Comparison of acoustic characteristics in female trained (Carnatic style) singers, untrained singers and non singers

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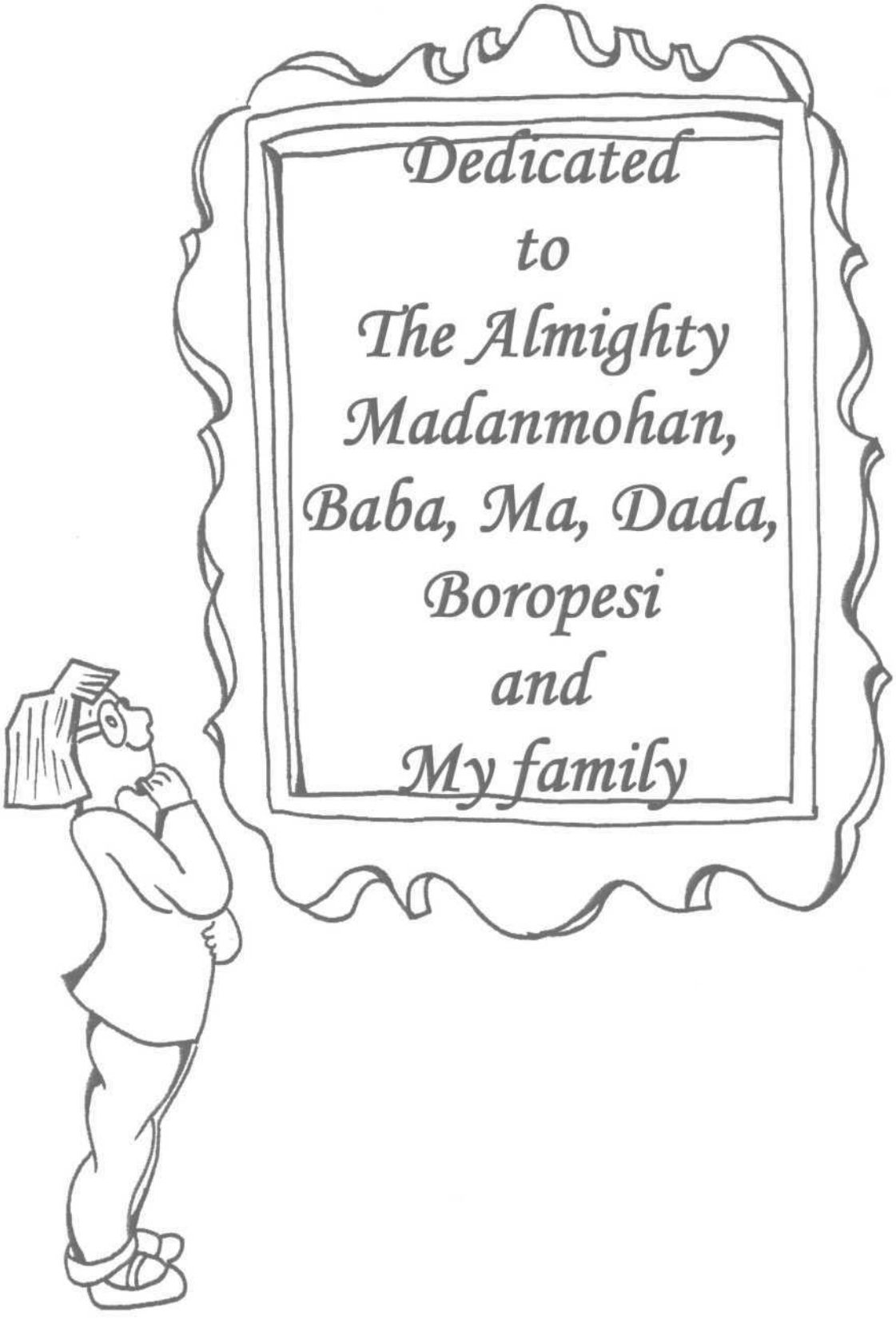
Dedicated
to
The Almighty
Madanmohan,
Baba, Ma, Dada,
Boropesi
and
My family

CERTIFICATE

This is to certify that this dissertation entitled **'Comparison of acoustic characteristics in female trained (Carnatic style) singers, untrained singers and non singers'** is the bonafide work submitted in part fulfillment for the degree of Master of Science (Speech Language Pathology) of the student (Registration No. 05SLP006). This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysore

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CERTIFICATE

This is to certify that this dissertation entitled **'Comparison of acoustic characteristics in female trained (Carnatic style) singers, untrained singers and non singers'** has been prepared under my guidance and supervision.

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DECLARATION

This is to certify that this dissertation entitled **'Comparison of acoustic characteristics in female trained (Carnatic style) singers, untrained singers and non singers'** is the result of my own study and has not been submitted in any other university for the award of any diploma or degree.

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CONTENTS

LIST OF TABLES

LIST OF GRAPHS

Chapter I

INTRODUCTION

A certain number of acoustical, and in particular spectrographic, studies on singing have already been made but work in this field lags far behind what has been done in the realm of speech. Singing is a subject which does not arouse such general interest as speech and in addition to this, as material for acoustical research it gives rise to peculiar difficulties, which it is well to consider at an early stage (Fry & Manen, 1957).

However, Singing is a unique way of communicating the ideas of writers and poets. Singers obviously use their voices in very special ways, influenced by and creating esthetic values (Bunch, 1995). The singing voice is the product of a delicate balance of physiologic control, artistry, and technique (Teachey, Kahane & Beckford, 1991).

Artistic performance by the singers depends largely on three factors: the singer's ability to characterize, i.e., to adopt a particular voice quality, his ability to portray an emotional mood and last his ability to articulate a sequence of words while preserving continuity of musical tone (Fry & Manen, 1957). One does not have to think about breathing for conversational speech but during singing performance, one becomes quite conscious of the need for adequate and efficient control of breath. The greater the skill of the performer in singing and speech, the more vital the role of conscious control of the mechanism of breathing while efficient patterns of activity are being established and once

established the good habits become unconscious. A singer must expend a great deal of energy in performance. In singing, the most efficient inspiration is one that allows the desired amount of air to be drawn in rapidly and inconspicuously without inducing undue muscular tension which might interfere with the functioning of the lips, tongue, jaw, pharynx and larynx. The performer, who cannot articulate the words of a song so that they are understood, has defeated the whole purpose of the art (Bunch, 1995).

Physiologic differences in laryngeal and vocal tract functioning have been found between trained and untrained singers (Brown, Hunt, Williams, 1988; Watson, Hixon, 1985; Sundberg, 1987; Gould, 1977; Shutte, Miller, 1983). Sundberg (1987) and Gould (1977) have reported that there are cross-training benefits for students of vocal pedagogy and these techniques could also enhance the non singing voice. The trained singer has been shown to outperform his untrained counterpart through superior control of respiratory, laryngeal, and articulatory dynamics while singing, although no differences appear to exist in the speaking voice (Brown et al., 1988; Shipp & Izdebski, 1975). It has not been established whether these differences between trained and untrained singers reflect innate or superior physiologic endowment. However, Peppard, Bless, & Milenkovic (1988) suggest that singers' vocal mechanisms are more robust than those of non singers. From physiologic analyses of several vocal parameters of trained and untrained singers, Brown et al. (1988) concluded that better performance by trained singers was due to the benefits of better vocal training rather than to superior physiologic endowment. This assertion is supported by Perello (1962). Vocal training can clearly have a prophylactic effect on the voice (Lawrence, 1979).

Artistic singing and speaking depend to a greater extent on a person's ability to establish optimum conditions of vocal resonance. The vocal tract resonances, formants, are of paramount significance to voice and vowel quality. Fant (1960) defined formants as 'the spectral peaks of the sound spectrum'. Formants are the most significant earmarks of sound and every vowel is formed by two or more formant ranges. In all languages the phonetic quality of vowels is due to resonances in the vocal tract created mainly by changes in the position of the tongue and to a lesser extent by the lips. As the tongue shifts into different positions, thereby changing the shape of the resonating chamber, resonances are either enhanced or damped producing formant frequencies of vowels. The lowest two formants decide what the vowel quality is going to be. The higher formants determine much of the personal voice characteristics, including voice classification.

Formant frequencies of vowels depend on the tongue height and tongue position. Frequency of the first formant (F1) is inversely related to tongue height, and frequency of the second formant (F2) is inversely related to the tongue position. In the production of vowels, oral tract is roughly divided into two cavities, namely back and front cavity. Back cavity refers to the space behind articulatory constriction and front cavity refers to the space in front of articulatory constriction. Though erroneously, Fl depends largely on the volume of the back cavity and F2 depends largely on the volume of the front cavity (Fant, 1960). Thus, one will get a high Fl if the tongue is positioned low at the back of the oral tract. High F2 is obtained when tongue is positioned in the front of the

oral tract. In normal speech, formant frequencies are used merely to pronounce different vowels and consonants. Also, when pitch varies, larynx height normally varies in speech and a change in larynx position results in changes of air cavity volume in low pharynx. All vowels reinforce the glottal vibration in the pharynx. Pharynx is the most important resonator of the voice. The efficient co-ordination of the various alterable and unalterable parts of the vocal instrument is requisite for the ultimate good quality of sound. The most favorable conditions of the pharynx for vocal quality are an elevated soft palate; comfortably low larynx, relaxed tongue and a lack of tension in neck and chest. Visible factors influencing vocal quality are the position and movement of the lower jaw.

Singers are special also with respect to formant frequencies (Sundberg, 1989). It is difficult to observe what happens inside a singer while he is performing and therefore many of the changes in the pharynx remain a shrouded mystery. In female high-pitched singing, the two first formants are tuned so that they optimally match the pitch frequency, thereby increasing the loudness of the voice considerably. However, differences occur when vowels are sung, partially because of the extended range of pitch used in singing compared with that of speaking. A singer ascending a scale requires certain shifts of resonance, which are usually achieved by a modification of the vowel sound (Sundberg, 1997). Even those singers well endowed by nature must then bend efforts to vocal training: the component, which they can control. In speech production, many patterns of speech include the action of protruding the lower jaw rather than lowering it. In singing, this forward displacement alters the shape of the resonator and position of the larynx and

creates articulatory problems. It cannot be stressed too often that the elevator muscles of the jaw must be relaxed so that the jaw is able to move freely upwards and downwards.

Good vocal production and efficient articulation go hand in hand. Proper articulation is important not only for clear and precise diction and meaning but also because of the effect it has on facial expression. The desired expression may not be obvious if the singer /speaker is having difficulties with the technicalities of articulation (Bunch, 1995).

Vennard (1967) discussed the importance of articulation in singing and stated that it is by means of consonants that we express not merely the emotions or pattern of the movement, but also the events of the past and aspirations of the future. It seems that trained singers are faced with the challenge of producing a superior tone to convey the paralinguistic intent of a song without sacrificing consonant articulation and thus, the linguistic message. Singers are trained to sing in several languages. For example, as part of their training they are taught to articulate precisely and to differentiate vowel quality between languages (Rothman, Brown, Sapienza & Morris, 2001).

McCrea & Morris (2004) reported that trained singers and non singers consistently display articulatory and phonatory differences during singing and similar articulatory and phonatory patterns during speech. Most of the studies have concentrated on laryngeal parameters not articulatory dynamics. No studies have examined specific consonant sound durations during speech and singing. Some studies have speculated that

over time, continuous singing training has an effect upon professional singer's everyday speech pattern. Vocal training has, in part, been associated with the distinctions in the physiological, acoustic, and perceptual parameters found in singers' voices versus the voices of non singers (Mendes, Rothman, Sapienza & Brown, 2003). It is well known that in addition to formal voice training, life-style and practices in daily voice use are important factors affecting vocal health and longevity of the voice and precise articulatory movement.

Information available on the trained and untrained vocalist with regard to articulatory dynamics is limited. The effectiveness of temporal and spectral parameters which indicate subtle articulatory-phonatory interaction/differences in speech production may prove an effective measure for acoustically representing the demonstrated physiologic differences among female trained (Carnatic) singers, female untrained singers and female non singers. It may be a useful, noninvasive method for documenting the articulatory-phonatory aspects of vocal training. Hence, the present study was undertaken to, identify specific articulatory attributes and the influence of training (formal and informal).

Chapter II

REVIEW OF LITERATURE

Sundberg (1970) has investigated lateral cineradiographic X-ray pictures of opera singers speaking and singing vowels and has concluded that the primary articulatory alteration is the lowering of the larynx during singing. He also stated about professional singer's articulatory difference from a physiological view point. In some dimensions, notably (1) larynx position (2) the jaw and the lip openings (3) the cross-sectional area of the vocal tract in the velum region and 4) the tongue shape in the back vowels , typical difference were found between spoken and sung vowels.

He also concluded that sung vowels as compared with the spoken vowels displayed the following four characteristics as regard to the formant frequencies: a) F2 is lowered in non back vowels b) F3 is raised in back vowels and lowered in the other vowels c) F4 and F5 are lowered in all the vowels d) The frequency distance between F3 and F4 is reduced in all vowels.

Acoustical analysis of the speaking and singing voices of two types of professional singers was conducted by Burns (1986).The vowels /i/, */a/ & /o/* were spoken and sung four times each by seven opera and seven country and western singers. Vowel spectra were derived by computer software techniques allowing quantitative assessments of formant structure (F1-F4). The formant values F1, F2, F3, and F4 were obtained for each vowel spectrum. Statistical analysis of formant structure proved to be the most sensitive measure highlighting the acoustic differences between Opera and

Country and Western voices. Results revealed that Country and Western singers basically maintained the same mean formant in speaking and singing while Opera singers lowered their mean formant value in switching from a speaking voice to a singing voice.

Studies on male and female Opera singers have revealed that both articulation and phonation peculiarities yield an acoustic output which is different from that of speech (Ross, 1992). In Opera singing, the hitherto observed deviations from formant frequencies in speech may be summarized. The lowest two formant frequencies in female singing are pitch dependent due to an overlap between the fundamental frequency range (which in opera singing may be considerably higher than in speech) and the normal first formant region (which starts at about 400 Hz). The first formant should not be lower than the fundamental frequency, which means that if the fundamental frequency becomes close to or higher than the normal first formant frequency, the latter should be raised. Normally, it is set to a frequency in the near vicinity of the fundamental, accompanied by a rise of the second formant (Sundberg, 1987). At the same time, Bloothooft and Plomp (1985) have shown that differences between vowels when considering their first two formant frequencies become smaller at higher fundamental frequencies. The vowels tend to form two sets of front and back vowels in the F 1/F 2 planes at a frequency of about 600 Hz, and a single vowel cluster at a fundamental frequency of about 900 Hz. As the two lower formant frequencies are believed to be to a large extent responsible for the vowel quality, an alteration of the formant frequencies would lead to a reduction of the vowel intelligibility-a phenomenon commonly observed in Opera singing. In male singers, an overlap between the fundamental frequency and the first formant frequency

ranges rarely occurs, and therefore the formant frequencies are assumed to be more or less pitch independent. The first formant in singing, however, is found to be slightly higher than in speech for most of the vowels, and the second and the third formants to be lower for front vowels (Sundberg, 1970).

Comparison of choir and opera singing (Rossing, Sundberg & Ternstrom, 1986, 1987; Ternstrom & Sundberg, 1989) has indicated the presence of both articulation and phonation differences between these two styles. These differences were depicted as more power in the singer's formant region in the opera singing versus more power in the fundamental frequency region in the choir singing. Similarly, Colton and Estill (1981) have found more energy at high frequencies in twang, a voice quality in country-western singing, and in opera singing, in contrast to speech. Ross (1992) investigated the formant frequencies in an old Estonian folk song performed by two female voices. The formant frequencies were estimated for two back vowels /a/ and /u/, and for two front vowels *Id* and *lil.* The first formant in the sung vowels is raised with respect to the spoken ones in three vowels measured: for *Id,* (615 Hz vs. 341 Hz), for /i/, (530 Hz vs. 263 Hz) and for */v/,* (605 Hz vs 295 Hz). With the sung /a/, the first formant is slightly lower than in the spoken vowel (777 Hz vs 810 Hz). The rise of the first formant has earlier been reported in female opera singing for all vowels but generally at higher fundamental frequencies (Sundberg, 1987). Its primary articulatory reason was considered to be a widening of the jaw opening, which also may change the higher formant frequencies to some extent. At the fundamental below 300 Hz, the first formant has been demonstrated to rise for the/i/vowel only. For/e/and/u/, the increase were noticed above the fundamental of 400

Hz, and for/a/, above 600 Hz. The second formant of front vowels showed a tendency to decrease in female opera singing at the fundamental between 200 and 300 Hz. It was noted that the average difference between the second formants of/e/and/i/ was larger in singing (426 Hz) than in speech (161 Hz). As for the back vowels/a/and/u/, their second formants were raised in singing as compared to speech: for/a/, 1319 Hz vs 1121 Hz, and for/u/, 1021 Hz vs. 615 Hz. The same rise was earlier noticed in opera singing at the fundamental above 400 Hz (Sundberg, 1987). The results indicated that formant frequencies in sung vowels, when compared to spoken ones, tend to cluster (or to neutralize) in the F 1/F2 plane. The clustering was due to (a) the increase in first formant frequency for vowels /e/, /i/, and /u/, but not /a/ (b) the decrease in second formant frequency for front vowels, but increase in back vowels. The third formant showed little deviation from the spoken vowels.

Stone, Cleveland & Sundberg (1999) studied the "formant frequencies in country singers' speech and singing". In this study, the formant frequencies were measured for identical phonemes after recording the country singers' spoken and sung versions of the national anthem and of the a song of their own choice. Comparisons revealed that the singers used the same or slightly higher formant frequencies when they were singing than when they were speaking. Authors conclude that the formant frequencies used in country singing are similar to those used in speech. This result is not surprising under the hypothesis that country singers do not need to alter their vocal productions when singing. They revealed that Classically trained singers show considerable formant frequency differences between speech and singing. The results of the study suggest that articulatory

habits employed in speech were also used in this type of singing. If country singers change their formant frequencies in singing they are higher rather than lower, as is typically found in classical singers.

The review revealed that regular voice training could influence speech production patterns. But this belief is still under experimentation. Studies that have been done till date have been on some groups of singers in Western countries. Very limited studies have been done in Indian context.

Therefore, an attempt has been made to understand the differences in acoustic characteristics in 3 groups of subjects that are trained (Carnatic style) singers, untrained singers and non singers. Further, an attempt is made to investigate the influence of voice training on everyday speech pattern.

Aim of the study

The aims of the present study are as follows:

1) To investigate the temporal and spectral characteristics of speech sounds in spoken and sung tasks in the three groups of female subjects i.e. trained (Carnatic style) singers, untrained singers and non singers.
2) To compare the results across three groups of subjects i.e. trained (Carnatic style) singers, untrained singers and non singers.

3) To examine whether influence of vocal training (formal/informal and or practice of singing) will have any influence on general speech pattern.

Chapter III

METHOD

Subjects: Thirty literate female subjects (in age range of 18 to 40 years) who were native speakers of Kannada were selected for the study. They were divided into three groups as follows,

1. *Trained (Camatic style) singers* consisted of 10 trained singers. Singers who had undergone formal training in vocal music (Carnatic style) for a minimum of 10 years were chosen.
2. *Untrained singers* consisted of 10 untrained singers who practiced singing of folklore/ film music on a regular basis but did not have any formal vocal training.
3. *Non singers* consisted of 10 subjects who were not exposed to any formal/ informal vocal training and who did not practice any form of singing on a regular basis.

All subjects were screened for normalcy of orofacial structures, hearing and speech-language abilities. None of the participants had any other speech-language, hearing or neurological problems. Subjects with a recent history (1 month) of common cold, throat infections were ruled out from participation.

Procedure

1) Instrumentation
   a) A portable Sony digital tape recorder (Sony M2R 30) with facility for external microphone was used for recording of the tasks.
   b) Praat software (version 4.1.21) was used for acoustic analysis

2) Recording

All recordings were done in quiet environment with the participants seated in comfortable position. The spoken and sung samples were recorded into the portable digital tape recorder using external microphone. The microphone was placed at a fixed distance of 6 cm from mouth level of the participant.

3) Token/ material

Song: The National song "/vandeː maθaram/" from the film 'Anand Math', 1952 sung by the famous playback singer, Ms. Lata Mangeshkar was chosen. First line of the first stanza including the chorus was selected. In the chorus there were multiple repetitions of the phrase /vande maθaram/ and the second repetition formed the token/ material and this was considered for extraction of temporal and spectral parameters after acoustic analysis.

Instruction: All participants were instructed to listen to the 'token/ material' (first line of the first stanza including the chorus). They were free to listen to the practice sample as many times as they wanted.

4) Tasks

a) Spoken task: All subjects were instructed to speak the token/ material (first line of the first stanza of the National song "/vandeː maθaram/") at their comfortable pitch and loudness levels.

b) Sung task: All subjects were instructed to sing the token/ material (first line of the first stanza of the National song "/vanðe maθaram/") similar to the token/ material.

5) Acoustic Analysis

The recorded data were transferred to the computer for acoustic analysis at sampling rate of 16 KHz using 16 bit quantization and were stored for spectrographic analysis. For acoustic analysis, one (the second) repetition from the chorus of the phrase '/vanðe maθ'aram/' was considered in both the sung and spoken conditions. Using Praat software (version 4.1.21) each token was displayed on the computer monitor and spectrograms were extracted after spectrographic analysis. The following temporal and spectral parameters were obtained,

Temporal parameters

1) **Phrase Duration (PD):** Time between the onset of the first word of the phrase and termination of end word. In this study, /vanðe; maθaram/ total phrase duration (PD) was extracted.
2) **Vowel duration (VD):** Time between the point of steady state of F1, F2 and F3 onset and end of the steady state of above mentioned formants. In this study, steady state of vowels /a/ and /e/ when preceded by /v/, /θ/, /m/, /v/, and /ð/ consonants (VD /va̲/, V /ða̲/, V D /θa̲/, VD /ra̲/, and VD /ðe̲/ respectively) were extracted.

3) **Burst duration (BD)I** Burst duration is the time between the onset of the burst and offset of the burst. Burst is the transient that is produced on release of the occlusion and is no more than 40 ms in duration and is usually much briefer (Kent & Read, 1992). In this study, burst duration / ð/ and /θ/ (BD /ð/ and BD /θ/) were extracted.

4) **Closure duration (CD):** It is the interval of stop closure indicating the time for which the articulators are held in position for a stop consonant. In this study, closure duration of /θ/ consonant (CD /θ/) has been extracted.

5) **F2 Transition duration (TD):** The duration of the formant transition were measured as the time difference in ms. between the onsets of F2 transition at the beginning of the vowel till the steady state. In this study, F2 transition duration for /e/ and /a/ preceded by /ð/ and /θ/ consonants (F2 TD /ðe/ and F2 TD /θa/ respectively) were extracted.

Spectral parameters

1) **Formant frequencies**

A formant is a peak in acoustic frequency spectrum which results from the resonant frequencies of any acoustical system. Formants are characteristic partials that identify vowel.

First, Second and Third Formants i. e. Fl, F2 and F3 for the vowels /a/ and *Id* vowels each when preceded by /v/, /m/, /θ/, */r/,* and / ð / consonants (F1 /va/, F2 /va/, F3 /va/ , Fl /ma/., F2 /ma/, F3 /ma/, Fl /θa/, F2 /θa/, F3 /θa/, Fl /ra/, F2 /ra/,

F3 /ra/ and Fl /ðe/, F2 /ðe /, F3 /ðe /', respectively) were derived from the spectrograms.

Statistical analysis

The analyzed data was tabulated for all groups, for all the parameters and subjected to the statistical analysis. SPSS-Statistical Package for the Social Sciences (Version 10) was used for the statistical analysis. Parametric test, One-way ANOVA was used to calculate the means and standard deviations as well as to find out the significant difference in three groups. Furthermore, Duncan's post-hoc analysis was used to find out the pair-wise differences among female trained (Carnatic style) singers, untrained singers and non singers. Moreover, parametric paired 't' test was performed to find out the significance difference between spoken and sung task for each groups.

Chapter IV

RESULTS

The aims of the present study was,

1) To investigate the temporal and spectral characteristics of speech sounds in spoken and sung utterances in the three groups of female subjects, that is, trained (Carnatic style) singers, untrained singers and non singers.
2) To compare the results across three groups of subjects, trained (Carnatic style) singers, untrained singers and non singers.
3) To examine whether influence of vocal training (formal/informal and or practice of singing) will have any influence on general speech pattern.

The temporal and spectral measures were extracted from one repetition of /vaɳðe maθaram/. SPSS- Statistical Package for the Social Sciences (version 10) was used to do statistical analysis. Parametric test. One-way ANOVA was used to compare the speech acoustic characteristics in spoken and sung tasks. Furthermore, Duncan's post-hoc analysis was used to find out the pair-wise difference between female trained (Carnatic style) singers, untrained singers and non-singers. The results of the statistical analysis for the acoustic parameters for each group is shown in table 1 and 2 for spoken and table 3 and 4 for sung tasks.

Table 1: Mean values (M), Standard deviation (SD), F (2, 27) values and pair-wise significance for the temporal parameters in female trained (Carnatic style) singers, untrained and non-singers for spoken task.

Acoustic Parameters	Trained Singers		Untrained Singers		Non Singers		F(2,27) Values	Significant Pairs-Wise Differences
	M	SD	M	SD	M	SD		
PD	866.4	86.6	903.1	90.8	1041.3	131.1		^
VD /va̲/	30.4	6.8	33.1	9.3	40.9	19.5	1.73	
VD /ma̲/	65.3	11.1	82.2	24	90.7	31.1	2.99*	^
VD /ta̲/	38.7	10.1	48.4	13.3	53.8	15.7	3.33*	^
VD /ra̲/	28.3	9.1	24.8	5.3	38.6	14.6	4.75**	^ and#
VD /ðe̲/	49.1	16.7	45.6	18.2	83.1	46.4	4.64**	^ and#
BD /ð/	6.4	1.7	5.9	2.3	5.2	1.6	0.99	
BD /θ/	10.8	2.2	11.0	4.5	7.3	2.1	4.21**	
CD /θ/	82.3	8.8	72.7	19.5	88.9	9.4	3.62**	#
F2 TD /ðe̲/	20.2	10.4	23	9.6	15.7	2.9	1.93	
F2 TD /θa̲/	12.1	2.9	12.7	7.7	11.5	2.6	0.14	

Note: * $0.05<p<0.1$, * * $p<0.05$, * * * $p<0.01$, * * * *$p<0.001$

▼ Trained vs. Untrained Singers, ^Trained vs. Non-singers, # untrained vs. Non-singers

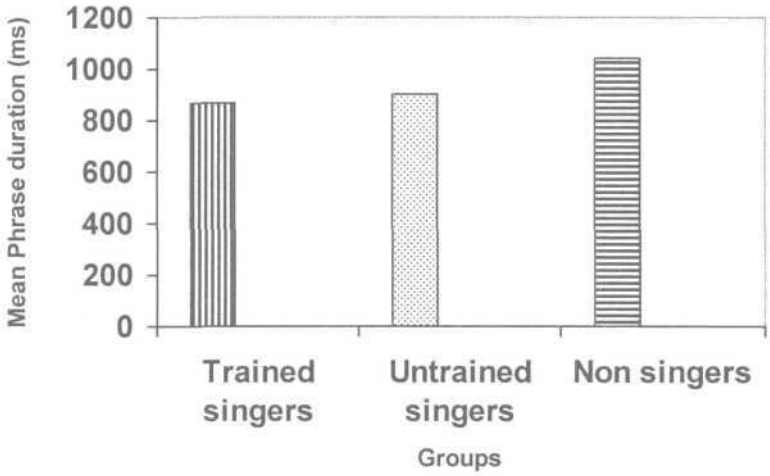
Spoken task: Temporal Parameters

Table 1 depicts the Mean, Standard Deviation, F (2, 27) values for the temporal parameters for all three groups of subjects.

Phrase Duration (PD)

The mean value of PD was shortest in trained singers followed by untrained singers and non-singers [Graph-1]. When the comparison was done between the three groups using one-way ANOVA, significant difference was found for PD between trained

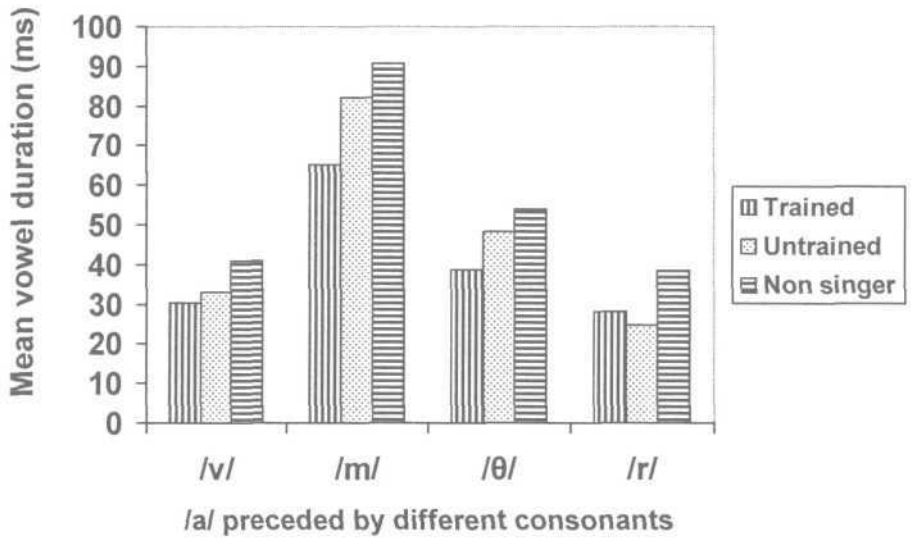
singers vs. non singers, and between untrained singers vs. non singers [F (2, 27) = 7.74, p<0.01]. But, no significant difference was found between trained vs. untrained singers..



Graph 1: Mean value of Phrase Duration

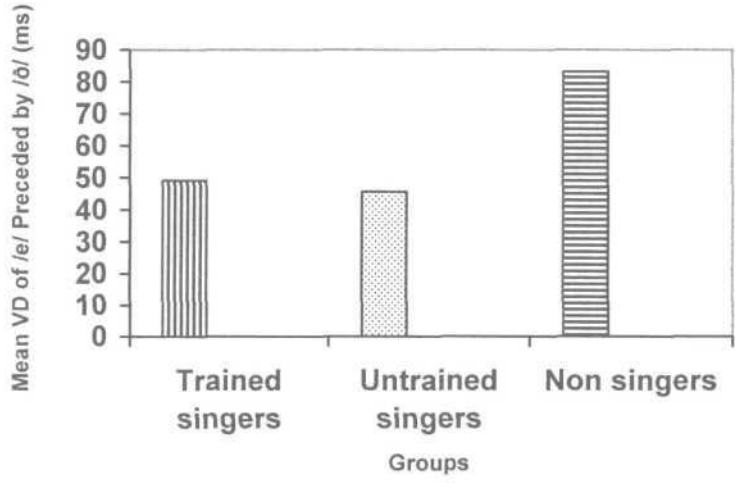
Vowel duration (VD)

From Graph 2, the mean value of VD for /a/ when preceded by /v/, /θ/, /m/, /r/ was shortest in trained singers except when preceded by /r/. Similarly, mean value of VD for /a/ was highest in non- singers when preceded by all consonants. Comparisons between groups using one-way ANOVA showed that there was no significant difference in vowel duration between trained vs. untrained singers. In trained singers, significant difference was observed for VD of /a/ when preceded by all consonants [{F (2, 27) = 2.99, p<0.1}, {F (2, 27) = 3.33, p<0.1}, {F (2, 27) = 4.75, p<0.05}] except when preceded by /v/. Significance was noticed for VD of /a/ when preceded by /r/ only in untrained vs. non singers groups.



Graph 2: Mean values of VD /a/ when preceded by different consonants.

The mean value of VD for /e/ when preceded by /ð/ consonant was shorter in trained singers than non-singers. But, from Graph 3 it is seen that trained singers exhibited slightly higher mean value than untrained singers. So, VD of /e/ was shortest in untrained singers. Significant difference was seen between trained vs. non singers and untrained vs. non singers [F (2, 27) =4.64, P<0.05].

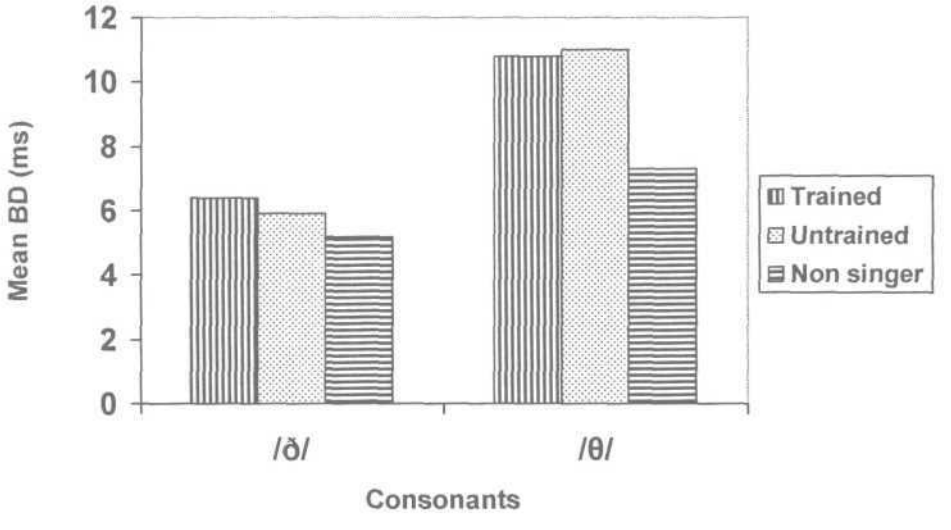


Graph 3: Mean value of VD for /e/ when preceded by / ð /' consonant.

Burst Duration (BD)

The mean BD for /ð/ was longer in trained singers followed by untrained singers when compared to non singers. But, no statistical significance difference was found between any groups.

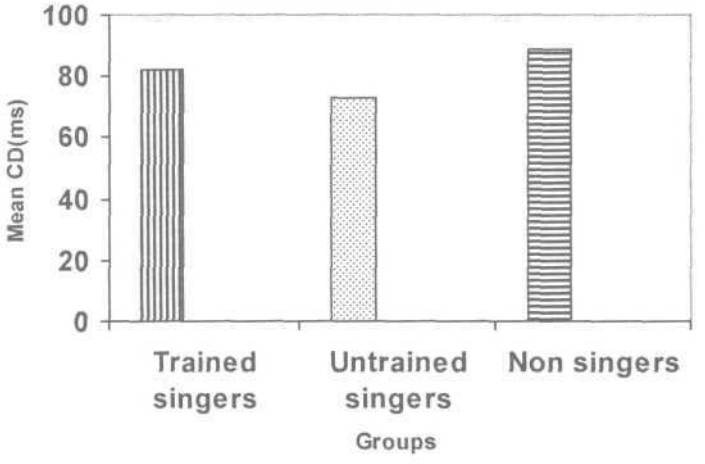
The mean BD for,/θ/ was almost similar between trained and untrained singers. The mean BD was shortest for non singers. The difference was found to be significant between trained vs. non singers and untrained vs. non singers group.



Graph 4: Mean values of Burst Duration of / ð / and /θ/ consonants.

Closure Duration (CD)

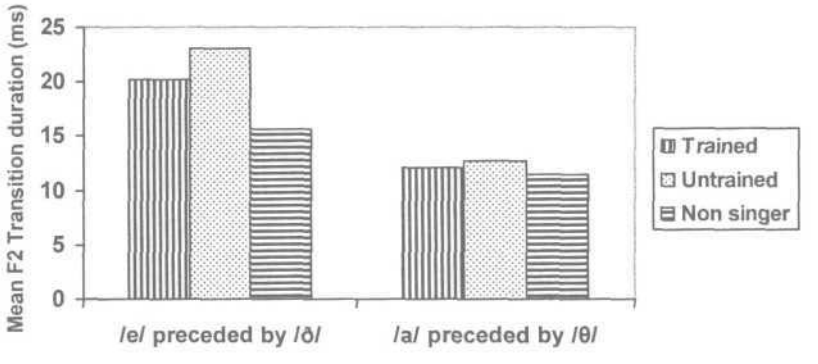
The mean value of CD for /θ/ consonant was longer in trained singers than untrained singers, but in non singers the mean value was longest. Untrained singer exhibited shortest mean value of CD for /θ/. On comparison, there was a significant difference between untrained singers vs. non-singers. [F (2, 27) =3.62, p<0.05] only.



Graph 5: Mean value of closure duration (CD) for /θ/ consonant

F2 Transition duration (TD) of /e/ and /a/ *vowels*

The mean value of F2 TD for /e/ and /a/ when preceded by / ð / and,/θ/ consonants respectively was shorter in trained singer compared to untrained singers. But it was shortest in non singers. Overall, it was highest in untrained singers (Graph 6). However no significant difference was found between any of the groups.



Graph 6: Mean value of F2 transition duration for vowels /e/ and /a/ when preceded by /ð/ and /θ/ consonant

Spoken: Spectral Parameters

Table 2: Mean values (M), Standard deviation (SD), F(2, 27) values and pair-wise significance for the spectral parameters for vowels /a/ and /e/ in female trained (Carnatic style) singers, untrained and non-singers for spoken task.

Acoustic Parameters	Trained Singers		Untrained Singers		Non Singers		F-Values (2,27)	Significant Pairs-Wise Differences
	M	SD	M	SD	M	SD		
Fl/va/	679	77	727	115	654	126	1.15	
F2/va/	1588	242	1557	319	1428	266	0.92	
F3/va/	2783	540	2652	498	2530	626	0.52	
F1 /ðe/	532	55	519	70	533	66	0.14	
F2 /ðe/	1845	497	2028	511	1903	465	0.36	
F3 /ðe/	2697	312	2868	194	2618	405	1.63	
Fl/ma/	710	143	813	137	828	143	2.04	
F2/ma/	1311	283	1436	193	1417	188	0.89	
F3/ma/	2256	613	2647	552	2753	482	2.25	
F1 /θa/	582	103	629	80	684	87	3.12*	^
F2 /θa/	1520	365	1572	261	1644	366	0.35	
F3 /θa/	2666	436	2603	472	2696	448	0.11	
Fl/ra/	580	102	666	126	708	108	3.35**	^
F2 /ra/	1429	353	1630	253	1627	270	1.51	
F3/ra/	2481	590	2545	475	2672	452	0.36	

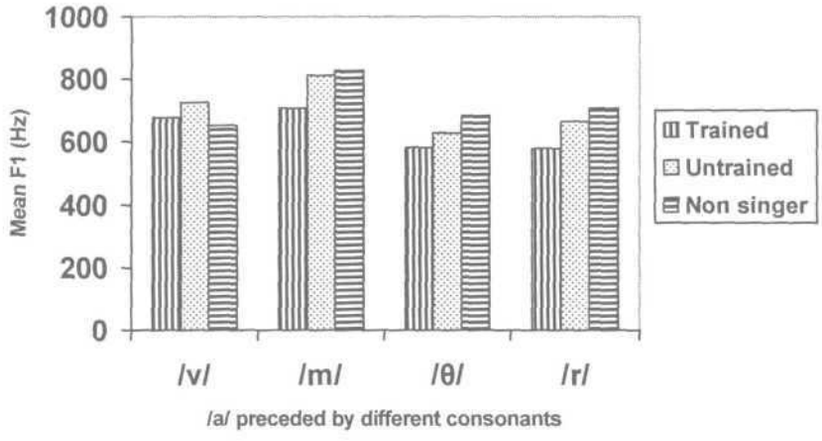
Note: * 0.05<p<0.1, ** p<0.05, *** p<0.01, ****p<0.001

• Trained vs. Untrained Singers, ^ Trained vs. Non-singers, # untrained vs. Non-singers

Table 2 depicts the mean, standard deviation, F (2, 27) values and pair-wise significance for the formant frequencies for vowels /a/ and *Id* when preceded by different consonants for all three groups of subjects.

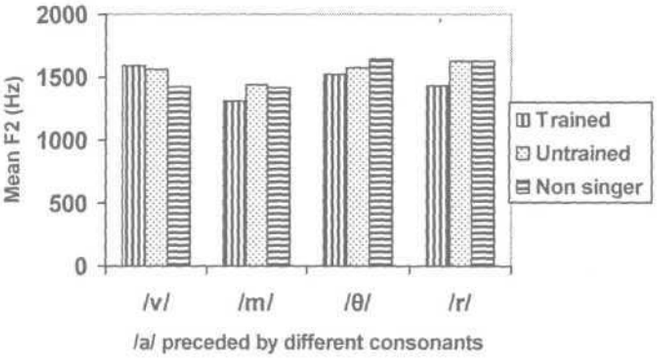
Fl for /a/: Mean Fl values were lowest for trained when preceded by /m/, /θ/ and /r/. Mean Fl values were highest in non singers when preceded by /m/, /θ/ and /r/. In

untrained singers it was highest when preceded by /*v*/ (Graph 7). When comparisons were made across groups, significance difference was noticed for trained vs. non singers only for formant F1 values when preceded by /θ/' and /r/ [{ F(2, 27)=3.12, p<0.1}, { F(2, 27)=3.35,p<0.05}].



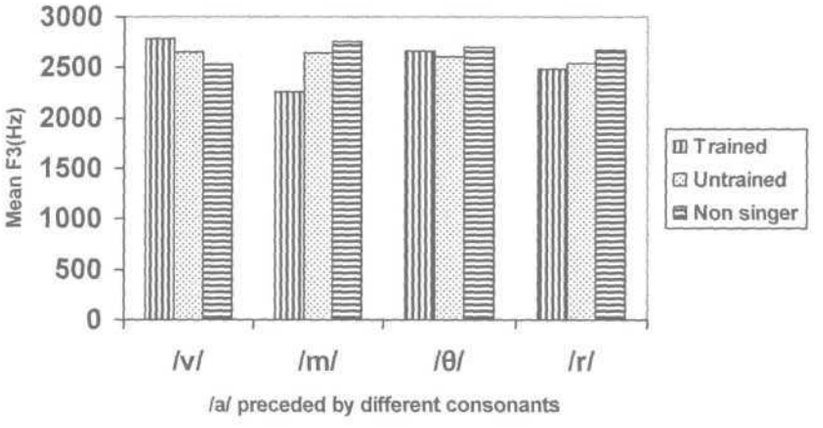
Graph 7: Mean values of first formant (Fl) for vowel /a/ when preceded by different Consonants

F2 for /a/: In trained singers mean F2 values were lowest when preceded by */m/*, /θ/ and /r/. Mean F2 values were highest in untrained singers when preceded by /m/, and */x/*. In non singers the mean value was highest when preceded by /θ/ (Graph 8). However, no significance was noticed across any groups.



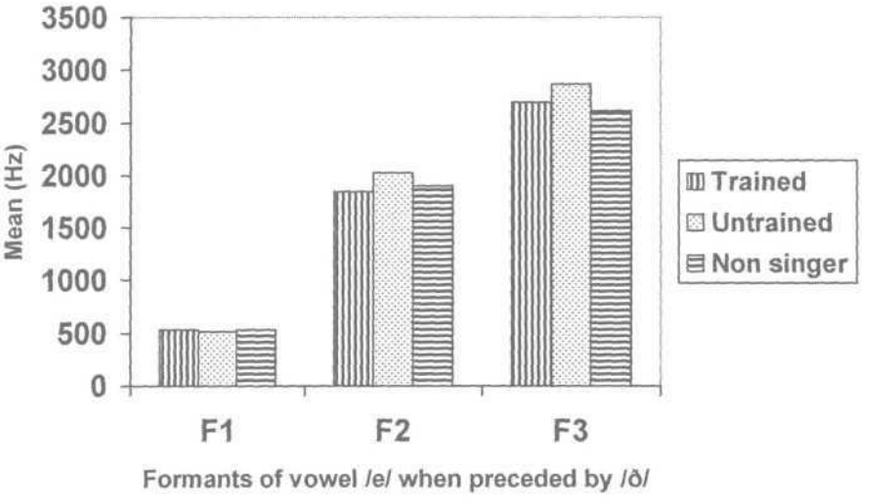
Graph 8: Mean values of second formant (F2) for /a/ vowel preceded by different consonants

F3 for /a/: Mean F3 values were lowest for trained when preceded by /m/, and /r*l* but was highest when preceded by /v/. Mean F1 values were highest in non singers when preceded by /m/, /θ/ and /r/ but was least when preceded by /v/ (Graph 9). However, significance was not noticed in mean F3 of vowel /a/ when preceded by any of the consonant.



Graph 9: Mean values of third formant (F3) for /a/ vowel preceded by different consonants.

Formants F1, F2, F3 for *Id:* No consistent pattern was observed for the formants when preceded by /ð/. From the Graph 10, it was noticed that mean Fl was higher in non singers and lower in untrained singers. Mean F2 values were higher in untrained singers but lower in trained singers. The mean values for F3 were higher in untrained singers but lower in non singers. When between groups comparison was made, no significance differences were noticed across any group.



Graph 10: Mean values of F1, F2 and F3 formants for vowel *Id* when preceded by / ð / consonant.

Table 3: Mean values (M), Standard deviation (SD), F (2, 27) values and pair-wise significance for the temporal parameters in female trained (Carnatic style) singers, untrained and non-singers for sung task.

Acoustic Parameters	Trained Singers		Untrained Singers		Non Singers		F (2,27) Values	Significant Pair-Wise Differences
	M	SD	M	SD	M	SD		
PD	1091.5	102.3	1253.2	74.9	1237.9	128.7	7.32* * **	^and ▼
VD/va/	37.8	8.7	37.2	9.7	42.5	19	0.47	
VD/ma/	134.8	33.2	145.2	25.2	127.6	27	0.94	
VD/ta/	80.8	19.8	83.8	13.3	67.9	10.1	3.16*	^and#
VD/ra/	36.5	15.1	31.8	8.3	43.8	9.9	2.75*	#
VD /ðe/	77.3	18.5	71.3	20.2	62.5	11.9	1.85	
BD /ð/	6	1.6	5.6	1.8	6.5	3.1	0.38	
BD /θ/	9.3	3.5	10.7	3.5	8.4	4	0.98	
CD /θ/	78.7	13.8	82.6	24.6	84.5	18.3	0.23	
F2 TD /ðe/	19.8	6.5	21.4	9.5	19.5	6.5	0.18	
F2 TD /θa/	16.7	4.2	12.2	6.4	15.4	7.7	1.33	

Note: * 0.05<p<0.1, ** p<0.05, *** p<0.0l, ****p<0.001

Trained vs. Untrained Singers, ^ Trained vs. Non-singers, #Untrained vs. Non-singers

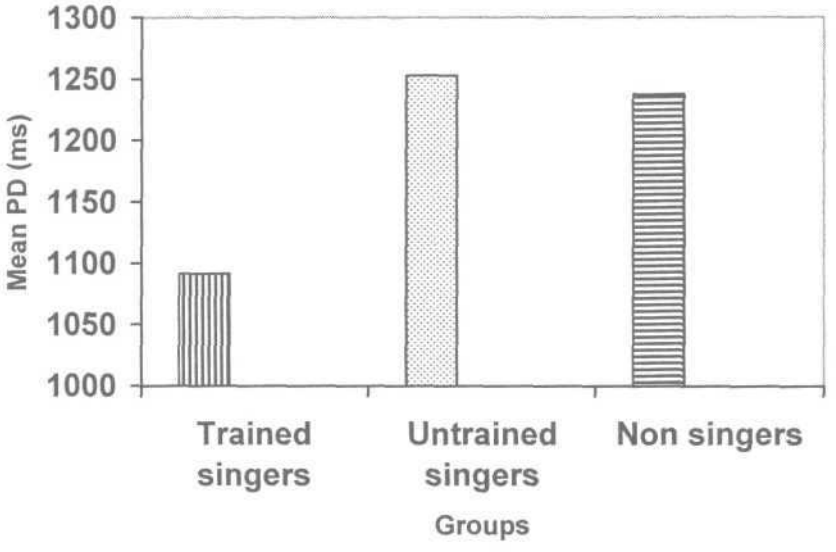
Sung task: Temporal Parameters

Table 3 depicts the Mean, Standard Deviation, F (2, 27) values and significance for the temporal parameters for all three groups of subjects.

Phrase duration (PD)

Graph 11 showed that trained singers as a group, exhibited shortest mean value of PD of /vande maθaram/. In untrained singers, mean PD was highest. When groups were

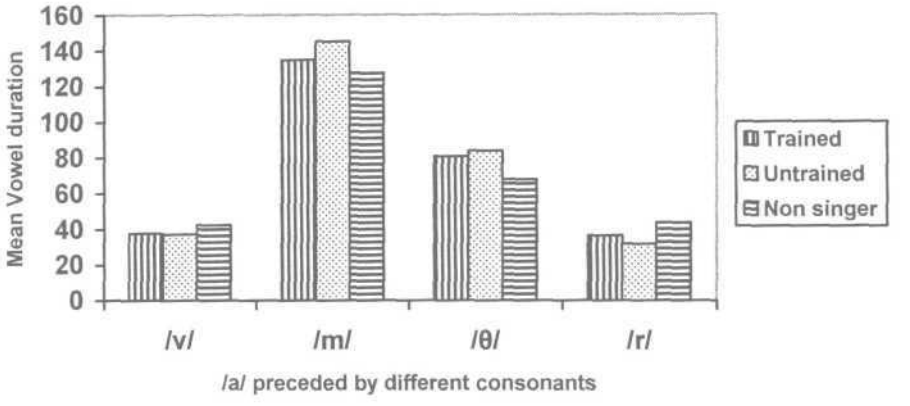
compared, the difference was found to be significant between trained singers vs. untrained singers and trained singers vs. non-singers [F (2, 27) =7.32, p<0.001].



Graph 11: Mean value of Phrase Duration.

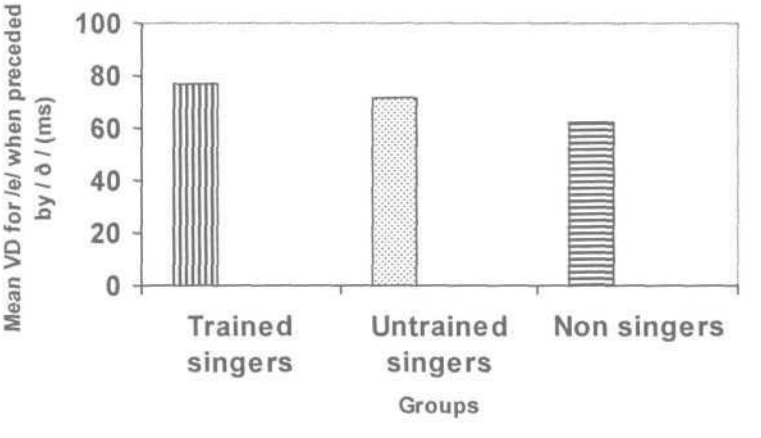
Vowel duration (VD)

From Graph 12, the mean value of VD for /a/ when preceded by /θ/ and /m/ was longest in untrained singers followed by trained singers. Similarly, mean values of VD for /a/ when preceded by /θ/ and /m/ was shortest in non singers whereas it was longest in non singers when preceded by /v/ and /r/. Comparisons between groups using one-way ANOVA showed that there was no significant difference in vowel duration between trained vs. untrained singers. But, significant difference was observed for VD of /a/ when preceded by /*xl* and /*v/* in untrained vs. non singers [{F(2,27)=3.2, P<0.1}, {F(2,27)=2.75, P<0.1}] and also significance was noticed for VD of /a/ when preceded by / θ/ in trained vs. non singers groups.



Graph 12: Mean value of vowel duration for /a/ when preceded by different consonants.

The mean value VD for *Id* when preceded by /ð/ was highest in trained singers followed by untrained and non singers. But, these differences were not found to be statistically significant.

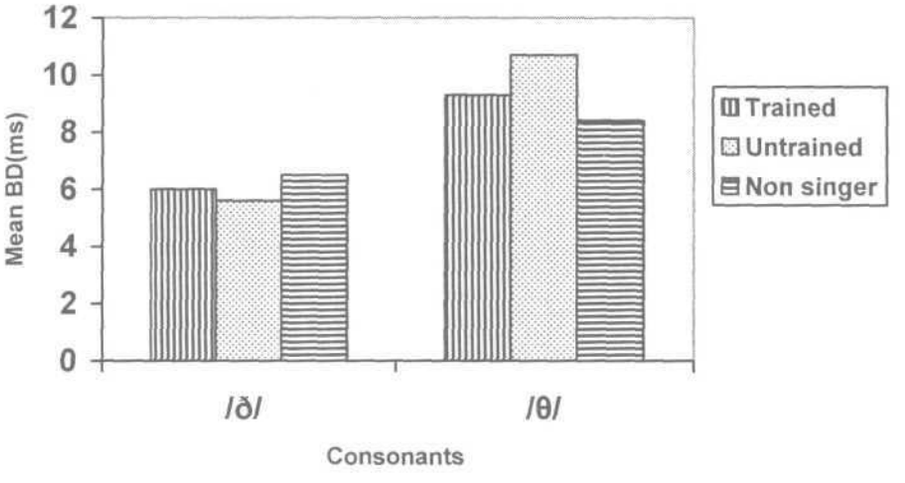


Graph 13: Mean value of vowel duration for /e/ when preceded by / ð / consonant.

Burst Duration (BD)

The mean value of BD for /ð/ consonant was shortest in untrained singers followed by trained singers and non singers. So, non singers had longest mean value. But, these differences did not achieve statistical significance.

The mean value of BD for /θ/ consonant was longest in untrained singers followed by trained singers and non singers. But, these differences did not achieve statistical significance (Graph 14).



Graph 14: Mean value of Burst Duration for /ð/ and /θ/ consonants respectively.

Closure Duration (CD)

Graph 15 showed that trained singers exhibited shortest mean value of CD of /θ/ consonant followed by untrained and non-singers. So, non singers had longest mean value. But, these differences were not found to be significant for any groups.

Sung task: Spectral Parameter

Table 4: Mean values (M), Standard deviation (SD), F (2, 27) values and pair-wise significance for the spectral parameters in female trained (Carnatic style) singers, untrained and non-singers for sung task.

Acoustic Parameters	Trained Singers		Untrained Singers		Non Singers		F (2,27) Values	Significant Pair-Wise Differences
	M	SD	M	SD	M	SD		
Fl/va/	673	58	670	99	602	144	1.43	
F2/va/	1515	306	1583	340	1424	244	0.71	
F3/va/	2404	588	2736	566	2655	613	0.86	
Fl /ðe/	555	66	511	45	500	73	2.17	
F2 /ðe/	1792	550	1772	569	1889	524	0.13	
F3 /ðe/	2630	367	2705	250	2775	326	0.52	
Fl/ma/	784	126	825	128	737	171	0.95	
F2/ma/	1369	258	1397	132	1426	187	0.21	
F3/ma/	2104	760	2723	499	2565	400	3.13**	▼
Fl /θa/	628	89	632	112	615	63	0.09	
F2 /θa/	1431	388	1591	395	1733	276	1.78	
F3 /θa/	2177	411	2670	457	2708	462	4.45 ** *	^ and ▼
Fl/ra/	624	101	634	122	649	87	0.14	
F2 /ra/	1493	356	1762	263	1683	246	2.24	
F3/ra/	2272	477	2830	300	2726	453	5.04** *	^ and ▼

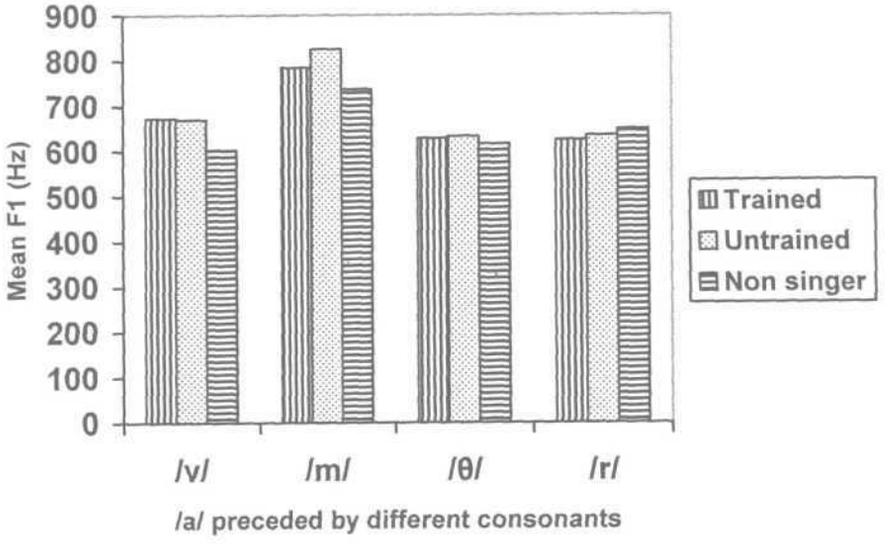
Note: * 0.05<p<0.1, ** p<0.05, *** p<0.01, ****p<0.001

▼Trained vs. Untrained Singers, ^ Trained vs. Non-singers, #Untrained vs. Non-singers

Table 4 depicts the mean, standard deviation, F (2, 27) values and pair-wise significance for the formant frequencies for vowels /a/ and /e/ when preceded by different consonants in all of the groups.

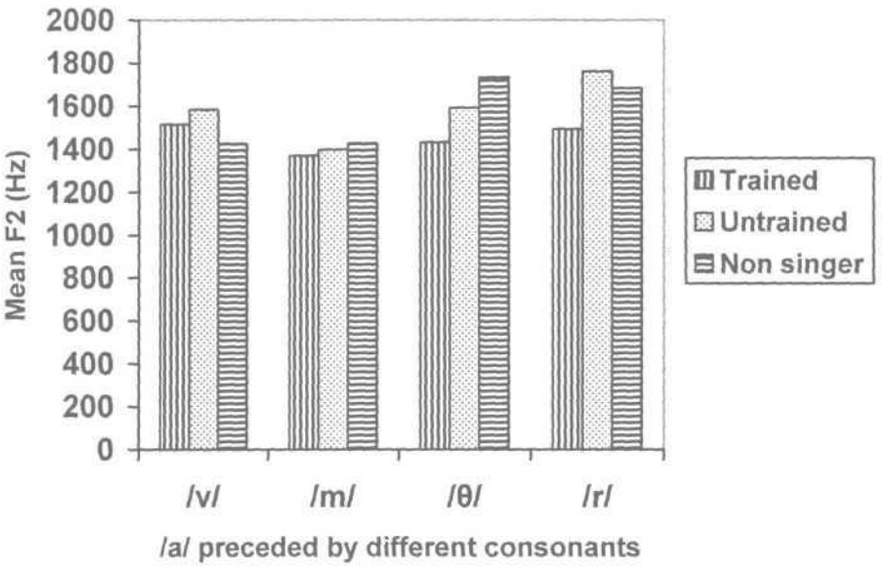
F1 for /a/: Mean Fl values were lowest for trained singers when preceded by /r/ only whereas it was highest for trained singers when preceded by /v/ only. Mean Fl values

were highest in untrained singers when preceded by /m/ and /θ/. In non singers it was lowest when preceded by /v/, /m/ and /θ/ whereas it was highest for non singers when preceded by /r/ (Graph 17). When comparisons were made across groups, significance difference was not found in any groups.



Graph 17: Mean values of first formant (F1) of vowel /a/ when preceded by different consonants.

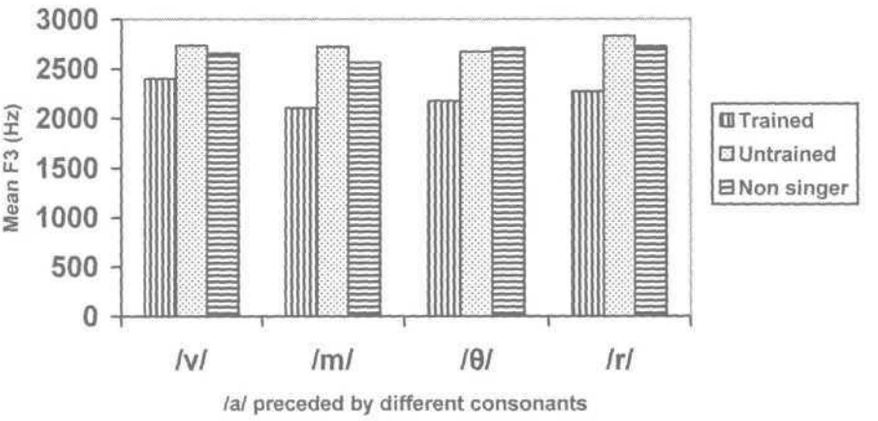
F2 for /a/: Mean F2 values were lowest for trained singers when preceded by /m/, /θ/ and /r/. Mean F1 values were highest in untrained singers when preceded by /v/ and /r/. In non singers it was highest when preceded by /m/ and /θ/ whereas it was lowest for non singers when preceded by /v/ only (Graph 18). When comparisons were made across groups, significance difference was not found in any groups.



Graph 18: Mean values of second formant (F2) of vowel /a/ when preceded by different consonants

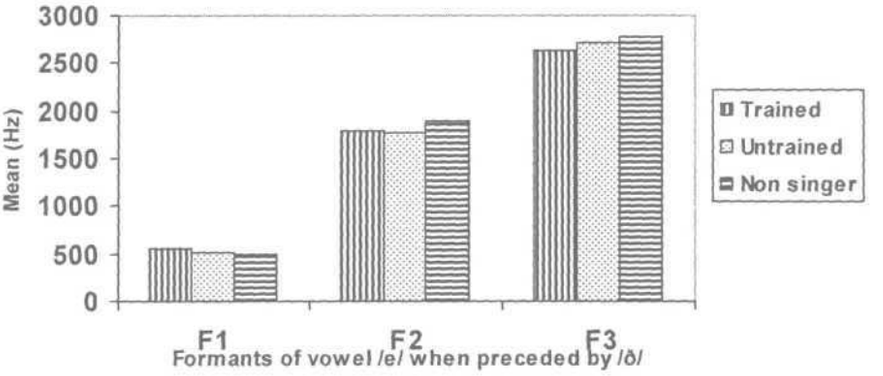
F3 for /a/: Mean F3 values were lowest for trained singers when preceded by /v/, */m/*, /θ / and /r/. Mean F3 values were highest in untrained singers when preceded by /v/,, */m/* and /r/. In non singers it was highest when preceded by /θ/ only (Graph 19).

When comparisons were made across groups, significance difference was noticed when preceded by */m/*, /θ/ and /r/ in trained vs. untrained singers [{F(2,27)= 3.13, $p<0.05$}, {F(2,27)= 4.45, $p<0.01$}, {F(2,27)= 5.04, $p<0.0l$} Similarly, significance differences were found when preceded by /θ/ and /r/ in trained vs. non singers.



Graph 19: Mean values of third formant (F3) of vowel /a/ when preceded by different consonants.

Formants Fl, F2, F3 for *Id:* No consistent pattern was observed for the formants when preceded by /ð/. Mean Fl was highest in trained singers and lowest in non singers. Mean F2 values were lowest in untrained singers but highest in non singers. The mean values for F3 were lowest in trained singers but highest in non singers. When between groups comparison was made, no significance differences were noticed across any group.



Graph 20: Mean values of F1, F2 and F3 formants for vowel /e/ when preceded by / ð / consonants

The parametric paired't'-test was used to compare within group similarities and differences across parameters in spoken and sung tasks.

Trained singers

a) Temporal parameters

Table 5: Mean values (M), Standard deviation (SD), t (9) values and significance for the temporal parameters in spoken and sung tasks in female trained (Camatic style) singers.

Acoustic Parameters	Spoken		Sung		'T'(9) Value
	M	SD	M	SD	
PD	866.4	86.6	1091.5	102.3	5.21* * *
VD/va/	30.4	6.8	37.8	8.7	2.28* *
VD/ma/	65.3	11.1	134.8	33.2	6.54* * * *
VD/ta/	38.7	10.1	80.8	19.8	6. 49* * * *
VD/ra/	28.3	9.1	36.5	15.1	1.65
VD /ðe/	49.1	16.7	77.3	18.5	3.64* * *
BD /ð/	6.4	1.7	6	1.6	0.65
BD /θ/	10.8	2.2	9.3	3.5	1.37
CD /θ/	82.3	8.8	78.7	13.8	0.54
F2TD /ðe/	20.2	10.4	19.8	6.5	0.15
F2TD /θa/	12.1	2.9	16.7	4.2	2.51**

Note: * 0.05<p<0.1, ** p<0.05, *** p<0.01, ****p<0.001

Table 5 depicts the mean, standard deviation (SD), 't'(9) values for the temporal parameters in spoken and sung task in female trained (Camatic style) singers.

Phrase duration (PD)

The mean value of PD was longer in sung task than spoken task and this difference was also found to be statistically significant [t (9) =5.217, p<0.01], (Table 5).

Vowel Duration (VD)

The mean values of VD for /a/ when preceded by /v/, /m/, /θ/, /r/ was longer in sung than spoken tasks and these differences were statistically significant in mean value of VD for /a/ when preceded by /v/, /m/, /θ/, respectively [{t(9)=2.28, p<0.05},{t(9)=6.54, p<0.001},{t(9)=6.492, p<0.001}], except when preceded by /r/ consonant (Table 5).

The mean value of VD for /e/ when preceded by /ð/ consonant was longer in sung than spoken task and same was found to be statistically significant [t (9)=3.64, p<0.01]

Burst Duration (BD)

The mean values of BD for /ð/ and /θ/ was slightly shorter in sung than spoken task and these differences were not found to be significant (Table 5).

Closure Duration (CD)

The mean value of CD for ,/θ/ consonant was found to be shorter in sung than spoken task. But, this difference did not achieve significance (Table 5).

F2 transition duration (TD)

From Table 5 it can be inferred that F2 TD for /a/ when preceded by /θ/ consonant was longer in sung task than spoken task and this difference was found to be significant [t (9)=2.51, p<0.05]. The mean value of F2 TD for /e/ when preceded by / ð / consonant

was slightly lower in sung than spoken task and this difference did not achieved significance.

*b) **Spectral Parameters***

Table 6: Mean values (M), Standard deviation (SD),'t'(9) values for the spectral parameters in spoken and sung tasks in female trained (Carnatic style) singers.

Acoustic Parameters	Spoken		Sung		'T'(9) Value
	M	SD	M	SD	
F1/va/	679	77	673	58	0.20
F2/va/	1588	242	1515	306	1.05
F3/va/	2783	540	2404	588	1.29
F1/ðe/	532	55	555	66	1.11
F2 /ðe/	1845	497	1792	550	0.46
F3 /ðe/	2697	312	2630	367	0.71
Fl/ma/	710	143	784	126	1.66
F2/ma/	1311	283	1369	258	0.98
F3/ma/	2256	613	2104	760	0.68
Fl/θa/	582	103	628	89	1.24
F2/θa/	1520	365	1431	388	1.24
F3/θa/	2666	436	2177	411	3.55***
F1/ra/	580	102	624	101	1.78
F2 /ra/	1429	353	1493	356	0.74
F3/ra/	2481	590	2272	477	2.47**

Note: * 0.05<p<0.1, ** p<0.05, *** p<0.01, ****p<0.001

Formant frequencies of /a/ and /e/ vowels

Table 6 depicted Mean values (M), Standard deviation (SD),'t'(9) values for the formant frequencies of vowel /a/ and /e/ in spoken and sung task in female trained (Carnatic style) singers.

F1 of /a/: Mean F1 values were slightly higher when preceded by /m/, /θ/ and /r/ in sung than spoken task except when preceded by /v/. But, no significant differences were found (Table 6).

F2 of /a/: Mean F2 values were lower when preceded by /*v*/ and /θ/ in sung than spoken whereas it was slightly higher when preceded by /*m*/ and /*x*/ in sung than spoken. But, this difference was not found to be statistically significant (Table 6).

F3 of /a/: Mean F3 values exhibited lower when preceded by /*v*/ and /*m*/ in sung than spoken. But, no significant difference was found (Table 6).On the other hand, mean F3 values were significantly lower when preceded by /θ/ and /*v*/ consonants in sung than spoken task [{t(9)=3.55, p<0.01},{t(9)=2.47, p<0.05}].

Fl, F2 and F3 of /e/*:* Mean Fl value was slightly higher when preceded by /ð/ in sung than spoken task whereas mean F2 and F3 values were slightly lower when preceded by /ð/ in sung than spoken task (Table 6).

Untrained Singers

a) Temporal parameters

Table 7: Mean values (M), Standard deviation (SD), t (9) values and significant for the temporal parameters in spoken and sung task in female untrained singers.

Acoustic Parameters	Spoken		Sung		(9)Value
	M	SD	M	SD	
PD	903.1	90.8	1253.2	74.9	8.83 * * * *
VD/va/	33.1	9.3	37.2	9.7	1.0
VD/ma/	82.2	24	145.2	25.2	11.91****
VD/ta/	48.4	13.3	83.8	13.3	5.72 * * * *
VD/ra/	24.8	5.3	31.8	8.3	3.29 * * *
VD /ðe/	45.6	18.2	71.3	20.2	3.59 * * *
BD /ð/	5.9	2.2	5.6	1.8	0.27
BD /θ/	11	4.5	10.7	3.5	0.25
CD /θ/	72.7	19.5	82.6	24.6	0.83
F2 TD /ðe/	23	9.6	21.4	9.5	0.45
F2 TD /θa/	12.7	7.7	12.2	6.4	0.15

Note: * 0.05<p<0.1, ** p<0.05, *** p<0.01, ****p<0.001

Table 7 depicts the mean (M), Standard deviation (SD), t (9) values and significant for the temporal parameters in spoken and sung task in female untrained singers.

Phrase Duration (PD)

The mean value of PD was longer in sung than spoken task and this difference was found to be significant [t (9) -8.83, p<0.00l], [Table 7], (Table 7).

Vowel Duration (VD)

The mean value of VD for /a/ when preceded by /v/, */m/*, /θ/ and /r/ is longer in sung than spoken task (Table 7) and these differences was found to be significant except when preceded by /v/ consonant [{t(9)=11.91, p<0.00l}, { t(9)=5.72, p<0.00l}, {t(9)=3.29, p<0.01},].

The mean value of VD for /e/ when preceded / ð / was longer in sung than spoken task and this difference was found to be significant {t(9)=3.589, p<0.01} (Table 7).

Burst Duration (BD)

The mean value of BD for /ð/ and /θ/ was slightly shorter in sung than spoken task. But, these differences were not found to be statistically significant (Table 7).

Closure Duration (CD)

The mean value of CD for /θ/ was longer in sung task than spoken. But, no significant difference was found (Table 7).

F2 transition duration (TD)

The mean value of F2 TD for *Id* when preceded by /ð/ was slightly shorter in sung than spoken. Similarly, mean value of F2 TD for /a/ preceded by /θ/ was slightly shorter in sung than spoken. But, these differences were not found to be statistically significant (Table 7).

b) Spectral Parameters

Table 8: Mean values (M), Standard deviation (SD), t (9) values and significant for the spectral parameters in spoken and sung task in female untrained singers.

Acoustic Parameters	Spoken		Sung		(9)Value
	M	SD	M	SD	
Fl /va/	727	115	670	99	1.67
F2/va/	1557	319	1583	340	0.29
F3/va/	2652	498	2736	566	0.42
Fl /ðə/	519	70	511	45	0.52
F2 /ðə/	2028	511	1772	569	1.92*
F3 /ðə/	2868	194	2705	250	1.84
Fl /ma/	813	137	825	128	0.55
F2/ma/	1436	193	1397	132	0.98
F3/ma/	2647	552	2723	499	0.93
Fl /θa/	629	80	632	112	0.11
F2 /θa/	1572	261	1591	395	0.16
F3 /θa/	2603	472	2670	457	0.41
F1/ra/	666	126	634	122	0.84
F2 /ra/	1630	253	1762	263	2.09*
F3/ra/	2545	475	2830	300	1.68

Note: * 0.05<p<0.1, ** p<0.05, *** p<0.01, ****p<0.001

Formant frequencies of /a/ and /e/ vowels

Table 8 depicts the mean, Standard deviation (SD), t (9) values and significance for the spectral parameters in spoken and sung task in female untrained singers.

F1 of /a/: Mean F1 values when preceded by /v/ and /v/ exhibited slightly lower values in sung than spoken task whereas same when preceded by /m/ and /θ/ consonant was slightly higher in sung than spoken task. But, these differences were not found to be significant (Table 8).

F2 of /a/: Mean F2 when preceded by /v/, /θ/ and /r/ exhibited slightly higher values in sung than spoken task whereas same parameters when preceded by /m/ was lower in sung than spoken task. Significant difference was noticed when preceded by /r/ {t(9)=1.92,p<0.1}, (Table 8).

F3 of /a/: Mean F3 values when preceded by /v/, /m/ and /r/ respectively exhibited higher values in sung than spoken task. But, these differences were not found to be significant (Table 8).

Fl, F2 and F3 of /e/*:* Mean Fl, F3 and F3 values when preceded by / ð / were lower in sung than spoken task and significant difference was noticed only for mean F2 value [t(9)=2.09, p<0.1] (Table 8).

Non-singers

a) Temporal parameters

Table 9: Mean values (M), Standard deviation (SD), t (9) values and significant for the temporal parameters in spoken and sung task in female non-singers.

Acoustic Parameters	Spoken		Sung		't' (9) Value
	M	SD	M	SD	
PD	1041.3	131.2	1237.9	128.7	3.76 * *
VD /va/	40.9	19.6	42.5	19.1	0.32
VD /ma/	90.7	31.2	127.6	27.5	3.40* * *
VD /ta/	53.8	15.7	67.9	10.2	3.4 * * *
VD / ra/	38.6	14.6	43.8	9	1.14
VD /ðe/	83.1	46.5	62.5	11	1.62
BD /ð/	5.2	1.7	6.5	3.1	1
BD /θ/	7.3	2.2	8.4	4	1.13
CD /θ/	88.9	9.5	84.5	18.3	0.91
F2 TD /ðe/	15.7	2.9	19.5	6.5	1.96*
F2 TD /θa/	11.5	2.6	15.4	7.8	1.37

Note: * 0.05<p<0.1, ** p<0.05, *** p<0.01, ****p<0.001

Table 9 depicts the mean, Standard deviation (SD), t (9) values and significance for the temporal parameters in spoken and sung task in female non-singers.

Phrase duration(PD)

The mean value of PD was longer in sung than spoken task (Table 9) and this difference was found to be significant [t (9)=3.76, p<0.05].

b) Spectral Parameters

Table 10: Mean (M), Standard deviation (SD), t (9) values and significant for the spectral parameters in spoken and sung task in female non-singers.

Acoustic Parameters	Spoken		Sung		't' (9) Value
	M	SD	M	SD	
Fl /va/	654	126	602	144	1.32
F2 /va/	1428	266	1424.2	244	0.08
F3 /va/	2530	626	2655.6	613	1
Fl /ðe/	533	*66*	500	73	1.17
F2 /ðe/	1903	465	1889	524	0.1
F3 /ðe/	2618	405	2775.4	326	1.42
Fl /ma/	828	143	737.3	171	2.43* *
F2 /ma/	1417	188	1426.8	187	0.18
F3 /ma/	2753	482	2565.2	400	1.13
Fl /θa/	684	87	615.9	63	2.45* *
F2 /θa/	1644	366	1733.9	276	1.09
F3 /θa/	2696	448	2708.9	462	0.12
Fl /ra/	708	108	649	87	2.13*
F2 /ra/	1627	270	1683	246	0.77
F3 /ra/	2672	452	2726	453	0.36

Note: * 0.05<p<0.1, ** p<0.05, *** p<0.01, ****p<0.001

Table 10 depicts the mean, Standard deviation (SD), t (9) values and significant for the spectral parameters in spoken and sung task in female non-singers.

Formant Frequencies of/a/ and *Id* vowels

Fl of/a/: Mean Fl value was lower when preceded by /v/, */m/*, /θ/, */r/* in sung than spoken task (Table 10). However, these differences was found to be significant except when preceded by /v/ {t (9)=2.43, p<0.05},{t (9)=2.45, p<0.05},{ t (9)=2.131,

F2 of /a/: Mean value of F2 when preceded by */m/*, /θ/, and /r/ consonants was slightly higher in sung than spoken task whereas mean F2 value was slightly lower when preceded by */v/* only in sung than spoken task. But, no significant difference was noticed (Table 10).

F3 of /a/: Mean F3 values were slightly higher when preceded by */v/*, /θ/ and /r/ in sung than spoken task whereas the mean F3 value when preceded by */m/* was lower in sung than spoken task. However, no significant difference was found (Table 10).

Fl, F2 and F3 of /e/*:* Mean Fl and F2 values when preceded by /ð/ were lower in sung than spoken task whereas mean F3 value was higher when preceded by /ð/. But, no significant difference was noticed (Table 10).

Chapter V

Discussion

The aims of the present study was a) to investigate the temporal and spectral characteristics of speech sounds in spoken and sung utterances in the three groups of female subjects, that is, trained (Carnatic) singers, untrained singers and nonsingers and b) to compare the results across three groups of subjects and c) to examine whether influence of vocal training (formal/informal and or practice of singing) would have any influence on general speech pattern. The results of the present study are discussed below.

Temporal parameters

In spoken task, phrase duration, closure duration, mean VD for /a/ and *Id* when preceded by /v/, /m/, /θ/, /r/ and /ð/ consonants were significantly shorter in trained singers followed by untrained and non-singers except for VD of /a/ when preceded by /v/ consonant. However, the trained (Carnatic) and untrained singers showed an increase (but no statistical significance) in the burst duration and F2 transition duration of stop consonants in spoken task to achieve the accurate and time-based articulation relative to non singers.

Similar results were noted for sung task in trained (Carnatic) singers when compared to the other two groups. Mean values for phrase duration, vowel duration for /a/ when preceded by /v/ and /r/ consonants respectively were shorter in trained singers followed by untrained and non-singers whereas VD for /a/ and /e/ when preceded by /m/, /θ/ and /ð/ consonants respectively were longer in singers groups. The same was not

significant across groups. The mean values of closure duration of consonant /θ/ was found to be shortest in trained singers followed by untrained and non-singers indicating that singer groups emphasize more on vowel lengthening resulting in shortening the closure duration of stop consonant, although this difference did not achieve statistical significance. Furthermore, mean value of burst duration of,/θ/ consonant was longer in singer groups whereas mean values of burst duration of /ð/ and F2 TD of /5/ and /θ/ consonants was almost similar in singing task.

This indicates increased vowel lengthening when preceded by nasal and voiceless stop consonants in trained and untrained singer groups. Singers in general may have used vowel lengthening to achieve acoustical enhancement and bring aesthetic characteristics to their sung utterances.

In general, a hierarchical trend was noticed between trained (Carnatic) singers, untrained singers and non singers. In that, the mean values for most temporal measures was better for trained (Carnatic) singers compared to untrained singers and non singers respectively.

Rothman et al. (2001) reported that as part of vocal training singers are taught to articulate precisely. They implied that the trained singers regulate the proper setting of supraglottic air spaces and the correct use of lips, tongue and palate in very accurate manner. Continuous vocal practices on a routine basis will have an unconscious impact on the everyday speech characteristics. Perello, (1962); Lawrence, (1979) and Brown, et

al., (1988) have reported that better performance in trained singers was due to the benefits of training rather than due to superior physiologic endowment.

Spectral parameters

The spectral parameters revealed relatively lower mean values of F1, F2 and F3 for vowel /a/ and /e/ when preceded by /m/, /θ/, /r/ and /ð/ consonants except for F1, F2 and F3 of vowel /a/ when preceded by /v/ consonant in trained singers followed by untrained singers and non singers. This indicates that the singer groups tried to increase their front and back cavity volumes resulting in low Fl, F2 and F3 values for vowels /a/ and *Id* in spoken task. Burns (1986) reported that opera singers decreased their formant values in sung utterances when compared to country and western singers. The formant frequencies were lower for spoken vowels compared to sung vowels (Ross, 1992).

In sung task, /a/ mean values of Fl when preceded by /r/ only, F2 when preceded by /m/, /θ / and /x/ and F3 /v/, /m/, /θ/ and /r/ were lowest for trained singers. Higher mean values of F1 when preceded by /m/ and /θ/, F2 when preceded by /v/ and /r/ and F3 when preceded by /v/, /m/ and /*xl* were noted in untrained singers. Intermediate results were noted in non singers. No consistent pattern was observed for the formants of /e/ when preceded by /ð/. Mean F1 was highest in trained singers and lowest in non singers. Mean F2 values were lowest in untrained singers but highest in non singers. The mean values for F3 were lowest in trained singers but highest in non singers. When between groups comparison was made, no significance differences were noticed across any group. These results agreed with the studies of Brown et al. (1988) and Perello (1962).

Comparison of spoken and sung task in each group

Similarities and differences in each group for spoken and sung tasks were compared pair-wise using paired 't' test.

Temporal parameters were found to be prolonged in singing task in general than speech in all groups. Phrase duration, vowel duration of /a/ preceded by /m/ and /θ/ consonant respectively was longer across all groups. But, singer groups showed prolonged vowel duration for other consonant conditions. This could be due to maintenance of musical tempo and rhythmic property of singing.

In spectral parameters, speech and song tasks were compared within each group i.e. trained, untrained and non-singers, apart from few parameters, most parameters were not found to be statistically significant. This view is supported by Sundberg et al. (1999) who reported similar or slightly higher formant frequencies in country singers singing. Burns (1986) reported that country and western singers performed similarly in term of formants and hence, opined that they used similar resonatory voice characteristics for both spoken and sung output.

Specifically, Mean F1 values were slightly higher when preceded by /*m*/, /θ/ and /r/ in sung than spoken task except when preceded by /v/ in trained singers. But, no significant differences were found. Mean Fl values when preceded by /*v*/ and /r/ exhibited slightly lower values in sung than spoken task whereas same when preceded by /*m*/ and /θ/ consonant was slightly higher in sung than spoken task in untrained singers but overall no significance was found. Mean Fl value was lower when preceded by /*v*/,

/m/, /θ/, /r/ in sung than spoken task in non singers. Mean values of F2 for vowel /a/ were lower when preceded by /v/ and /θ/ in sung than spoken and mean F3 values of vowel /a/ were significantly lower when preceded by /θ/ and /x/ consonants in sung than spoken task in trained singers. These results find support from Sundberg (1970) who reported that F2 was lowered in non back vowel and F3 was lowered in all vowels except back vowel.

In singing the regular and rhythmic progression from speech sound to speech sound and the necessity to use clear vowels are self evident. Preliminary experiments suggest that acoustic differences (apparent in spectrograms) may be found regularly correlated with the differences of voice, mood and articulation covered by the system of classification (Fry and Manen, 1957). It is also considered to be, in part, a factor in developing those parameters that make a singer's voice different from that of non singers. Singers' voice characteristics are determined by the interactions among the breathing mechanism, the vibrating vocal folds, and the resonances of the vocal tract. An exhaustive description of vocal technique must include the resonatory aspects of voice production. These are generally described in terms of formant frequencies which are determined exclusively by the configuration of the vocal tract. One intuitively believes that years of vocal training will eventually have an effect upon the trained singers' everyday speech pattern. The results obtained in the present study strengthened this belief.

Chapter VI

SUMMARY AND CONCLUSIONS

The present study was designed to (a) investigate the temporal and spectral characteristics of speech sounds in spoken and sung utterances in the three groups of female subjects: trained (Carnatic style) singers, untrained singers and non singers and (b) compare the results across three groups of subjects and to examine whether influence of vocal training (formal/informal) and or practice of singing would have any influence on general speech pattern. A total of thirty participants in age range of 18 to 40 years were considered for the study. Equal numbers of participants were present in all three groups. The subjects were literate and native Kannada speakers.

Subjects were instructed to listen to the audio-recorded sample of the National song /Vanðe Maθaram/ from the 1952 film "Anand math", sung by playback singer Ms.Lata Mangeshkar and were asked perform two tasks. They had to speak (spoken task) and sing (sung task) the first line of the first stanza of the song in similar manner including the chorus portion and the same were audio-recorded. The second repetition of / Vanðe Maθaram / from the chorus was selected for acoustic analysis. Spectrographic analysis was done using Praat software. The following temporal parameters: phrase duration, vowel duration of /a/ and /e/ when preceded by /v/, /m/, /θ/, /r/ and /ð/ consonants respectively, burst duration of /ð/ and /θ/ consonants respectively, closure duration of /θ/ consonant, F2 transition duration of /e/ and /a/ when preceded by /ð/ and /θ/ consonants respectively and spectral parameters: Fl, F2 and F3 of /a/ and /*e*/ vowel

preceded by /v/, /m/, /θ/, /r/ and /ð/ consonants respectively were extracted. The analyzed data were tabulated for all groups, for all the parameters and subjected to the statistical analysis. SPSS (Version 10) software was used for statistical analysis. Descriptive and significance tests were performed.

Results indicated that significant difference for most of the temporal parameters in speech except burst duration of /d/, steady state of vowel duration when preceded by /v/ consonant, F2 transition duration of /e/ and /a/ preceded by /ð/ and /θ/ consonants respectively across all groups. On the other hand, no significant difference was found in spectral parameters for spoken task except Fl of vowel /a/ when preceded by /θ/ and /r/ consonant respectively. In singing, few parameters were found to be significant especially temporal parameters: phrase duration, vowel duration of /a/ when preceded by /θ/ and /r/ consonants respectively. Similarly, a few spectral parameters were found to be significant, i. e., F3 of vowel /a/ when preceded by */ml*, /θ/ and /r/ consonants for all groups.

When speech and singing were compared in each group using paired 't' test, most of the temporal parameters was found to be significant across all groups. On the other hand, a few spectral parameters were found to be significant which were F3 of vowel /a/ preceded by /θ/ and /r/ consonants respectively in trained singer, F2 of vowel /a/ and /e/ preceded by /r/ and /ð/ respectively in untrained singers and F1 of vowel /a/ preceded by /m/, /θ/' and /r/ consonants respectively in non singers.

Based on the results it can be speculated that continuous formal/ informal vocal training and vocal practice regularly influenced the general speech characteristics of singer groups [both trained (Carnatic) and untrained].

Implication of the study

1) The present study attempted and documented differences in temporal and spectral characteristics in female singers (Trained Carnatic and untrained) and non singers

2) This study also helped us to understand the effects of formal/informal vocal training on general speech pattern

3) This study could also help professional voice users to understand impact of formal/informal vocal training on everyday speech pattern

4) Results cannot be generalized as the sample size was small. Further studies in this regard have to be attempted by controlling the type of informal training.

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