2010). Effect of Vowels on Consonants in Nasalance. *Journal of the All India Institute of Speech & Hearing*, 27 (3).

Ramesh, A. (2009). Singing Voice Nasality Detection in Polyphonic Audio. Master thesis UPF. *Universitat Pompeu Fabra,* Barcelona.

Ranjini, M. (2010). Effect of Training on the Voice of Carnatic Classical Singers. Dissertation: University of Mysore.

Reid, Cornelius. Bel *Canto.* (1950). *Principles and Practices*. New York: Coleman-Ross Company, Inc.

Roy, N., Weinrich, B., Gray, S. D., Tanner, K., Stemple, J. C., & Sapienza, C. M. (2003). Three Treatments for Teachers with Voice disorders: A Randomized Clinical Trial. *Journal of Speech, Language, and Hearing Research*, 46, 670–688.

Russell, G. O. (1931). Speech and Voice. New York: Macmillan.

Sadjadi, V., Ali, G., Farhad, T., Amiri, Y., & Keyhani, M. R. (2010). The Effect of Vocal Loudness on Nasalance of Vowels in Persian Adults. *Iranian Rehabilitation Journal,* 9 (12).

Scott, McCoy. (2004). Your Voice an Inside View, (Princeton: Inside View Press).

Scotto, di, Carlo. N. H., & Autesserre, D. (1987). Movement of Velum in Singing. *Journal of Research in Singing,* X1, 3-13.

Sriram, P. (1990). *A Karnatic Music Primer.* Carnatic Music Association of North America.

Stemple, J. (2000). Voice Therapy: Clinical Studies (2nd ed.). San Diego, CA: Singular.

Sundberg, J. (2005). Effect on the Glottal Voice Source of Vocal Loudness Variation in Trained Female and Male Voices. *Journal of Acoustic Society of America*, 117 (2), 879-885.

Tanner, Roy, K. N., Merrill, R. M., & David, P. (2005). Velopharyngeal Port Status during Classical Singing. *Journal of Speech, Language, and Hearing Research,* 48, 1311-1324.

Titze, Ingo. (1994). Acoustics of the Tenor High Voice. *Journal of the Acoustic Society of America,* 95 (2), 1133-1142.

Troup, G. J., Welch, G. F., Volo, M., Tronconi, A., Ferrero, F., & Farnetani, E. (1989). On Velum Opening in Singing. *The Journal of Research in Singing and Applied Vocal Pedagogy*, 13, 35–39.

Van Lierde, K. M., Borsel, J. V., Cardinael, A., Reeckmans, S., Bonte, K. (2010). The Impact of Vocal Intensity and Pitch Modulation on Nasalance Scores: A Pilot Study. *Folia Phoniatrica Logopaedica,* 63, 21-26.

Vennard, W. (1964). An Experiment to Evaluate the Importance of Nasal Resonance in Singing. *Folia Phoniatrica,* 16, 146-154.

Vennard, W. (1968). Singing: The Mechanism and the Technic. (New York: Carl Fischer), 234-251.

Vennard, William (1967). Singing: The Mechanism and the Technic (4th ed.), New York, Carl Fischer.

Verdolini, K. (2000). Resonant Voice Therapy. In *Journal of Communication*, Stemple (Ed.), Voice therapy: Clinical studies (2nd ed.), 46–61. San Diego, CA: Singular

Verdolini, K., Druker, D. G., Palmer, P. M., & Samawi, H. (1998). Laryngeal Adduction in Resonant Voice. *Journal of Voice,* 12, 315–327.

Verdolini-Marston, K., Burke, M. K., Lessac, A., Glaze, L., & Caldwell, E. (1995). Preliminary Study of Two Methods of Treatment for Laryngeal Nodules. *Journal of Voice,* 9, 74–85.

Vijaya, A. (1994). Fundamental Frequency Relation of the Sapta Svaras of Karnatic Vocal Music. Dissertation: University of Mysore.

Volo, M., Farnetani, E., Troup GJ., Ferrero, F. E. (1986) A Pilot Study of Nasal Aerodynamic Flow in Singing. Quaderni del Centro di Studio per le Ricerche di Fonetica del C.N.R, 5, 395–404.

Von Berg, S. (2002). The Effect of Vowels on Nasalance Measures and Nasality Judgments [dissertation]. *University of Nevada.*

Watterson, T., Lewis, K. E., & Foley-Homan, N. (1999). Effect of Stimulus Length on Nasalance Scores. *Cleft Palate Craniofacial Journal*, 36, 243–247.

Watterson, T., York, S. L., & McFarlane, S. C. (1994). Effects of Vocal Loudness on Nasalance Measures. *Journal of Communication Disorders*, 27, 257–262.

Yanagisawa, E., Estill, J., Mambrino, L., & Talkin, D. (1991). Supraglottic Contributions to Pitch Raising Videoendoscopic Study with Spectro Analysis. *Annals of Otology, Rhinology and Laryngology,* 100, 19-30.

APPENDIX I

Percentage of Matching the Model Pitch in Participants Pitch (Singers & Non-Singers)

(1-15 = singers, 16-40 = non-singers)

Vowels

Participants	Low /a/	Mid /a/	High /a/
1	98.33	99.81	96.62
2	98.63	98.53	98.07
3	100.00	99.64	98.55
4	98.20	98.81	100.00
5	99.38	99.31	98.82
6	98.13	98.31	98.18
7	94.42	94.95	96.69
8	95.67	96.29	95.55
9	98.92	98.28	97.76
10	98.13	97.48	96.58
11	98.88	99.11	97.35
12	94.92	96.70	95.05
13	99.00	99.14	97.91
14	96.33	98.86	95.92
15	97.83	97.92	97.89
16	96.54	99.28	97.31
17	99.92	98.92	96.19
18	98.92	98.03	99.44
19	99.04	98.59	99.59
20	96.25	96.15	95.19
21	98.08	96.20	98.74
22	98.22	98.53	99.46
23	99.25	97.73	99.25
24	97.12	98.46	100.00
25	99.13	100.00	98.82
26	99.21	98.06	97.39
27	95.63	98.23	97.72
28	98.25	98.59	96.83
29	96.33	96.34	94.82
30	89.25	91.20	88.48
31	91.79	98.31	92.34
32	96.75	92.87	80.13
33	98.29	95.65	96.71
34	90.74	97.87	99.73
35	100.00	97.62	100.00
36	99.63	98.06	99.21
37	99.75	98.53	98.84
38	98.63	97.75	97.33
39	97.54	99.42	98.84
40	98.29	98.13	97.24

Participants	Low /i/	Mid /i/	High /i/
1	96.21	100.00	96.87
2	100.00	100.00	98.74
3	97.04	100.00	99.46
4	100.00	98.64	100.00
5	98.42	99.42	99.32
6	100.00	99.75	99.42
7	97.71	98.72	97.43
8	95.38	96.42	96.21
9	100.00	98.75	100.00
10	98.42	97.98	97.62
11	99.58	97.81	97.80
12	97.75	97.92	97.45
13	98.58	98.84	99.11
14	97.08	96.37	95.69
15	100.00	99.22	98.51
16	96.54	98.97	99.19
17	99.92	97.98	93.99
18	98.91	100.00	100.00
19	99.04	97.45	96.66
20	96.25	94.51	96.79
21	98.08	97.50	95.63
22	96.21	99.14	90.70
23	99.54	98.31	98.94
24	94.46	94.76	98.11
25	96.75	98.17	100.00
26	99.46	98.59	99.09
27	99.38	98.02	98.20
28	96.92	98.86	91.94
29	99.46	96.59	98.22
30	91.54	94.87	92.77
31	90.29	97.17	90.56
32	96.67	99.14	90.11
33	97.33	89.71	97.51
34	90.33	91.24	97.61
35	95.67	100.00	98.94
36	99.42	98.72	98.78
37	98.83	97.39	97.33
38	98.21	97.98	96.19
39	96.92	97.62	96.08
40	90.42	98.34	95.12

Participants	Low /u/	Mid /u/	High /u/
1	95.38	99.42	97.95
2	98.75	99.22	98.11
3	96.04	99.36	96.89
4	100.00	98.50	100.00
5	99.42	96.51	96.46
6	98.58	99.45	99.11
7	98.29	99.83	99.94
8	95.46	96.62	96.37
9	98.46	99.36	98.57
10	94.17	97.78	97.53
11	99.79	97.89	97.85
12	91.75	91.99	90.41
13	100.00	98.39	98.74
14	96.08	97.12	95.88
15	100.00	99.03	98.82
16	100.00	100.00	99.46
17	99.00	97.42	95.46
18	99.04	97.42	98.53
19	100.00	100.00	99.54
20	97.50	97.48	96.42
21	99.67	97.50	92.44
22	99.25	98.36	94.78
23	98.54	96.84	99.50
24	93.96	97.84	95.03
25	99.38	99.56	100.00
26	98.58	100.00	98.74
27	98.13	98.17	97.64
28	100.00	98.28	97.45
29	99.75	95.79	96.15
30	92.92	98.81	94.63
31	90.42	93.18	97.24
32	100.00	94.65	90.95
33	97.96	93.79	98.40
34	92.58	92.13	95.73
35	94.20	90.34	94.28
36	98.04	98.25	98.26
37	99.71	97.26	97.74
38	99.08	96.65	94.70
39	97.21	99.64	95.19
40	96.92	93.74	94.56

Oral non-words

Participants	Low /pava/	Mid /pava/	High /pava/
1	95.56	97.11	95.40
2	95.52	95.83	96.18
3	92.55	94.78	93.53
4	98.41	98.77	98.73
5	98.49	96.12	97.51
6	97.48	96.44	96.67
7	97.84	96.98	98.25
8	95.93	98.23	96.26
9	97.80	98.58	95.98
10	97.64	97.89	95.94
11	98.66	98.47	96.77
12	95.32	95.34	94.21
13	97.56	94.67	94.23
14	91.98	93.77	93.45
15	99.10	95.29	95.32
16	95.56	97.56	95.00
17	95.89	96.31	92.71
18	96.09	96.25	96.50
19	98.05	97.78	96.50
20	98.70	97.08	97.51
21	96.46	98.13	91.57
22	95.32	98.88	93.59
23	98.24	98.66	98.94
24	97.72	95.32	94.60
25	96.38	96.04	95.38
26	95.20	97.35	98.45
27	96.50	96.04	95.60
28	98.86	98.53	98.11
29	95.81	93.18	95.12
30	90.90	90.78	91.34
31	90.00	100.00	93.81
32	98.29	96.66	92.67
33	96.29	97.86	98.53
34	98.94	99.06	97.93
35	92.14	94.19	96.89
36	99.02	99.09	97.99
37	99.51	97.46	98.29
38	96.34	96.79	96.26
39	98.70	97.08	97.65
40	98.94	98.25	93.45

Participants	Low /piva/	Mid / piva /	High /piva /
1	96.82	99.25	95.78
2	97.35	96.84	96.00
3	97.76	94.43	94.21
4	97.11	98.94	99.30
5	98.62	98.58	97.99
6	97.92	99.36	98.47
7	100.00	99.41	98.17
8	95.52	98.93	98.03
9	96.38	95.77	95.86
10	97.80	96.31	99.24
11	98.53	96.52	96.30
12	97.23	95.83	95.62
13	96.05	94.94	94.90
14	93.57	93.15	90.82
15	97.11	96.17	95.82
16	93.69	95.48	93.69
17	95.85	93.90	93.73
18	100.00	97.97	98.71
19	100.00	97.51	97.33
20	97.43	94.65	95.32
21	97.03	98.88	92.41
22	93.61	99.12	96.20
23	98.98	99.06	98.29
24	100.00	99.25	98.27
25	98.25	96.04	95.70
26	97.43	99.84	99.46
27	93.53	92.61	95.20
28	96.70	93.82	92.29
29	90.68	96.23	94.56
30	90.57	86.89	90.99
31	90.01	98.64	90.78
32	92.59	96.63	93.45
33	94.91	95.75	98.43
34	95.24	98.88	98.53
35	95.77	98.34	100.00
36	98.57	98.85	97.51
37	99.76	93.63	96.93
38	96.66	95.16	95.70
39	98.25	95.93	98.27
40	98.58	96.81	98.20

Participants	Low /puva/	Mid /puva /	High /puva /
1	97.84	99.14	97.85
2	98.09	95.34	94.70
3	94.34	92.99	94.13
4	96.70	98.64	99.42
5	98.57	98.42	98.33
6	100.00	100.00	99.22
7	100.00	100.00	99.74
8	97.35	99.20	98.92
9	97.64	100.00	98.13
10	98.94	97.14	99.02
11	99.23	98.98	97.17
12	97.76	97.97	96.63
13	94.83	95.85	95.70
14	92.39	92.94	92.73
15	96.95	96.17	94.96
16	96.13	97.89	94.31
17	94.42	94.35	91.86
18	100.00	99.12	99.06
19	93.40	91.89	92.71
20	99.43	96.36	96.28
21	96.38	95.56	92.27
22	95.85	99.36	97.75
23	99.10	98.50	98.61
24	97.96	98.47	97.89
25	96.86	96.60	96.10
26	96.17	97.75	100.00
27	100.00	99.84	99.50
28	98.57	99.20	93.93
29	99.63	96.55	94.09
30	85.91	82.95	90.78
31	90.66	93.74	91.67
32	97.80	98.31	92.00
33	98.21	97.19	100.00
34	92.47	95.16	100.00
35	98.98	93.68	95.58
36	99.47	98.72	97.69
37	99.71	98.26	97.79
38	98.33	96.28	96.52
39	99.67	99.52	96.32
40	97.76	97.74	94.78

Nasal non-words

Participants	Low /mava/	Mid /mava/	High /mava/
1	98.04	97.64	95.57
2	94.64	94.95	94.26
3	91.44	91.66	93.74
4	98.60	98.75	98.70
5	96.56	97.82	97.33
6	99.60	98.38	97.85
7	98.28	99.65	98.34
8	95.56	98.11	97.93
9	97.48	97.08	97.19
10	100.00	97.90	98.98
11	96.92	96.41	95.49
12	89.96	93.23	92.54
13	93.72	94.66	93.72
14	89.04	90.73	90.13
15	94.80	93.92	95.15
16	95.40	95.30	94.99
17	92.48	92.46	91.74
18	97.48	98.51	98.78
19	100.00	97.16	97.61
20	98.88	97.56	97.23
21	90.60	94.85	90.27
22	98.92	99.39	97.83
23	99.24	99.55	99.20
24	98.40	97.34	97.85
25	97.92	98.65	99.12
26	96.36	97.40	98.70
27	91.28	92.03	92.38
28	99.28	99.28	98.98
29	95.52	94.63	96.07
30	91.52	83.00	93.78
31	100.00	97.74	93.56
32	97.76	95.06	91.34
33	97.04	102.39	99.60
34	97.20	95.99	96.11
35	93.76	92.19	92.12
36	93.16	96.81	97.81
37	99.56	98.65	91.72
38	98.88	93.12	97.19
39	98.64	97.69	97.79
40	97.24	95.41	98.11

Participants	Low /miva/	Mid /miva /	High /miva/
1	95.24	99.15	96.17
2	96.16	96.39	94.04
3	91.92	92.40	91.94
4	100.00	99.87	99.02
5	96.52	96.71	95.65
6	98.16	99.26	97.79
7	97.48	100.00	98.98
8	97.00	96.20	96.35
9	97.08	98.09	97.15
10	100.00	96.84	96.89
11	97.48	98.22	97.57
12	95.00	92.91	92.76
13	93.92	93.94	93.64
14	91.24	89.80	89.29
15	96.20	96.47	95.85
16	95.00	95.86	94.10
17	94.44	90.92	91.20
18	99.65	98.99	99.32
19	98.08	98.03	100.00
20	95.16	95.09	95.33
21	96.48	94.53	90.77
22	96.12	99.31	97.75
23	98.64	98.67	98.76
24	96.22	98.34	98.01
25	95.40	99.52	96.07
26	96.64	98.06	99.12
27	95.44	94.56	93.82
28	94.25	98.25	97.51
29	100.00	100.00	99.36
30	89.36	94.34	93.68
31	91.00	94.66	91.18
32	99.72	99.26	90.57
33	99.08	95.41	99.50
34	96.34	95.51	99.48
35	92.80	97.53	97.19
36	96.04	97.24	98.86
37	99.44	97.88	92.78
38	98.72	94.98	92.50
39	98.32	98.41	97.47
40	99.63	98.06	93.82

Participants	Low /muva/	Mid /muva/	High /muva/
1	97.84	97.85	97.11
2	93.96	94.24	94.32
3	91.76	93.04	91.14
4	97.12	99.23	97.77
5	97.48	95.33	94.79
6	97.44	96.79	96.71
7	98.24	73.73	98.92
8	96.48	97.26	97.09
9	93.48	93.81	92.70
10	100.00	98.11	98.34
11	97.92	97.16	97.51
12	90.72	92.78	94.40
13	94.80	95.75	95.35
14	90.88	91.34	90.45
15	95.08	94.42	94.60
16	97.04	97.95	97.89
17	91.16	92.64	91.01
18	99.88	98.38	98.48
19	96.54	97.50	99.76
20	100.00	98.57	97.49
21	100.00	96.10	90.21
22	95.00	98.30	99.32
23	99.52	99.58	99.40
24	99.76	99.47	98.52
25	95.56	95.96	93.90
26	99.04	99.60	99.70
27	96.60	95.83	96.33
28	98.25	98.59	97.03
29	97.64	96.71	95.33
30	90.90	91.23	89.29
31	100.00	95.01	89.03
32	100.00	98.94	90.05
33	97.24	94.18	98.92
34	100.00	97.85	97.11
35	98.52	99.81	100.00
36	96.52	97.10	97.47
37	99.72	96.07	93.08
38	97.48	94.37	95.45
39	97.84	97.18	95.45
40	85.91	94.56	93.90