ACOUSTIC PARAMETERS OF VOICE IN SINGING

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DEDICATED

TO

"annaiah"

who ia responsible to motivate me to reach this stage of my education and also to make me what I am today.

"amma"

who has borne all the pain to give me the best comforts this world can ever think of.

DECLARATION

I hereby declare that this dissertation entitled "Acoustic Parameters Of Voice In Singing" is the result of my own study understand under the guidence of Mr. N.P. Nataraja, Reader, and Head of the Department of Speech Sciences, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any University for any other diploma or degree.

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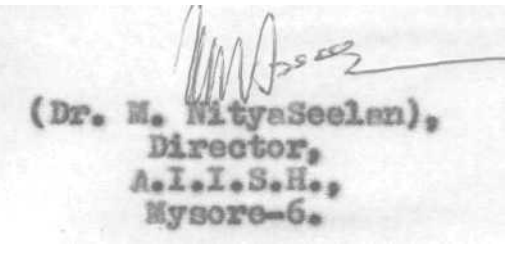
CERTIFICATE

This is to certify that the dissertation entitled "Acoustic Parameters of Voice in Singing" is the bonfide work in part fulfilment for the Degree in M.Sc. (Speech and Hearing), of the student with the Register Number 8406.



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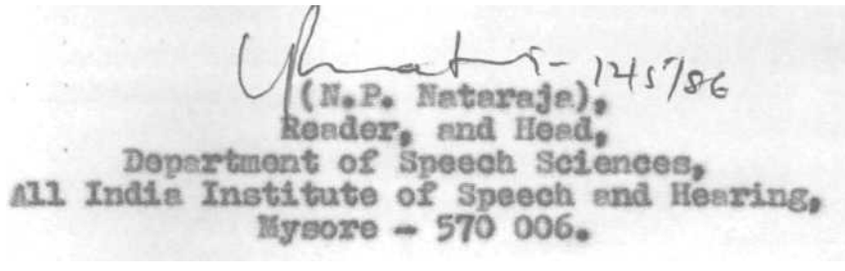

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C O N T E N T S

Chapter

CHAPTER - I

INTRODUCTION

Voice production in human beings is an outcome of vibrations of vocal cords set by expiratory airflow. Voice is used for speaking and singing. Same speech apparatus is used but differently. Singing against speaking is a matter of sophisticated use and precision in the use of speech apparatus.

"The act of speaking is a very specialised way of using the vocal mechanism. The act of singing is even more so. Speaking and singing demand a combination and interaction of the mechanisms of respiration, phonation, resonance and speech articulation". (Boone, 1977).

In principle there is no difference between the sounds of speech and of singing. However in singing the consonants shouldnot break the flow of vocal sound in the same way as in speech. Singing demands considerable resonance and arti culation. (Butenschn and Borah grevink, 1982)*

In singing the vowels are prolonged since they are especially suited to carry melody. It follows that the rhythmical, dynamic and melodic qualities of speaking and singing differ only in regard to quantity and quality. These formal elements are complicated by additional psychological factors and aesthetic requirements. (Luchsinger, 1965)

Another major difference between speaking and singing ia rhythmic progression from sound to sound and use of

vowels. According to Bunch (1982) "singing mekes some poor speech habits difficult or impossible. Good speech habit is 'sine quo non' for beautiful singing voice. For good speech habit involves good breathing habit, good control of subglottic pressure, proper shaping of supra-glottic air spaces and active use of articulators".

Fluent speaking proceeds with continuously gliding pitch fluctuations of speech melody. Speeking uses glid-ing vocal inflections, which are not tied to discrete tonel intervals. This variation of pitch occurs rapidly.

Singing however, requires that a melody be followed through prescribed leaps over the musically customary dis-crete intervals. Moreover, the rhythmically fixed tonal steps ef singing may be sustained for longer periods of time (Luchsinger, 1965).

The main differences between speech and singing are

(a) Isochronism of vibration ef vocal fold which is not much stressed in speech as while singing,
(b) More controlled breathing is seen singing.
(c) Greater vocal range ia used in singing as compared to speech.
(d) Vibrato, singer forments are used by singers.
(e) Vocal apparetus is under greater stress during sing-ing than speech.

Achievement of loudness with minimal vocal effort is of paramount concern for the professional vocalist, whose livelihood depends on maintainance of a healthy voice under the meat stressful condition. (Perkins, 1971).

Good speakers employ a range of an octave or more. The vocal range in singing is considerably wider with the overall range (from Bass to Sopramo) of about four octaves. But usually singers have pitch range of two and a half octaves, but exceptional cases have been reported in which singers have been able to produce as low as 45 c/s and as high aa 2048 c/s. Arnold (1965) states that "the untrained singing voice will have a range of one end a half to two octave or leas while the trained singers may exceed their limits as much as an octave or more in some cases". The need of choosing the correct natural range of voice is greater in singing than in speaking since the outer ends of the singing range need very careful production and sho-uld not be overworked even in trained voice (Greene, 1964).

Various aspects of pulmonery function of the profe-ssional singers have been the interest of voice researcers from a long time, the assumption being that the superior vocal quality of the trained singer is due to a concomi-tant superiority in vital capacity, in part reflecting and in part stemming from an increased volume.

A basic requirement for the trained speaker or singer in the ability to prolong expiration which is really the ability to maintain a smooth steady air flow. The determination of the phonation time is as important a phoniatric test as a test for vital capacity. This provides information on the functional state of the entire respiratory system. (Daniel Boone 1971 and Luchsinger, 1965).

Sheela (1974) observed no significant difference in vital capacity between trained and untrained singers and also low correlation between phonation time and vital capacity.

Very few studies have been done in India on the acoustic analysis of voice in singing. This study is intended at investigate some of the acoustic parameters of voice

Need for the present study:

Speech science deals with the understanding of the physical (acoustic), physiological (articulatory and aerodynamic) sad perceptual aspects of normal speech. Through that it helps in the assessment and treatment of speech and language disorders and super normal use of speech like in singing.

We know that reading, speaking sad singing are the

different expressive forms of language. There are several studies about the normal process of speech. But there are very few studies which explain the physical and physiological aspects of reading and singing.

This study is an attempt to investigate some of the Acousitc parameters of voice in singing.

Purpose of the Study:

The aim of the present study is to investigate some of the Acousitc parameters of voice in singing

This will be done by measuring and comparing the different voice parameters in the following conditions, viz. reading, reciting and singing

Hypothesis:

1. There is no significant difference in the Acoustic parameters among the 3 conditions Viz., reading, reciting and singing.

Auxilary Hypothesis:

1. There is no significant difference between reading and reciting conditions in female group when the mean fundemental frequency is compared.

2. There is no significant difference between singing and reciting conditions in female group when the mean fundemental frequency is compared.
3. There is no significant difference between singing and reading conditions in female group when the mean fundamental frequency is compared.
4. There is no significant difference between reading end reciting conditions in male group when the mean fundamental frequency is compared.
5. There is no significant difference between singing and reciting conditions in male group the mean fundamental frequency is compared.
6. There is no significant difference between singing and reading conditions in male group when the mean fundamental frequency is compared.
7. There is no significant difference between male and female subjects in reading condition when fundamental frequency is compared.
8. There is no significant difference between male and female subjects in reciting condition when mean fundamental frequency is compared.
9. There is no significant difference between male and female subjects in singing condition when fundamental frequency is compared.

10. There is no significant difference between reading and reciting conditions in female group when the range of fundamental frequency is compared.
11. There is no significant difference between singing and reciting conditions in female group when the range of fundamental frequency is compared.
12. There is no significant difference between singing and reading conditions in female group when the range of fundamental frequency is compared.
13. There is no significant difference between reading and reciting conditions in male group when the range of fundamental frequency is compared.
14. There is no significant difference between singing and reciting conditions in male group when the range of fundamental frequency is compared.
15. There is no significant difference between singing and reading conditions in male group when the range of fundamental frequency is compared.
16. There is no significant difference between male and female group in reading condition when the range of fundamental frequency is compared.
17. There is no significant difference between male and female group in reciting condition when the range of fundamental frequency is compared.
18. There is no significant difference between male and female group in singing condition when the range of

fundamental frequency is compared.

19. There is no significant difference between male and female groups in reading, reciting and singing conditions the vowel durations of /a/, /i/ & /u/ is compared.
20. There is no significant difference between reading and reciting conditions in female group when the vowel duration of /a/ is compared.
21. There is no significant difference between singing and reciting conditions in female group when the vowel duration of /a/ is compared.
32. There is no significant difference between singing and reading conditions is female group when the vowel duration of /a/ is compared.
23. There ia no significant difference between reading and and reciting conditions in male group when the vowel duration of /a/ is compared.
24. There is no significant difference between singing and reciting conditions in male group when the vowel duration of /a/ is compared.
25. There is no significant difference between singing and reading conditions in male group when the vowel duration of /a/ is compared.
26. There is no significant differeaee between reading and reciting conditions in female group when the vowel duration of /i/ is compared.

27. There is no significant difference between singing and reciting conditions in female group when the vowel duration of /i/ is compared.
28. There is no significant difference between singing and reading conditions in female group whan the vowel duration of /i/ is compared.
29. There is no significant difference between reading and reciting conditiona in male group when the vowel duration of /i/ is compared.
30. There is no significant difference between singing and reciting conditions in mala group when the vowel duration of /i/ is compared.
36. There is no significant difference between singing and reading conditions in male group when the vowel duration of /i/ is compared.
32. There is no significant difference between reading and reciting conditions in female group when the vowel duration of /u/ is compared.
33. There is no significant difference between singing and reciting conditions in female group when the vowel deration of /u/ is compared.
34. There is no significant difference between singing and reading conditions in female group when the vowel duration of /u/ is compared.
35. There is no significant difference between reading and reciting conditions in male group when the vowel

duration of /u/ is compared.

36. There is no significant difference between singing and reciting conditions is male group when the vowel duration of /u/ is compared.
37. There is no significant difference between sisging and reading conditions in male group when the vowel duration of /u/ is compared.
38. There is no significant difference between reading and reciting conditions in female grogp when the mean word duration is compared.
39. There is no significant difference between sisging and reciting conditions in female group when the mean word duration is compared.
40. There is no significant difference between singing and reading conditions in female group when the mean word duration is compared.
41. There is no significant difference between reading and reciting conditions in male group when the mean word duration is compared.
42. There is no significant difference between singing and reciting conditions in male group when the mean word duration is compared.
43. There is ne significant difference between singing and reading conditions in male group when the mean word duration is compared.

44. There is no significant difference between male and female group in reading condition when the mean word duration is compared.

45. There is no significant difference between male and female group in reciting condition when the mean word duration is compared.

46. There is no significant difference between male and female group in singing condition when the mean word duration is compared.

Implications of the study:

This study provides information regarding:

a) The changes in fundamental frequency, range of fundamental frequency, vowel duration and word duration with respect to reading, reciting and singing conditions

b) The differences in the above parameters between males and females.

CHAPTER - II

REVIEW OF LITERATURE

The most unifying theme for Speech and Music is that both of them provide the oldest, most common and most efficient and most universal acoustical means of expression of emotions, feelings, ideas and thoughts. Both of them may be considered as the highest manifestations and human communications.

Understanding of speech in its various cannotations with regards to feelings, impressions, sentiments etc. and the appreciation of music in its aesthetic content and expression of feeling are high order tasks involving Linguistics, Syntax Semantix sad other semiotic properties. The tasks of identifying phonetic units of speech, like phonemes (even words) in speech end that of identifying notes and short movements in music are primary in nature. The constant interaction between these two levels enables the attainment of perfection in perception.

(Datta, Genguli and Dutta Najumder, 1983)

Sunderberg (1977) explains about singer's voice. The voice organ obeys the same acoustic laws in singing that it does in ordinary speech. The radiated sound can be explained by the properties of the voice - source spectrum and the formants in singing as in speech. From an acoustical point of view, there is a major difference between the way formant frequencies are chosen in speech and the way they are chosen in singing,and hence between the way vowels are produsedin singing sad the way they are produced in speech.

Daniel Boone (1971) states that "The best speakers and

singers are often those persons who by natural gift or by training or by a studied blend of both have mastered the art of optimally using the voice mechanism". Singing requires all that speaking does but for greater skills in all spheres (Greene, 1972).

Singing is a highly specialized form of using the vocal organs that produces both the speaking and singing voice. we know less of the singing voide than of speaking voice(Boone,l971).

"Singing requires more exacting performance in every department than does speech, and it requires a complete mastery of techniques, the control not merely of the mechanics of singing but of fine shades of tome colour which defy analysis bat convey the emotional message of the passage. No such extraordinary physical demands are made upon the speaker" (Greene, 1972).

Proctor (1980) and Bunch (1982) believe that singing is specialization over speech. And some theories state that "the human speech took origin from singing" (Critchley, 1975). It ia still not clear what led to what.

From this, it can be concluded that singers have specialized themselves in using speech apparatus more efficiently for singing.

Comparison of respiration during quiet breathing, speaking and singing, have shown that more air is used in singing as compared to quiet breathing. Alveolar pressure ranges from high negative pressures during inspiration to relatively high positive pressures during expiration while singing. But

fluctuates only a few cim of water in quiet breathing. It has also been found that expiratory air flows are low in speech and singing, higher inspiratory air-flow have been found to be associated te speeeh and much higher in singing. Further Proctor (1980) states, that phonation either for speech or singing deesnot demand high degree of pressure but delicacy of use of breathing mechanism is required.

While discussing perception of vowels, Sundberg (1979) states that singers learn te adopt vowels which are typically different from that of normal speech.

In singing the vowels are prolonged since they are especially suited to carry melody, it follows that the rhythmical, dynamic and melodic qualities of speaking and singing differ only in regard to quantity and quality. These formal elements are complicated by additional psychological factors and aesthetic requirements. (LUCHSINGER, 1965).

The attributes of voice are, Pitch, Loudness and quality, knowledge of pitch, its control mechanism, modulation and maintainance is important for a singer.

Pitch is the psychological correlate of frequency. There is no one to one relation between the two, as Stevens and Davis (1938) say that the frequency of sound does not uniquely determine its pitch. The relationship between freqnency and pitch is logarithmic with intensity held constant; doubling the frequency raises the pitch by an octave (Judson and weaver 1965).

According to Stevens and Davis (1935) the pitch of complex tone depends upon the frequency of its dominant component, that is, the fundamental frequency in a complex tone. Plomp(1967)

found that even in a complex tone, where the fundamental frequency is absant or weak, the ear is capable of perceiving the fundamental frequency based on periodicity of pitch.

Ohala (1978) states that pitch and fundemental frequency are interchangeable as it means the rate of vibration of vocal cords during phonation. The production of pitch and its variation are not as simple, the lacuna is still there in understanding of there mechanisms in speech and little is known regarding this mechanism in singing.

".... both quality and loudness of voice are mainly dependent upon the frequency of vibration. Hence it seems apparent that frequency is an important parameter of voice (Anderson, 1961).

Pitch is determined by the number of vibrations (per second) ef the vocal cords, and thus in turn is determined by the length, mass and stiffness of the vocal cards. Thus the mass, length and tension of the vocal cords determine the fundamental frequency of voice.

Anatomically the average pitch of human voice varies with length and stiffness of the cords and also age and sex. (Van Riper and Irwin, 1958). Zimmerman (1867) studied the vocal fold length in fifty singers. The soprano voice ranges from 14 to 18 mm in length, and tenor voice never exceeded 22 mm and a maximum length of 25 mm was found in Bass voice. The childs vocal cords are short and in woman usually shorter than in man. Although 1ess is known about mass per unit length,

this probably varies with age and sex (Borma, 1975). Various investigators have studied the changes in fundamental frequency of voice with age. Some among those are Feirbanks {1940, 1949) Curry (1940), Sindocor (1943), HanKy (1949), Mysak (1950) Samuel (1973), Usha Abraham (1978), Gopal (1980), Kushal Raj (1983) and Rashmi (1985).

Hollien and Colenman (1970) studied the vocal fold area and thickness as a function of fundamental frequency of phonstion using Stroboscopic Laminograph (STROL). Results indicated a moderate trend forr vocal fold area to decrease0 with increasing fundamental frequency and vocal thickness to decrease with increasing fundamental frequency. The fundamental frequency of voice is referred to as pitch, is an important feature of speech conveying both linguistic and non lingustic informations.

Zinkin (1968) states that fundamental frequency varies depending upon the shape and volume of the resonating tract and is different for different vowels. Alterations of the shape of the vocal tract shifts formant frequencies, and singers use this technique to improve resonance and tone quality.

Range of pitch used for singing by most singers is 2 to 2 1/2 octaves. The range or compare of the human voice reach, is from the LOW C (64 c/s)of a deep Besso to the C_4 of the Soprano results in 5 actaves. Luchsinger (1965) studied the voice of a female singer and found the range as 41/2 octaves. Fairbanks (1949) comments on the fact that very few colarature Sopranos can achieve a range in singing covering 3 octaves above mid C. She child's singing ranges which varies very little in boys and

girls covers the middle octave at the age of 7 years and at 8 years the lower range is slightly extended and the voice ranges from B_2 to B_3. At 9 years the range extends a little further in both directions to B_2 to D_4.

A special classification for the speaking voice doesnot exist. The singing voice fully justifies a well defined classification because of its notable extension and the vocal texture. However the classification of singing voice presents problems not easily solved. There primarily 6 main classifications ranging from the lowest to the highest. They are Bass, Baritone tenor, Coutralto, Mezzo soprano and Soprano (Greene,1964) The laryngeal dimensions are the main determinants of the above type ef voice. It also depends on body type, dimensions of supraglottic resonators, artistic inclination, vocal education, personality structure and cultural influences.

Cleveland (1977) considers that the quality of the speaking voice is often an indication of the correct classification for a singing voice.

Fundamental frequency seems to be the main acoustic cus in the classification of voice (Coleman, 1976; Cleveland, 1977). However, formant frequencies typically differ between Bass, Baritone and tenor voices. This difference reflects the differeces in the pharynx to mouth length ratio which serves as secondary cue in voice classification. Thus physiologically the maximum range of pitch is determined by the length and shape of the singer's vocal folds, shape of the vocal tract and ability to co-ordinate muscles for phonation.

2.7

Vibrato is an essantial characteristic ef singing voice. The artistic quality of singing is frequently judged by the presense of vibrato in the voice. Sea shore (1932) has defined a good vibrato as a "pulsation usually accompanied with synchronous pulsations of loudness and timbre, of such a extent and rate as to give a pleasing flexibility, tenderness and richness to the tone". Average rate of vibrato of a good singer is 6 to 7 c/s is found by Seashore (1935), Vennard etal (1971), Luchsinger and Arnold (1970) Larger and Iwata (1971) and shipp etal(1980). Human ear can pick up pulsations slower than 5 per second as separate pitches which are unpleasant and referred as wobble t times and can be result of fatigue, tension or excessive contraction of the itnrinsic muscles of the larynx (Sounienen, 1970, Sounienen etal, 1972)

Van den Berg (1968) Vennard etal (1971) etc have extensively studied the registers in singing. Bunch (1982) quotes Nadoleizny's view, based on his work of 1923, which it states that an enaggerated vibrato, or a rate more than 8 pulsations per second is considered fast and referred as bleat or tremole. This causes too much pressure on vocal folds. Modern rock and discotheque music do not care for vibrato which makes their singing "yelling" like putting more strain on vocal apparatus (Bunch, 1982). Winckel (1971) believes that vibrato is due to fluctuating activity in vocal musculatures. Large (1973) suggests its combined laryngeal and respiratory mechanism with laryngeal factor as being dominant. It is defined as series of succeeding sounds of equal quality on a scale from low to high produced by the application of the same mechanical principle, the nature of which differs basically from another

series of succeeding sounds of equal quality produced by another mechanical principle", still Bunch (1982) further states that this definition of register is considered as comprehensive and classic current concept is that there are 3 basic registers, the glottal fry, modal and Falsetto; flute and whistle are included as the extreme top.

(Boone (1971) states that "related to the production of voice pitch range of any individual is voice register". It appears that a particular register characerizes a certain pattern of vocal cord vibration with the vocal cords approximated in a similar way through out the pitch range. Once the pitch range reaches its maximum limit the folds adjust to new approximation contour, which produces an abrupt change in vocal quality.) Van Den Berg (1959) classifies and describes voice registers as, chest, mid voice and Falsetto; from the perceptual view point voice register is confined to the similar sound of the individual voice at various pitches. Klein(1967) states that the lower tones have bean called the chest register and the higher tone has been called as upper register or head register.

Moses (1954) states that "register, refers to a physical acoustic event which results from an energetic change within the muscular coordination ef the vocal cords", In singing from the highest tones possible to the lowest, the untrained singer first passes a sequence of tones which seems unified. Then he comes to a node, a switching point from which he continues with a sequence of tone of a different character, then he reaches another node and switches to the lowest third of the range in

a specific tone quality. The trained singer does not reveal these nodes since he has learned to unify the hear register. the mixed and the chest register. The mixed register is that combination of the head and chest register. This is used in normal speaking, it is a well balanced coordination of the width of the vocal cords. (Moses, 1954).

Usually a singer adopts two techniques to achieve equalization of register, are is to "cover" or darken the tone at transition point, the toher is to modify the vowel sounds, The first is achieved by more space being maintanined in pharynx and the larynx remains moderately low (Luchsinger and Arnold, 1965; Bunch, 1977, Sunderberg, 1977).

Formants are the peaks in the sound spectrum which include one or more haromincs, and are independent of the pitch being sung. These can be varied by changing the position of articulators. One can change two lowest formant frequencies two octave or more by changing the position of the articulators. Higher formants frequencies cannot be varied much. They give individuality to the voice characteristics. In singing more or less substantial deviations are observed from vowel ranges. Indeed a male opera singer may change the formant frequencies so much that they enter the area of different vowel. For in stance, in vowel (i) as sung the lowest two formant frequencies may be those of vowel (y) still we tend to identify such vowel structure. This shows the frequencies of the lowest formants do not determine the vowel identity entirely.

Duni triev and Kiselev (1979) studied the relationship

between the formant structure of different types of singing voices and the dimensions of supraglottic cavities. Integrated spectra of different type of singing voices were obtained, each type characteristic of a certain frequency range for high and low singing formants. They showed that the formant frequency increases in the following order: Bass, baritone, mezzo-sporano and soprano.

The "singing formant" is a high spectrum envelope peak near 2.8 K characteristic of vowel sounds in mael western opera and concert singing. These "singer's formants" have been studied from acoustic and perceptional points by sundberg (1974). There are strong reasons to assume that there is an acoustic cons of clustering of the third, fourth and fifth formant frequencies. If formants approached each other in frequency, the ability of the vocal tract to transfer sound increases in the correspond-ing region. Hence they seem to be primarily due to respiratory phenomenon. An articulatory configuration which clusters the higher formants in such a way that a "singer's formant" is generated by involving a wide pharynx which appears to result from lowering the larynx. (Sundberg, 1974; Holhein etal, 1978).

Bunch (1982) states that the phonetic quality of vowel is due to resonances in the vocal tract altered by the position of the articulator. Singers make use of this in singing also in ascending and descending scale. Winckel (1967) states that a soprano voice that ascends to the level of O_3 where the voice will be able to stimulate only the formants of the bright vowels. Small but significant adjustments have to be made in

the shape of the resonators to produce appropriate vowel sounds. The gradual and controlled modification is soft palate is also called as "covering". There is controversy on the term, but essentially it means acoustical consequence with basic resonatory changes. This means that the singer has given more pharyngeal space to a sound by keeping the soft palate high while allowing the larynx to remin comfortably low (Bunch and Sonnien, 1977).

Vocal quality is the element in singing which attracts the listener. This quality is determined by two factors - (1) physical characteristics, ideally symmetrical bony structures of head, high wide dental archade, shape and length of the vocal tract including palate, vocal folds, all help in determining the vocal quality. (2) Efficient coordination of the various alterable and unalterable parts of the vocal instruments parts eg. the most favourable conditions of the pharynx for vocal quality are an elevated soft palate, comfortable low larynx, relaxed tongue and lack of tension in the neck and chest, facial muscles, position of jaw rigidity of tongue, manipulation of pharyngeal isthumus, emotional and physical health can reflect the quality of voice (Sundberg, 1978; Bunch 1982).

Frequency Range in Speech:

The patterned variations of pitch over linguistic units of differing length (syllables, words, phrases, clauses, paragraphs) yield the critical prosodic feature, namely Intonation (Freeman, 1982). The fundamental frequency of phonation varies

during speech. This range is called speech range or the speech frequency raage by Hirano (1981). As discussed by Fairbanks and Pronovast (1939) variations in fundamental frequency and the extent of range used are also relate to the intent of the speaker. The spread of frequency change used corressponds to the mood of the speaker. cheerful animated speech exhibits greater range use than serious thoughtful speech (Skinner, 1935).

Changes in duration and fundamental frequency during syllable elements of words are basic to the melody and rhythm patterns unique to English. Stressed syllables are perceived as being higher in pitch than unstressed syllables (Freeman, 1982).

Hudson and Holbrook (1981) studied the fundamental vocal frequency range in reading, in a group of young black adults, age ranging from 13 to 29 years. Their resutls indicated a mean range from 81.95 to 158.50 Hz in males and 139.05 to 266.10 Hz in females, compared to a similar white population studied by Pitch and Holbrook (1970), the black population had greater mean freqeuncy ranges, Hudson (1981) pointed out that such patterns of vocal behaviour may be important clues which alert the listener to the speaker's racial identity.

Abnormal pitch ranges, have been found to be used in different pathological conditions (Huntington 1965, Doherty, 1980).

Very few studies have been done, to determine the range of fundamental frequency during reading, reciting and singing.

Therefore it is intended to study the range in the above mentioned conditions.

Fundamental Frequency:

Fundamental frequency used by an individual in phonation is not a true representation of fundamental frequency used in speech. Hence it becomes important to evaluate the speaking fundamental frequency.

Many investigators have studied the speaking fundamental frequency as a function of age and in various pathological conditions. But relatively little is known about the speaking fundamental frequency during reading and reciting.

Most of the therapies of voice disorders are based on the assumption that each individual has an optimum pitch at which the voice will be a good quality and will have maximum intensity with least expense of energy (Nataraja and Jayaram 1982).

Michel, Hollien and Moore (1965) studied the speaking fundamental frequency characteristics of 15, 16 and 17 years old girls, in order to determine the age at which adult female speaking fundamental frequencies are established. Their results indicated that females attain adult speaking fundamental frequencies by fifteen age years of age. In order to determine when adult frequencies are first evidenced, it is necessary to study the girls of fourteen years and younger. (Michek, Hollien and Moore, 1965).

Hudson and Holbrook (1981) investigated the mean modal fundamental frequency, in reading, in two hundred young black adults whose age ranged from 18 to 29 years and found it to be 110.15 Hz in males and 193.10 in females. Compared to a similar white population studiedby Fitch and Holbrook (1970), the black population had lower mean modal fundamental frequencies.

The fundamental vocal frequency is recognized as an important characteritic of expressive language in a society that is becoming increasingly dependent on the spoken word to convey information.

Past research on this topic have shown that the fundamental vocal frequency is dynamic and provided important clues regarding the emotional state, type of speech, activity, race, sex and physical maturity of the speaker.

It has been shown-that different emotional states produce distinctive differences in the fundamental (Cowan, 1936, Fairbanks and Pronovast, 1939, Williams and Stevens, 1972) that the mean fundamental is higher for reading than speaking (Hanley 1951, Hollien and Jackson, 1973, Mysak 1959, Schultzcoulon 1975, Suidecor 1943) that fundamental characeristics which differenciate the sex of the speakers are most noticeable during puberty when the fundamental drops approximately one octave but a leas noticeable change occurs in females (Duffy 1970, Fitch and Holbrook 1970, Hollien, MalciK and Hollien 1965 Hollien and Paul 1969, Hollien and Shipp 1972).

Not many attempts have been made to note the variations of speaking fundamental frequency during reading and reciting. It was, therefore decided to investigate this in the present study.

Vowel Duration:

In speech, vowel and consonant interact. The tongue doesnot completely shape itself for the vowel but retains aspects of the consonant throughout the syllable. This incompleteness of vcwel is characteristic of speech, in rapid speech consonants tend to be increasingly dominant.

In singing, the words are presented artificially, because the composer dictates the pitch and durations of the notes, under such circumstances the vowel dominates the consonant sicnce it can be sustained and developed, and therefore projected for the better acoustically. (Buten schon and Borah grevink, 1982).

Singing prolongs the vowels, since they are especially suited to carry melody. It follows that the rhythmical, dynamic and melodic quantities of speaking and singing differe only in regard to quantity and quality, (Luchsinger, 1965).

In speech the long vowel in speech has a relatively long duration, and therefore can be shaped more completely, substituting long vowel for a short vowel sound will entirely

change the meaning of a word.

In singing an awkward situation often arises when the performer is asked to sing a long note on a short vowel sound. On occassions it may even be necessary to change notes one the same short vowel sound. As this distorts the length of the vowel, it is important not to lose the original quality and character of the short vowel sound, otherwsie the word will not be understood.

In speech the vowel has four characteristics: Volume, pitch, infelciton and duration.

A stressed vowel either increases in volume and then decreases or starts at full volume in which case the stress will be more extreme. The vowel may change pitch, gliding upwards or downwards or rising and falling: the more it varies in itself the stronger the stress will be. A stressed vowel is of relatively long duration.

An unstressed vowel is invariable in its volume and inflection, is of relatively short duration and being a short vowel is characterised by a blurred or indistinct form. A long vowel in an unstressed position ia also blurred.

In song, as in speech, vowel stress in song is produced by means of a 'Crescendo or decrescendo', and in the case of strng stress the vowel has to be started fall volume, however pitch is determined by the melody and

length by the value of the note. The volume of an unstressed vowel is stable. In speech a long vowel sound is blurred in an unstressed position, in song it must be distinct in the unstressed position. This is an important factor in clear enunciation of the words in singing. (Butenschn and Borchgrevink, 1982).

Rajapurohit (1982) made oscillopgraphic measurements of duration of vowels in initial, medial and final position.

The absolute duration of vowels in milliseconds in all 3 positions have been tabulated in the following table.

	Initial	Medial	Final
i	75.00	60.77	80.81
i:	132.00	136.41	138.16
e	114.00	83.16	118.85
e:		151.16	
a	67.13	71.84	68.54
a:	169.50	157.80	138.06
o	98.00	84.00	
o:	196.66	146.22	
u	64.73	58.05	84.98
u:	150.00	168.00	
	75.14	64.08	
	194.00		

Spectral analysis of sung vowels was done by Bloothooft and Plomp (1984).x They studied the variation due

to differences between vowels, singers and modes of singing.

Average 1/3 octave filter spectra of vowels, sung by 7 xx male and 7 professional female singers were measured The material consisted of nine different vowels, sung at six fundamental frequencies (ranging from 93 upto 880 Hz). For each vowwel the singers were requested to sing in the following nine modes neutral, light, dark, pressed, free, loud, soft, straight, and extra vibrato.

A considerable decrease in total spectral variance was found when fundamental frequency rose from 98 to 880 Hz mostly due to the reduced spectral variance between vowels. Above, about fundamental frequency - 660 Hz spectral variation was dominated by differences related to singers and mode of singing.

Additional a nalysis revealed that for all fundamental frequency values (1) Vowel spectra of the Tenor and the soprano singers varied more than those of the Bass and the alto singers. (2) There was only a slight dependence of spectral differences between vowels on the mode of singing and (3) The amount of spectral variation in a vowel, sung by differenct singers with different modes of singing, was vowel dependent.

The literature contains very little about gross aspects of speech timing, as the durations of vowels and consonants (Kent, 1976).

Di Simoni (1974) made oscillographic measurements of vowel and consonant durations in CVC and VCV utterences, of children aged 3,6 and 9 years. The conclusion of these studies was that the variability of the durations tended to decrease with age. In addition, the vowel duration in the voiceless consonant enviornments remained relatively constant for all ages tested, while the duration of vow in voiced consonant enviornments were found to increase with age. Vowel durational values compared both voiced an voiceless consonant enviornments were found to be significantly different in 6 and 9 years old subjects but not in 3 year eld subjects.

Vowel duration in minimal pains differing only in the voicing characterstic of the final consonant was studied by Raphael, Dorman and Geffuen (1980), in 3 and 4 year old children. Spectrographic analysis revealed that children produced vowel duration differences of the same nature and magnitude as those found in adult speakers utterances. They also reported that the duration of voicing daring the final consonant closure, are reliable predictors of the voicing characteristics of the final consonant.

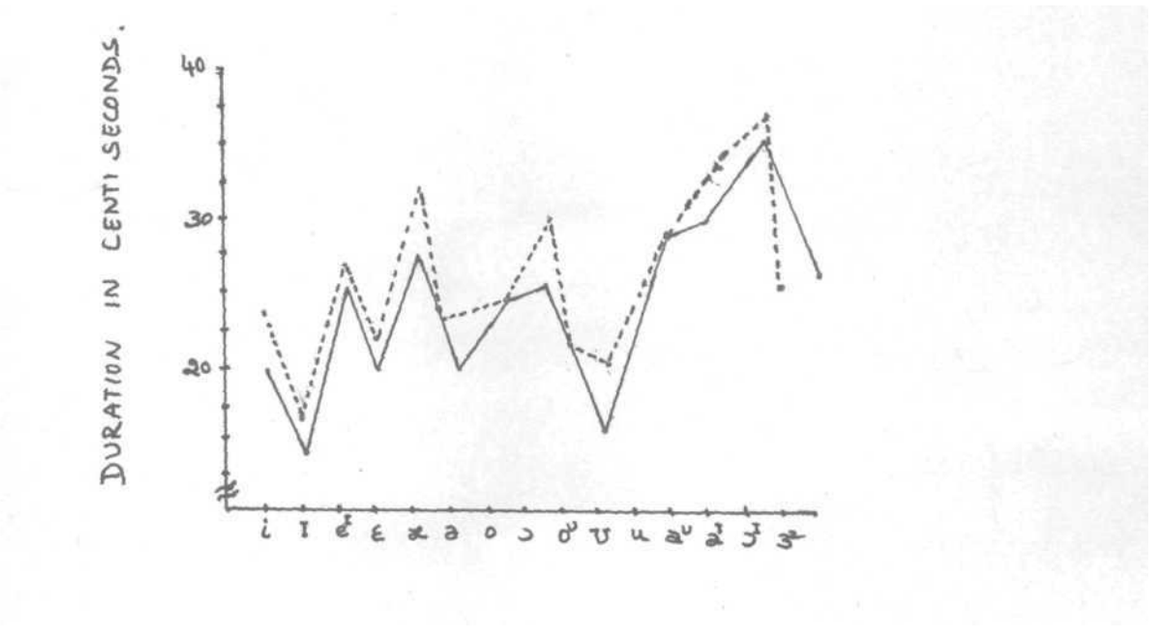
Previous investigators have shown that vowel duration decreases as the number of syllables in a word increases. When carrier phrases consitute the material Umeda found (1972) that, connected text factors other then the number

of syllables in the word have stronger influence in vowel duration. It turned out that differences were very small if present at all, in vowel duration in connected text material. In 1974 Umeda studied the 'effects of speaking mode on temporal factors in speech'. This investigation was conducted to find whether the differences result from speakers idisyncracies or rom different speech modes-carrier phrase reading and connected speech. Results indicated the dependence of vowel duration on number of syllables is one of the dominating factors in the carrier phrase mode, but is a negligle factor in connected speech.

Because few date have been reported an the durations of segments in children's connected, meaningful speech, it is not clear at this time if lengthening of segments is a uniform property of children' speech.

Vowel duration has been measured in various languages English (Klatt 1980; Raphael et al 1975; Walsh and Parker 1981); Kannada (Rajapurohit, 1982), Malayalam (Velayudan), Tamil (Balasubramniam, 1981), Japanese (Homma, 1981), French (O' Shanghnessy, 1981, Meck, 1982), Swedish (Lyberg 1981), Hungarian (Fonagy, Fonagy and Dupuy, 1980) and in Dutch (Noote boom, 1972).

Peterson and Lehiste (1960) measured the average durations of the English vowels shown in figure.



Durations of individual segements differe widely from these averages due to systematic influences of phonetic and syntactic environments. There are a host of variables which affect the durations, summarized in the table below, Table:

Factors that influence the durational structure of a sentence (Klatt, 1976):

Extra linguistic:

| Psychological and Physical state (Williams and Stevens, 1972)

Speaking rate (Huggeins, 1964; Goldman Eisler, 1968).

Discourse level:

Position within a paragraph (Lehiste, 1975)

Semantic:

(Emphasis and Samantic novelty (Coker et. al. 1973).

Syntactic:

Phrase structure longthening (Martin, 1970; Klatt 1975)

World level:

Word final lengthening (Lehiste, 1972; Oller, 1973)

Phonological/phonetic:

Inherent phonological duration for a segment (Peterson and Lehiste, 1960).

Effect of linguistic stress (Paramenter end Trevino, 1936)

Effect of post vocalic consonant(House and Fairbanks 1953)

Segmental iinteractions, for example consonant clusters (Klatt, 1973; Haggord, 1973).

Physiological Incompressibility (Klatt, 1973).

The syllable or syllables at the end of a sentence are longer than they would be within an utterance (Gaitenby, 1965). A word spoken in isolation is about the same duration as it would be at the end of an utterance, and perhaps as much as twice as long as it would be at the beginning of a sentence. This durational effect is called 'Pre-pausal lengthening'.* The syllable before the pause increases by about 60-200 milliseconds. With most of the durational increment restricted to the vowel and any post vocalic sonorant or fricative consonants (Oller, 1973; Klatt, 1975).

Lybers reported a strong relationship between duratin and the fundamental frequency change. Further he says that

the fundamental frequency contour can never be a secondary effect of the segment durations and that it seems quite possible to generate the fundmental frequency contour only from duration values.

Lee (1978) has reported that the shape of the fundamental frequency contour determines the difference in duration between tone classes primarily. The intrinsic duration of a vowel in a tone language is conditioned by the tone that the vowel carries. Notteboom (1972) Cooper (1976), Lindblom etal (1976) and Lehiste (1976) on the other hand, have observed the duration to be independent of the fundamental frequency contour.

Klatt (1976) states that the duration of the preceding vowel is often cited as an important cue to the voicing feature of final stop consonants in English, preceding vowel duration has been called under certain conditions a primary (Klatt, 1976) and even necessary (Raphael, 1972) cue to the voicing distinction).

In neutral speech, vowel duration differences are probably neither necessary, nor adequate cues to this distinction and that voicing during closure may be required to disambiguate voiced stops (Wardrip-Frun, 1982).

For American English, the finding or shorter vowel duration before voiceless as opposed to voiced stops is

consistent over a large number of adult speakers, studies and phonetic environments (House, 1961; House and Fairbanks, 1953, Klatt, 1973). For the pre-pausal syllables the vowel before the voiceless cognate averages about 60% (range 52% to 69%) of the vowel before the voiced cognate.

Colling, Rosenbek and Wertz (1983) pointed out that most normal speakers of English reduce the duration of the vowel, as the words increase in length.

Investigations of adults speech have revealed that the timing of speech movements is uder fine control,such that successive movements in the production of a phonetic sequence may be seperated by as little as ten milliseconds (Kent, 1976). It is likely that timing variables could provide a sensitive metric for the evaluation of the neuromuscular maturation of the speech mechanism.

Nataraja and Jagadeesh (1984) have shown a relationship between fundamental frequency of voice and vowel duration.

Not many reports are available to show the variations in the duration of vowels in different conditions like reading reciting and singing. Hence it was decided to determine vowel duration in above mentioned conditions.

Word Duration:

In the course of work on language identification and word spotting it has become evident that information about the durational characteristics of speech segments will be useful (Crystal and House, 1982).

Most of the published studies dealing with durational phenomena are concerned with the segmental features of speech, but there has been work at the prosodic level - some dealing with vowel durations (Lehiste, 1970, Nooteboom, 1972) Lindblom, 1975; Harris and Umeda, 1974) and some with pauses and hesitationa phenomenon (Goldman-Eisler, 1961; Boomer and Dittman, 1962). Various reports have described factors that might be responsible for differences in speech rate. For example, there is some evidence, that, for most languages variations in speech rate are due primarily to variations in the durations of pauses (Goldman - Eisler, 1961,1968; Han, 1966; Grosjean and Des chaunpe, 1975; Lass and Deem, 1972).

Fluent pauses may occur within sentences, especially between words that are not syntactically related (Klatt 1971).

Lindblom and Rapp (1973) have analyzed a large quantity of production data for Swedish in which they observe lengthening at the ends of linguistc units that include

the sentence, each phrase and each word. The data are described by a set of recursive shortening rules that apply sequentially at the sentence, phrase and word levles. It is of some interest to determine whether this hierarchy is present in other language and/or whether it reflects the structure of sentence planning and production strategies taking place in brain (Klatt, 1976).

Martin (1970) showed that segments tended to be lengthened in spontanious speech just prior to major grammatical constituent boundaries.

Klatt (1975) measured the durations of all segments in a connected discourse, as read by a single talker. He determined which segmetns were greater than 1.4 times the median duration for that segment type and found that all but one of these lengthened segments were in a phrase final syllable. Lengthening was observed at the ends of noun phrases and a very phrase and at the end of conjoined or embeded clauses. The effect was large the increase in vowel duration, as averaged over all phrase boundaires in the corpus, was 30%.

The vowel in the final syllable was longer by 120 m.secs. in the phrase final environment.

Cooper (1975) has attempted to determine if all types of phrase and clause boundaries were preceded by about in the same amount of lengthening. Results suggested that

there was considerable variability in which types of phrase and clause boundaries were accompanied by increases in durations.

"It is not known whether a speaker learns to lengthen segments at the ends of phrase boundaries in order to help the listener decode the message, or if there is simply a natural tendency to slow down at the ends of all motor sequences or planning units. Since utterances final lengthening often extends over several syllables, it is porbably related to the general decleration of motor activity at the ends of speaking acts. This is in contrast to the lengthening seen at sentence interval phrase boundaries which is usually localized to the phrasefinal syllable" (Klatt, 1976).

Word final syllables are some what longer in duration even in non phrase final position (Oller, 1973; Klatt, 1975) Early investigations reported large word final leagthening effects (Barnwell, 1971; Lehiste, 1972; Klatt, 1973 b) but they didnot always control for phrase- final lengthea-ing effects word final lengthening has not been observed by all investigators (Harris and Umeda,1974) and is probably too small an effct to contribute significantly to the decoding of word boundary locations (Klatt, 1976).

The syllable or syllables at the end of a sentence are longer than they would be with in an utterance

(Gailinby, 1965). A word spoken in isolation is about the same duration as it would be at the end of an utterance, and perhaps as much as twice as long as it would be at the beginning of a sentence. This durational effect is called prepausal lengthening. The syllable before the pause increases by about 60- 200 m. secs. with most of the durational increment restrivted to the vowel and any post vocalic sonorant or fricative consonants (Oller, 1973; Klatt, 1975).

Kent and Porner (1980) used Spectrograms to study speech segment durations is recitations of 3 simple sentences by adults and children in each of 3 age groups: 4, 6 and 12 years. The 4 year olds typically had longer segment durations and greater variablity of segment durations then adults and the older children. The degree to which segments are lengthened by young children appears to depend on various segmental, suprasegmental and linguistic factors whcich have not yet been explored.

Thus the word duration is found to be varying depend ing on different factos. Therefore it is considered to be interesting to note word duration in reading, reciting and singing.

A good review of Indian Music has been made by Gupta (1984). He discusses various types of classical Indian Music - their origin, their differences and other factors related to them. Its considered that its beyond the scope of the present study to review all this as the present study to review all this as the present study was aimed at analysing the light vocal music which does not depend much upon any of the tranditional or classical types of Indian Music or singing. Light vocal music is also been considered as equally popular in the present day common man.

Acoustic analysis of sining particularly the light vocal music in Kannada has not been reported. Therefore it was considered that it will be interesting and useful to note the differences betweent his simplese form of singing in Indian Music and reading and recitation as to provide information regarding the acoustical changes that occur in singing as compared to reading and recitation. Therefore the present study has been proposed to investigate the Acoustical differences between three forms of speech ie. singing, reading and recitation in terms of fundamental frequency, frequency range, vowel duration and word duration.

CHAPTER-III

METHODOLOGY

The present study was aimed at investigating the following acoustical patterns of voice in singing.

1. Fundamental frequency.
2. Range of Fundamental frequency.
3. Vowel Duration.
4. Word Duration.

This was done by measuring and comparing the different voice parameters in the following conditions viz. reading, reciting and singing.

Subjects:

5 females and 5 males were taken as subjects. The criterion of selection were that,

1. They should not have any speech, hearing or respiratory problems or vocal pathology at the time of recording.
2. their mother tongue should be kannada.
3. they should know to read and write in kannada language and
4. they should have minimum of 5 years training in classical music.

Table 3.1 shows that the age, sex and years of training of the subjects, The age range was 19 to 33 years.

TABLE 3.1

Subjects	Age	Sex	Number of years of training
1.	33	F	10
2.	29	F	23
3.	21	F	8
4.	19	F	9
5.	22	F	7
6.	22	M	10
7.	19	M	7
8.	21	M	8
9.	28	M	6
10.	20	M	5

Subject number 2 was the only professional singer. 4ll others were Amateurs.

Selection of the recording material:

One popular kannada poem, which could be easily used for singing was selected for the purpose of the test. With the help of one singer, the tune which could be easily sung was composed for the whole poem. The poem could be recited and read without tune composed.

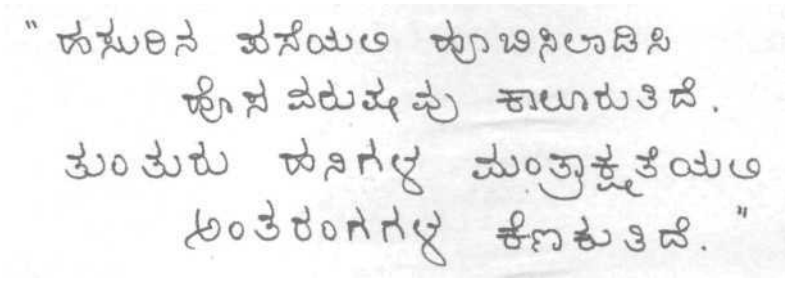
First stranza of this poem was selected for the pupose of acoustic analysis.

The criterion of the selection of this stranza was that

1. It include all the vowels that were intend to be analyzed and

2. there are no blends.

The text of the stranza was



"hasurina pasejali hu:bisiladisi
hosavaru awu ka:lu:rutide
tunturuhanigala mantrak atejali
antarangagala kenakutide.

Recording environment

Recordings were doen in a sound treated room of speech Science Laboratory at All India Institute of Speech and Hearing, Mysore.

Instructions:

The subjects were instracted to read the poem first. The script was given to them. Then they were asked to memorize the poem and recite the same without looking at the script.

Later, they were asked to sing the poem in a particular tune, as sung by the composer i.e., the model was provided to the subjects for practice, when the subjects and the experimenter were statisfied with the practice the subjects were made to sing the whole poem and the recording was done.

Recording Procedure:

Recording were done using a professional spool tape recorder which was the part of VII sound spectrograph series 700, having the speed of 7½ ips.

An omnidirectional microphone and it was kept at a distence of approximately 6 inces from the subject's mouth.

There tasks were performed by the subjects.

(a) Reading the poem.

(b) Reciting the poem.

(c) Singing the same in a particular time.

A time gap of 1 hour was given between each recordings i.e. between 1 and 2, 1 hour, and between 2 and 3, 1 hour.

The above 3 performances of all the 10 subjects were recorded and this served as the material for the acoustic analysis.

Sample:

She first stranza of the poem was selected as the sample for the acoustic analysis in all the three conditi-ons (reading, reciting and singing).

She following Acoustic parameters of voice were analysed in all the three conditions viz. reading, reciting and singing:

1. Range of fundamental frequency.
2. Fundamental frequency.
3. Segmental duration (Word duration).
4. Vowel duration.

Acoustic analysis:

The signal from the player of Spectrograph(Voice identification lnc. 700) was feel to pitch analyzer PM-100 (voice Identification lnc) which gave visual display of the signal of 9 seconds duration on the screen, displaying fundamental frequency and intensity of that signal fromt he screen with the help of cursor frequency and duration of the required signal were obtained and the values were noted.

1. Measurement of the Fundamental Frequency:

To determine the fundamental frequency, the segments were fed from the tape recorder to the pitch analyzer and the mean fundamental frequencies were determined.

2. Measurement of Range of Fundamental Frequency:

For the measurement of Range of fundamental frequency the recorded singnal was fed from the tape recorder to the pitch analyzer PM 1000 and the fundamental frequency curve was obtained on the screen.

The curson was moved to the lowest point on the fre-

quency curve and then to the highest point on the frequency curve. The difference between these two provided a measure of the frequency range used in that particular

3. Measurement of Vowel duration:

The following instruments were used for the measurement of vowel duration:

- High Resoluton Signal Analyzer (B&K 2033)
- VII Sound Spectrograph series 700.

The signal was fed from the output of the tape recorder to the High Resolution Signal Analyzer through the time in jack. With this experimental set up, the segment was fed to the High Resolution Signal Analyzer (B & K 2033) in the time mode with the following settings.

Input: "Direct" – connects the direct input to the input amplifier.

Full Sclae level: 2.82 volts. This indicates the full scale level display on the High Resolution Signal Analyzer display screen in volts peak, after tha input gain, etc. adjustments such that the High Resolution Signal Analyzer internal reference reads 100 dB or 100 MV.

Frequency: 200 Hz.

Input Function: "Time" - causes the input function to the display selector to the time function.

The following segments were taken to determine the duration of vowels /a/, /i/, /u/.

/a/in /pasejali/ /pa/

/i/ in /hu:bisiladisi/ /bi/

/u/ in/tunturu/ /tu/

The signal was fed to High Resolution Signal Analyzer An soon as the segment pasejali appeared on the display screen, the 'stop' key was applied. The cursor was moved to the point where the vertical striations began that is to the begining of the envelope, and than to the end of the envelope. The difference in milliseconds between these two points was recorded as the duration of the vowel/a/ in "pasejali". Thus the duration of the vowel /a/ in (pasejali) as uttered y each subject was obtained.

4. Word duration:

With the same experimental set up, words were fed to the pitch analyzer. The duration of each word was measured, by moving the cursor from the starting point of the word to the terminating point of the word and finding the difference between the two. This provided the duration of each word in centi seconds. The total duration of nine words was taken adn the mean was obtained. This mean duration was taken as the word duration for that subject.

CHAPTER - IV

RESULTD AND DISCUSSION

For each subject the following acoistic parameters were measured in reading, reciting and singing conditions. They were:

1. Fundemental Frequency
2. Range of Fundemental Frequency.
3. Vowel Duration.
4. Word Duration.

1. Fundemental Frequency:

Table 4.1 shows the mean fundemental frequency of each female subjects and table 4.2 shows the mean fundemental frequency of each sale subject in reading, reciting and singing conditions.

TABLE 4.1

Subjects	Reading	Reciting	Singing
1.	254 Hz.	246 Hz.	267 Hz.
2.	254.5 Hz.	280.5 Hz.	273.25 Hz.
3.	253.0 Hz..	247.5 Hz.	312.25 Hz.
4.	267.5 Hz.	275.5 Hz.	257.50 Hz.
5.	236.5 Hz.	210.0 Hz.	199.75 Hz.
Mean	253.1 Hz.	251.9 Hz.	261.95 Hz.
SD	11.02	28.22	40.53

Table 4.1: Mean fundamental frequency (in Hertz) for each female subject in reading, reciting and singing conditions.

The study of table 4.1 shows that two subjects (Subject No. 1 & 3) eat of five had used a high fundamental frequency in singing than in other 2 conditions.

Subject No. 2 & 4 had used a higher fundamental frequency in reciting than in other two conditions. Whereas subject number 5 had used a higher fundamental frequency in other two conditions.

The mean fundamental frequency for female group ranged from

i) 236.5 Hz. to 267.5 Hz. in reading.

ii) 210 Hz. to 280.5 Hz. in reciting.

iii) 199.75 Hz. to 312.25 Hz. in singing conditions.

The mean and the SD for this group was 253.1Hz and 11.02 respectively in reading, whereas the same subjects had shown a mean of 251.9 Hz. and SD of 28.22 in reciting and in singing the mean was 261.9 Hz. with a SD of 40.53.

when the mean fundamental frequencies of all the three conditions were considered, it was found that in singing a higher fundamental frequency (261.95 Hz.) had been used than is other conditions. It must also be noted that the variability of fundamental frequency in singing (SD 40.53) had been mere greater when compared to other two conditions.

The mean fundamental frequency of all the five female subjects was compared between reading and reciting; reciting and singing and singing and reading conditions using

Mann-Whitney U test.

The mean difference in fundamental frequency between reading and reciting conditions was not significant. Hence the auxilary hypothesis stating that"there is no significance difference between reading and reciting conditions, in femmale group, when the mean fundamental frequency is compared" was accepted.

The mean difference in fundamental frequency between reciting and singing condition was also not significant. Therefore the auxilary hypothesis stating that "there is no significant difference between reciting and singing conditions, in female group, when the mean fundamental frequency is compared" was accepted.

The mean difference is fundamental frequency between singing and reading conditions was not significant statistically. Hence the auxilary hypothesis stating that "there is no significant difference between singing and reading conditions, in female group, when the mean fundamental frequency was compared" was accepted.

Thus, statistically there is no significant difference between these three conditions i.e., reading, reciting and singing were found in terms of mean fundamental frequency. However, it must be noted that there were differences in the mean fundamental frequency when the mean values of these conditions were considered with heighest mean fundamental

fuequency under singing conditions.

The mean fundamental frequency for all the male subjects under all the three conditions are presented in Table 4.2.

TABLE 4.2

Subjects	Reading	Reciting	Singing
6.	137.5 Hz.	143.00 Hz.	204.25 Hz.
7.	105.0 Hz.	130.00 Hz.	131.00 Hz.
8.	104.5 Hz.	136.50 Hz.	105.25 Hz.
9.	151.5 Hz.	183.00 Hz.	143.00 Hz.
10.	116.0 Hz.	114.00 Hz.	134.25 Hz.
Mean	122.9 Hz.	141.50 Hz.	143.55 Hz.
SD	20.84	25.57	36.73

Table 4.2: Mean Fundamental frequency (in Hertz) for each male subject in reading, reciting and singing conditions.

The examination of the table 4.2 showing the fundamental frequencies for each male subject under all the three conditions reveals that three (Subject No. 6,7 & 10) out of five subjects had usad a higher fundamental frequency in singing than in other two conditions.

Subject No. 8 & 9 had used a higher fundamental frequency in reciting than in other two conditions.

The mean fundamental frequency of male group ranged from

i) 104.5 Hz. to 209.5 Hz. in reading.
ii) 114 Hz. to 262 Hz. in reciting.
iii) 105.25 Hz. to 262 Hz. in singing conditions.

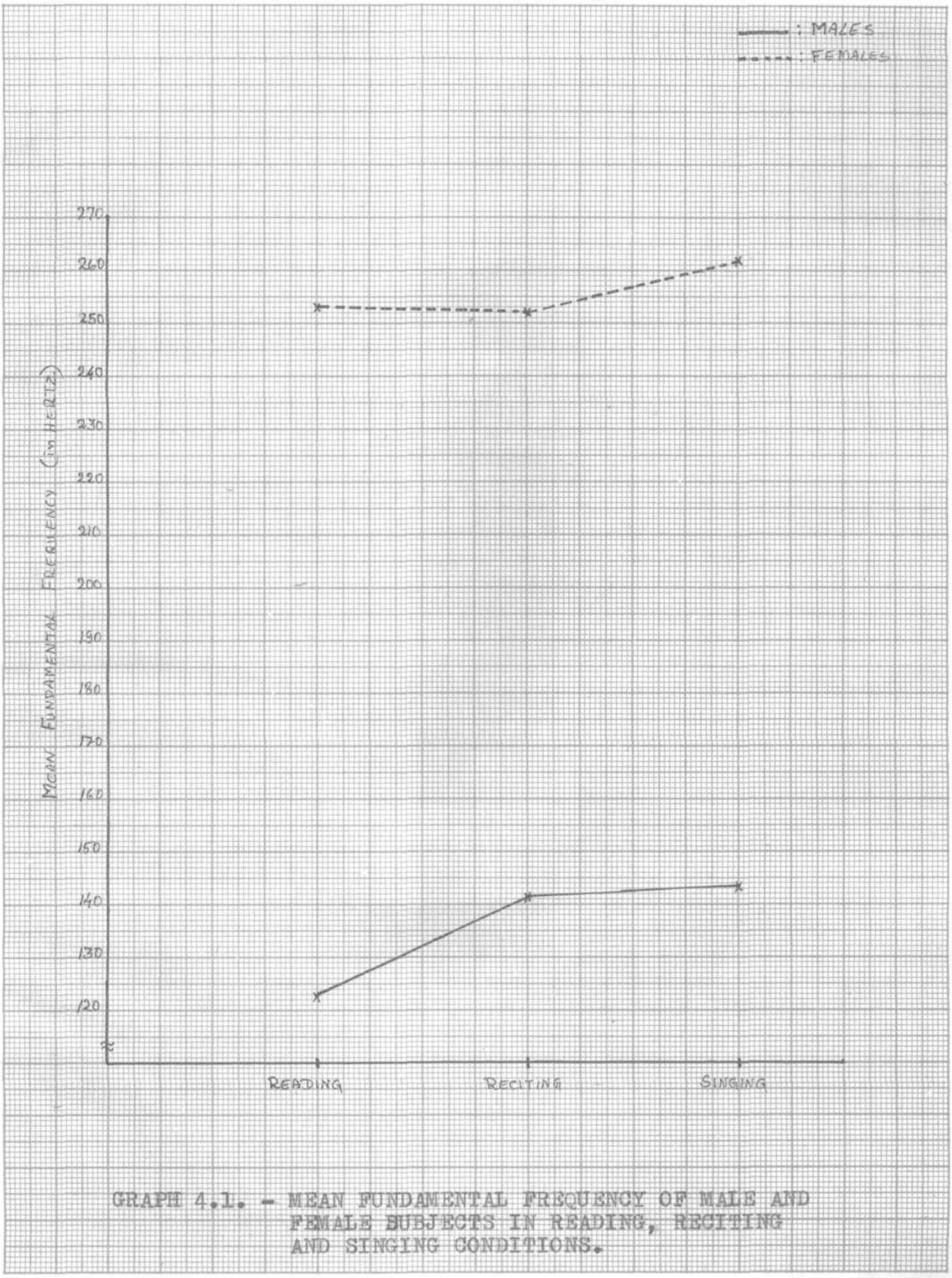
The mean and the SD for this group was 143.8 Hz. and 41.03 respectively in reading, and it was 167.7 Hz. and 58.3 in reciting, whereas in singing it was 261.95 Hz. sad 40.53.

She above values show that the male subjects had the highest mean fundamental frequency (261-95 Hz.) in singing and the lowest fundamental frequency (143.8 Hz.) in reading. The variation of fundamental frequency was maximum in reciting (SD 58.3) and minimum in singing(SD 40.53).

The mean fundamental frequency of all the five male subjects was compared between reading - reciting; reciting-singing; and singing-reading conditions using Mann-Whitney U test.

The mean difference in fundamental frequency between reading and reciting conditions was not sigificant statistically. Hence the auxilary hypothesis stating that "there is no significant difference between reading and reciting conditions, in male group, when the mean fundamental frequency is compared" was accepted.

Between reciting and singing conditions the mean



GRAPH 4.1. - MEAN FUNDAMENTAL FREQUENCY OF MALE AND FEMALE SUBJECTS IN READING, RECITING AND SINGING CONDITIONS.

difference in fundamental frequemcy was not significant . Therefore the auxilary hypothesis stating that "there is no significant difference between reciting and singing conditions, in male group, when the mean fundamental frequency is compared" was also accepted.

The mean difference in fundamental frequency between singing and reading conditions was not significant. Hence the auxilary hypothesis stating that "there is no significant difference between singing and reading conditions in male group, when the mean fundamental frequency is compared" was accepted.

Thus the results of statistical analysis of mean fundamental frequency under these conditions in case of males also show no significant difference, similar to females. But then, the mean of these values under three conditions had shown difference with highest mean fundamental frequency under singing condition.

The t t e s t was applied between the male and female groups in all the three conditions.

The mean difference of fundamental frequency between male and female subjects,

a) In reading was 109.2 Hz. and it was statistically significant at 0.01 level (t=5.74). Hence the auxilary hypothesis stating that "there is no significant differ-

ence between male aad female subjects in reading condition when fundamental frequency is compared" was rejected.

b) in recitation it was 84.2 Hz. and this was statistically significant at 0.05 level (t=3.91). Thus the auxilary hypothesis stating that "there is no significant difference between male and female groups in reciting condition, when fundamental frequency is compared" was rejected.

c) in singing it was 92.2 Hz. and this value was not significant at 0.05 level (t=2.76). therefore the auxilary hypothesis stating that "there is no significant difference between male and female subjects in singing condition, when fundamental frequency is compared" was accepted.

The significance of mean difference value shows that there is difference in fundamental frequency of males and females in both reading and reciting conditions whereas both the groups used alomost same fundamental frequency in singing i.e. both male and female subjects had used a higher fundamental frequency in singing and had not shown any significant difference, whereas males had used a lower fundamental frequency in reading and reciting when compared to females, and this difference was significant statistically also.

Even though there is difference in mean fundamental frequency used between reading and reciting this difference is not significant statistically as per Mann-Whitney U test and t test.

The results of the present stady indicate the seen fundamental frequency in reading to be 143.8 Hz. in males and 253.1 Hz. in females which are similar to Hudson and Holbrook's (1981) study.

Sheela (1974) in her study found that trained singers use their optimum frequency while speaking but they did not use their optimum frequency while singing whereas untrained singers did not use their optimum frequency while speaking sad also while singing.

Sheela (1974) found that the speaking fundamental frequency of trained male singers ranged from 100 Hz. to 155 Hz. and that of untrained male singers ranged from 110 Hz. to 160 Hz. In case of trained female singers it ranged from 140 Hz. to 320 Hz. and that of untrained female singers it ranged from 200 Hz. to 270 Hz.

The range of fundamental frequency in singing in case of trained male singers was 110 Hz. to 130 Hz. and in untrained male singers it was 130 Hz. to 200 Hz.

In case of trained female singers fundamental frequency in singing ranged from 160 Hz. to 520 Hz. and in untrained female singers the range was 190 Hz. to 320 Hz.

Jayaram (1975) found that normal male and female adults using a fundamental frequency which ranged from 100 Hz. to 150 Hz. and 200 Hz. to 280 Hz. , respectively, which are similar to the results of the present study.

Nataraja, Jagadeesh ad Kumar (1985) studied the fundamental frequency in different types of speech samples i.e. in phonation, spontaneous speech, reading and singing.

It was found that in case of males the fundamental frequency in phonation was 141.49 Hz., in reading it was 192.25 Hz. and in singing the fundamental frequency was 211.17 Hz. and in speaking it was 166 Hz.

They conclude that the subjects show a tendency to use a higher fundamental frequency for speaking than for phonation and much higher fundamental frequency in reading and singing than in speaking i.e., they had used the highest fundamental frequency in singing (211.7 Hz.).

In the same study, it was found that, just like males, females also use higher mean fundamental frequency for speaking, reading and singing. Again in female group, they used a highest mean fundamental frequency of 304.04 Hz. in singing and mean fundamental frequency of 266.26 Hz. for speaking. Increase in mean fundamental frequency was observed from phonation to singing condition.

Range of Fundamental Frequency:

The range of fundamental frequency i.e.,(the highest fundamental frequency - lowest fundamental frequency) used by each subject has determined.

Table 4.3 and 4.4 show the range of fundamental frequency of female and male subjects respectively in reading, reciting and singing conditions.

TABLE 4.3

Subjects	Reading	Reciting	Singing
1.	327.00 Hz.	272.00 Hz.	261.00 Hz.
2.	264.00 Hz.	224.00 Hz.	305.00 Hz.
3.	251.00 Hz.	232.00 Hz.	335.00 Hz.
4.	195.00 Hz.	310.00 Hz.	220.00 Hz.
5.	297.00 Hz.	372.00 Hz.	371.00 Hz.
Mean	208.17 Hz.	282.00 Hz.	293.40 Hz.
SD	110.02	60.92	59.58

Table 4.3: Range of fundamental frequency (in Hz.) for each female subject in reading, reciting and singing conditions.

I The study of table 4.3 shows that subject number 1 had shown the highest fundamental frequency range in reading, and subject number 4 had shown the lowest fundamental frequency range in reading. Further only one subject had used a greater range in reciting (Subject No. 4)

whereas all the 3 subjects had used greater frequency range in singing than in other two conditions.

In reciting subject number 5 had shown the highest fundamental frequency range and subject number 2 had shown the lowest fundamental frequency range.

In singing subject number 5 had shown the highest fundamental frequency range and subject number 4 had shown the lowest fundamental frequency range.

The range of fundamental frequency of female group ranged from,

i) 195 to 327 Hz. in reading.
ii) 224 Hz. to 372 Hz. in reciting.
iii) 220 Hz. to 371 Hz. in singing conditions.

The mean and the SD of range of fundamental frequency for female subjects in reading, reciting and singing conditions are provided in table 4.3.

As can be seen from the table 4.3, in singing that frequency range was highest whereas it was lowest in reading.

The range of fundamental frequency of all the female subjects was compared between reading - reciting; reciting – singing; and singing- reading conditions using Mann-Whitney U test.

The mean difference in range of fundamental frequency between reading and reciting conditions was not significant

statistically. Hence the auxilary hypothesis stating that "there is no significant difference between reading and reciting conditions, in female group, when the range of fundamental frequency is compared" was accepted.

The mean difference in range of fundamental frequency between reciting and singing conditions was insignificant statistically. Therefore the auxilary hypothesis stating that" there is no significant difference between reciting and singing conditions, in female group, when the range of fundamental frequency is compared" was accepted.

The mean difference in range of fundamental frequency between singing and reading conditions was not significant statistically. Hence the auxilary hypothasis stating that "there is no significant difference between singing and reading conditions, in female group, when the mean fundamental frequency is compered" was accepted.

TABLE 4.4

Subject	Reading	Reciting	Singing
6.	77.00 Hz.	88.00 Hz.	3379.00 Hz.
7.	353.00 Hz.	418.00 Hz.	338.00 Hz.
8.	318.00 Hz.	288.00 Hz.	290.00 Hz.
9.	301.00 Hz.	326.00 Hz.	317.00 Hz.
10.	92.00 Hz.	89.00 Hz.	435.00 Hz.
Mean	228.20 Hz.	241.80 Hz.	351.8 Hz.
SD	132.62	147.71	56.75

Table 4.4: Range of fundamental frequency (in Hz.) for each male subject is reading, reciting and singing conditions.

The results of measurement of frequency range under 3 conditions for all the male sabjects, are presented in table 4.4.

Examination of table 4.4 reveals that subject number 7 had the highest range of fundamental frequency and subject number 6 lowest fundamental frequency range in reading.

In reciting subject number 9 had the highest fundamental frequency range and subject number 6 had the lowest fundamental frequency years.

In singing, subject number 10 had the highest fundamental frequency range and subject number 8 had the lowest

fundamental frequency range.

The results also reveal that only 2 subjects had used a greater range of frequencies in singing and 2 subjects in reciting than in other two conditions. Whereas in reading only one subject (Subject No. 8) had used a greater range of frequency than in other two conditions.

In male subjects the range of fundamental frequency used ranged from,

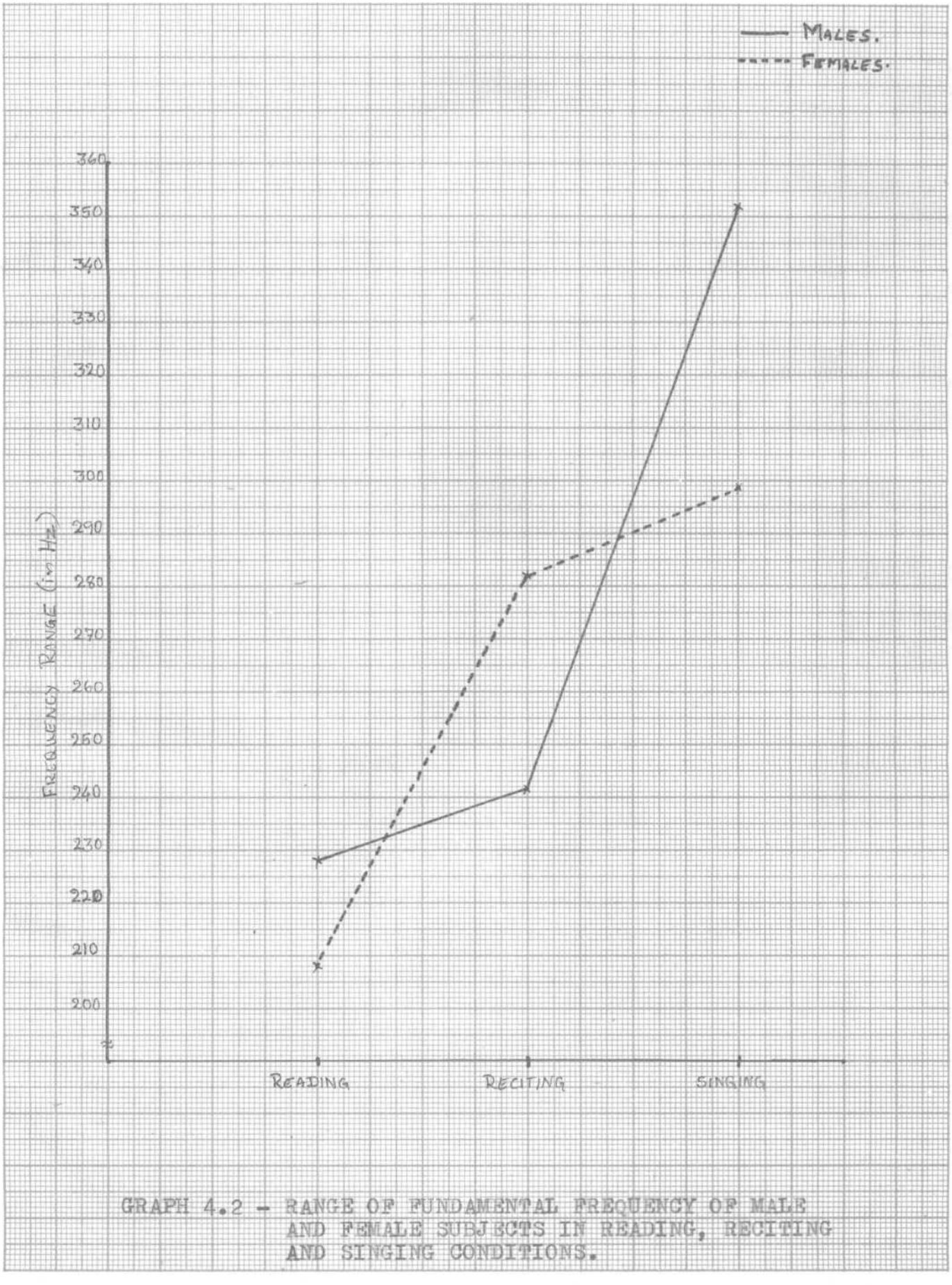
i) 77 Hz. to 353 Hz. in reading.
ii) 88 Hz. to 418 Hz. in reciting and
iii) 290 Hz. to 435 Hz. in singing conditions.

The mean and the SB for range of fundamental frequency of male subjects in reading reciting and singing conditions are also tabulated in table 4.4.

From table 4.4 it can be seen that the fundamental frequency range was the highest in singing and the lowest in reading for male subjects.

The range of fundamental frequency of all the male subjects was compared between reading-reciting; reciting-singing; and singing-reading conditions using Mann-Whitney U test.

The mean difference in range of fundamental frequency between reading and reciting conditions was insignificant statistically, hence the auxilary hypothesis stating that



GRAPH 4.2 - RANGE OF FUNDAMENTAL FREQUENCY OF MALE AND FEMALE SUBJECTS IN READING, RECITING AND SINGING CONDITIONS.

"there is no significant difference between reading and reciting conditions, in male group, when the range of fundamental frequency is compared" was accepted.

The mean difference in range of fundamental frequency between reciting and singing conditions was not statistically significant. Therefore the suxilary hypothesis stating that *there is no significant difference between singing and reciting conditions in male group when the range of fundamental frequency is compared" is accepted.

The mean difference in range of fundamental frequency between singing and reading conditions was statistically insignificant, hence the auxilary hypothesis stating that "there is no significant difference between singing and reading conditions in male group when the range of fundamental frequency is compared" is accepted.

To know the significance of mean difference in range of fundamental frequency between male and female groups, the 't' test was applied and the results were as follows:

The mean difference of fundamental frequency range between male and female groups,

a) in reading was 20.6 Hz, and it was statistically insignificant at 0.05 level (t=0.32), hence theauxilary hypothesis stating that "there is no significant difference between male and female group in reading condition when the range of fundamental frequency is compared" was accepted.

b) in reciting condition it was 40.2 Hz. and this was statistically not significant at 0.05 level (t=0.56). Therefore the auxilary hypothesis stating that " there is no significant difference between male and female group in reciting condition when the range of fundamental frequency is compared". was accepted.

a) in singing condition it was 53.4 Hz. and this was not significant statistically at 0.05 level (t=1.45), hence the auxilary hypothesis stating that "there is no significant difference between male and female group in singing condition when the range of fundamental frequency is compared" was accepted.

These values of significance of mean difference show that the difference in the range of fundamental frequency between male and female group was negligible.

Hudson and Holbrook (1981) studied the fundamental frequency range in reading, in a group of young black adults. Their results indicated a mean range from 81.95 Hz to 158.20 Hz. in males and 139.05 Hz. to 266.10 Hz. in females.

The results of the present study showed a mean range from 77 Hz. to 353 Hz. in males and 195 Hz. to 327 Hz. in females.

Results of sheela's (1974) study indicated that the trained singers possess significantly greater pitch range than untrained singers.

Vowel Duration:

The duration of vowels /a/ as in /paejali/; /i/ as in /Hu:bisiladisi/; and /u/ as in /tunturu/, under all the three conditions have been presented in table 4.5 and 4.6.

Tables 4.5 and 4.6 show the mean vowel duration of /a/, /i/, /u/ in reading, reciting and singing conditions of male and female groups respectively.

TABLE 4.5

Vowels	Reading		Reciting		Singing	
	Mean	SD	Mean	SD	Mean	SD
/a/	100.36	9.6	90.92	20.00	226.04	32*16
/i/	120.48	31.2	128.90	22.45	229.22	22*51
/u/	101.20	9.68	93.28	8.68	210.94	32.60

Table 4.5: The mean and the SD of the vowel duration(in milli seconds) of /a/, /i/, /u/ in reading, reciting and singing conditions of female group.

The study of table 4.5 shows that the subjects had the longest duration of vowel /a/ in singing condition and shortest duration of the same vowel in reciting condition. The vowel duration varied maximum in singing condition and it was minimam in reciting condition.

Whereas in case of the duration of the vowel /i/, it

was longest in singing condition and shortest in reading condition. The variation of duration of vowel was maximum in reading condition and it was minimum in reciting condition.

The duration of vowel /u/ was longest in singing and shortest in reciting condition. The duration of this vowel varied maximally in singing condition and minimaly in reciting condition.

It is seen from table 4.5 that the female group had the longest vowel duration in singing and shortest vowel duration in reciting condition. The variation in vowel duration was maximum in singing and minimum in reading.

In the female group the duration of the vowel /a/ rangedd from,

i) 84.4 milli secs. to 108 m. secs. in reading.
ii) 60.9 milli secs. to 117.2 m. secs. in reciting and
iii) 182.8 milli secs. to 262.5 m. secs. in singing.

The vowel duration of /a/ of all the female subjects was compared between reading and reciting; reciting and singing; and singing and reading conditions using Mann-Whitney U test.

The mean difference of the vowel duration of /a/ between reading sad reciting conditions was not statistically significant hence the auxilary hypothesis stating

that "there is no significant difference between reading and reciting conditions, in female group, when, the vowel duration of /a/ is compared" was accepted.

The mean difference of the vowel duration of /a/ between reciting and singing conditions was statistically significant, hence the auxilary hypothesis stating that "there is no significant difference between reciting and singing conditions, in female group, when the vowel duration of /a/ is compared" was rejecte.d

The mean difference of the vowel duration of /a/ between singing and reading condition was significant statistically, therefore the auxilary hypothesis stating that "there is no significant difference between singing and reading conditions in female group, when the vowel duration of /a/ is compared" was rejected.

Thus it was concluded that the duration of vowel /a/ which was considered as a reporesentative sample in all the three conditions was longest in sining than in other two conditions and there was no statistically singificant difference in terms of duration of this vowel under reading and reciting conditions.

In the same female group, the duration of the vowel/i/ ranged from,

i) 79*7 m. secs. to 157.0 m. secs. in reading
ii) 103.1 m. secs. to 154.6 m. secs. in reciting.
iii) 199.2 m. secs. to 262.5 m. secs. in singing conditions

The vowel duration of /i/, of all the female subjects was compared between - reading and reciting; reciting and singing; and singing and reading conditions using Mann-Whitney U test.

The mean difference of the vowel duration of /i/ between,

a) Reading and reciting conditions was not significant statistically, hence the suxilary hypothesis stating that " there is no significant differance between reading and reciting conditions in female group when the vowel duration of /i/ is compared" was accepted.

b) Reciting and singing conditions was significant therefore the auxilary hypothesis stating that "there is no significant difference between singing and reciting conditions in female when the vowel duration of /i/ is compared." was rejected.

c) Reading and singing conditions was significant hence the auxilary hypothesis stating that "there is no significant difference between singing and reading conditions in female group when the vowel duration of /i/ is compared." was rejected.

Similar to the results of the duration of vowel /a/, vowel /i/ also showed a significantly longer duration in singing than in other two conditions and no significant

difference between reading and reciting conditions were found.

In the same group the duration of the vowel /u/ ranged from,

i) 86.7 m.secs. to 107.8 m.secs. in reading.

ii) 86.7 m.secs. to 107.8 m.secs. in reciting.

iii) 175.8 m.secs. to 257.8 m.secs. in singing conditions.

The vowel duration of /u/, of all the female subjects was compared between - reading-reciting; reciting-singing; and singing-reading conditions using Mann-Whitney Utest.

The mean difference of the vowel duration of /u/ between,

i) Reading and reciting conditions was not significant, hence the auxilary hypothesis stating that "there is no significant difference between reading and reciting conditions in female group when the vowel duration of /u/ is compared" was accepted.

ii) Reciting and singing conditions was significant, thus the auxilary hypothesis stating that "there is no significant difference between singing and reciting conditions in female group when the vowel duration of /u/ is compared". was rejected.

iii) Reading and singing conditions was significant, hence the auxilary hypothesis stating that "there is no

significant difference between singing and reading conditions in female group when the vowel duration of /u/ is compared" was rejected.

No subject of this group had shown a large duration of vowels /a/, /i/ and /u/ in either reading or reciting conditions than in singing.

Again a similar trend as in case of vowels /a/ and /i/, the vowel /u/ also showed that it was longest in terms of duration in singing than in other two conditions.

Thus all the three vowels /a/, /i/ and /u/ which selected for measurement from the samples of all the three conditions had consistently shown that they were longer in terms of duration in singing than in other two conditions, and had shown no significant difference between reading and reciting in case of females. Hence it was concluded that the "vowels prolonged ia singing". Such reports have been made by several other investigators.

The results of analysis of durations of vowels /a/, /i/ and /u/ under all the three conditions for male subjects are presented in table 4.6.

TABLE-4.6

Vowels	Reading		Reciting		Singing	
	Mean	SD	Mean	SD	Mean	SD
/a/	91.86	11.5	91.38	12.71	157	29.53
/i/	129.86	32.53	159.34	5.47	258.74	72.04
/u/	90.32	12.36	98.46	55.17	176.28	41.04

Table 4.6: The mean and the SD of vowel duration (in milli seconds) of /a/, /i/ and /u/ in reading, reciting and singing conditions of male group.

The examination of Table 4.6 shows that the subjects had the longest duration of /a/ in singing conditions and shortest duration of the some vowel in reciting condition. The vowel duration varied maximum in singing condition and it was minimum in rading condition.

The duration of vowel /i/ was longest in singing condition and shortest in reading condition. The variation of duration of vowel /i/ was maximum in singing condition and minimum in reciting condition.

Whereas in case of the duration of vowel /u/, it was longest in singing condition and shortest in reading condition. The duration of vowel varied maximally in reciting condition and minimally in reading condition.

All the male subjects studied had shown the longest duration for all the three vowels, in singing than in other two conditions.

In the male group the duration of the vowel /a/ ranged from,

i) 82 m.secs. to 105.4 m.secs. in reading.
ii) 93.8 m.secs. to 105.4 m.secs in reciting.
iii) 114.8 m.secs to 211 m.secs. in singing conditions.

The vowel duration of /a/, of all the male subjects was compared between -

i) Reading and reciting conditions.
ii) Reciting and singing conditions and
iii) Singing and reading conditions

using Mann-Whitney U test.

The mean difference of the vowel duration of /a/ between,

i) Reading and reciting conditions was not significant. Hence the auxilary hypothesis stating that "there is no significant difference between reading and reciting conditions, in male group, when the vowel duration of /a/ was compared" is accepted.
ii) Reciting and singing conditions was significant, hence the auxilary hypothesis stating that "there is no significant difference between reciting and singing conditions, in male group, when the vowel duration

of /a/ is compared" was rejected.

iii) Singing and reading conditions was significant, hence the auxilary hypothesis stating that "there is no significant difference between singing and reading conditions, in male group when the vowel duration of /a/ is compared" was rejected.

The duration of /i/ ranged from ,

i) 82 m.secs. to 173.5 m.secs. in reading.

ii) 89 m.secs. to 225 m.secs. in reciting.

iii) 185.2 m.secs. to 365.6 m.secs in singing conditions.

Using Mann-Whitney U test, the vowel duration of /u/, of all the male subjects was compared between all the three conditions i.e., between reading and reciting; reciting and singing and singing and reading conditions.

Themean difference of the vowel duration of /i/ between,

i) Reading and reciting conditions was not significant. Hence the auxilary hypothesis stating that "there is no significant difference between reading and reciting conditions, in male group, when the vowel duration of /i/ is compared" was accepted.

ii) Reciting and singing conditions was significant stetistically. Hence the hypothesis stating that "there is no significant difference between reciting and

singing conditions, in male group, when the vowel duration of /i/ is compared" was rejected.

iii) Singing and reading conditions was significant statistically. Hence the auxilary hypothesis stating that "there is no significant difference between singing and reading conditions in male group, when the vowel duration of /i/ is compared" was rejected.

The duration of /u/ ranged from,

i) 72.7 m.secs. to 103.1 m.secs. in reading.

ii) 79.7 m.secs. to 11011 m.secs. in reciting and

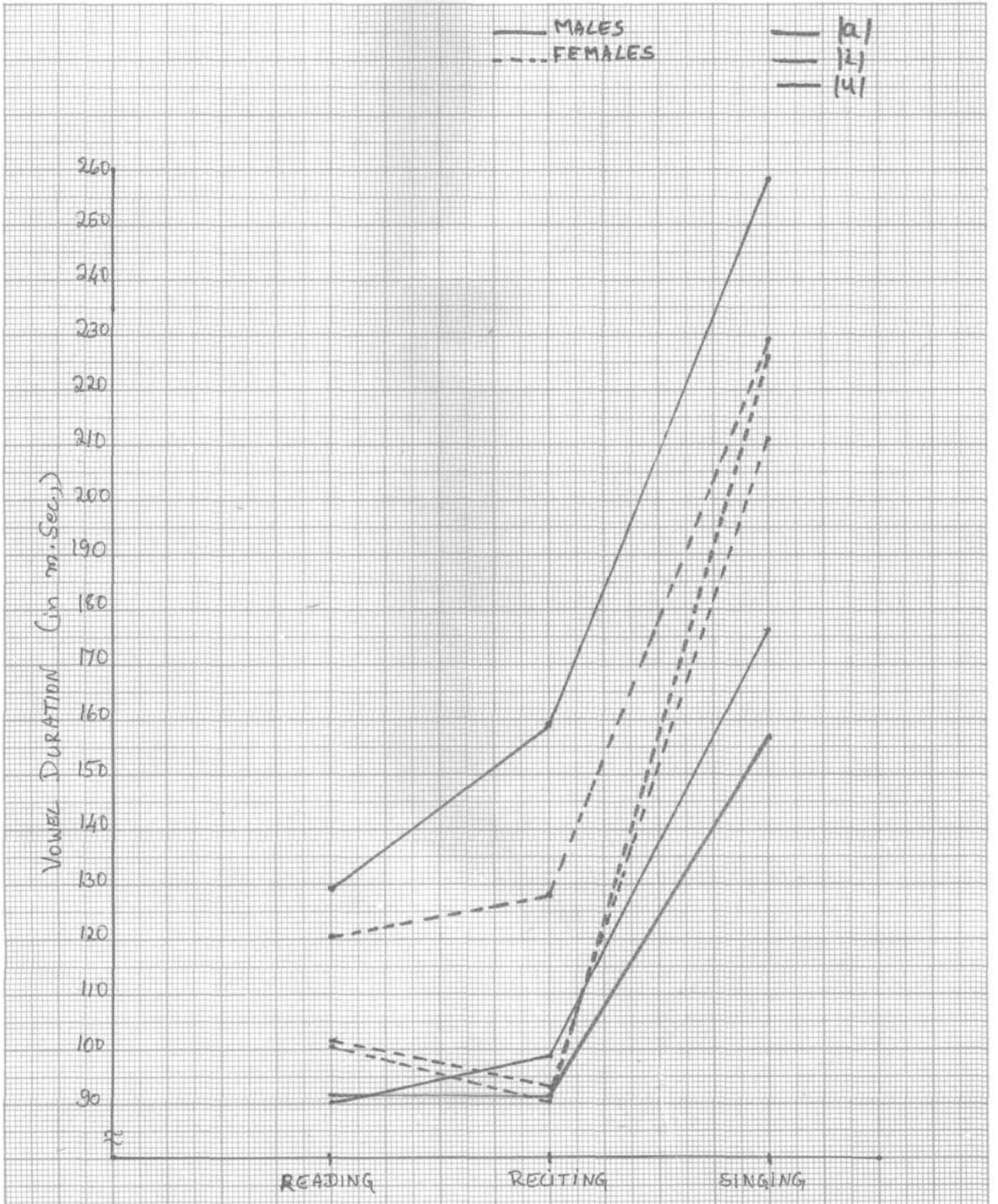
iii) 142.9 m.secs. 208.6 m.secs. in singing conditions.

The vowel duration of /u/, of all the male subjects was compared between reading-reciting; reciting-singing; and singing-reading conditions using Mann-Whitney U test.

The mean difference of the vowel duration of /u/ between,

i) Reading and reciting conditions was not significant. Hence the auxilary hypotheses stating that "there is no significant difference between reading and reciting conditions, in male groups when the vowel duration of /i/ is compared" was accepted.

ii) Reciting and singing conditions was significant statistically. Therefore the auxilery hypothesis stating that "there is no significant difference between reciting and singing conditions, in male group, when



GRAPH 4.3 - MEAN VOWEL DURATION OF /a/,/i/,/u/ IN MALE AND FEMALE SUBJECTS IN READING, RECITING AND SINGING CONDITIONS.

the vowel duration of /i/ is compared" was rejected.
iii) Reading and singing conditions was singificant, hence the auxilary hypothesi stating that "there is no significant difference between reading and singing conditions, in male group, when the vowel duration of /i/ is compared" was rejected.

Thus in case of males also all the three vowels studied i.e., /a/, /i/ and /u/ had the longest duration in singing than in other two conditions. Therefore it was concluded that the males also prolong the vowels in singing than in reading and reciting and not much difference was foundinterms of vowel duration between reading and reciting in case of males also.

The 't' test was used to compare the duration of vowels /a/, /i/ and /u/ between male and female groups.

The 't' test results showed that there was no significant difference between male and female groups interms of vowel duration in reading, reciting and singing conditions.

Hence the auxilary hypothesis stating"there is no significant difference between male and female groups in reading, reciting and singing conditions when the vowel duration of /a/, /i/ and /u/ is compared" was accepted.

The review of literature indicates that the vowel

duration varies depending upon the fundamental frequency. Therefore it is interesting to note, at this point that eventhough the females and males had used different fundamental frequencies under all the three conditions, there was no significant difference in terms of vowel duration. This lack of difference may be due to number of subjects used.

Klatt (1975) measured the durations of the segments in a connected discourse, as read by a single talker. The vowel in the final syllable was longer, found to be longer by 120 m.secs. in the phrase final environment. Oller(1973) and Klatt (1975) have stated that, word final syllables are longer ia durations, even in non phrase final position. Early investigations by Barn well (1971), Lehiste (1972) aad Klatt (1973 b) have reported large word final lengthening effects.

The results of the present study indicates that the duration of the vowel/i/ was longer and it was in the word final position.

The oscillographic measurements of the duration of vowels in initial, medial and final positions was done by Rajapurohit (1982). The results showed, that the duration of the vowel /a/ in themedical position was 71.84 m.secs. and that of /i/ in the final position was 80.81 m.secs. and the duration of vowel /u/ in the medial position was 58.05.

In Rajapurohit's study the subjects were asked to read the words whereas in the present study subjects were asked to read a poem.

Nataraja and Jagadeesh (1985) studied the relationship between vowel duration and fundamental frequency. The resutls showed that the relationship between fundamental frequency and vowel duration was not linear. The vowel duration was minimum, at normal pitch or fundamental frequency and it increased as frequency changed either upwards or downwards from the normal. Thus the increase in vowel duration in singing may be related to fundamental frequency used in singing. This warrants further studies.

Word Duration"

The table 4.7 and 4.8 show the total word duration (in centi seconds) and mean word duration (in centi secs.) for each female and male subject respectively in reading, reciting and singing conditions.

She range of mean word duration of female group ranged from,

i) 76.89 c.secs. to 90.67 c.secs. in reading
ii) 80.33 c.secs. 92.44 c.secs. in reciting.
iii) 200.56 c.secs to 209.22 c.secs. in singing condition.

By observing the table 4.8, it can be seen that singing had highest mean word duration and reciting and reading had almost same mean word duration. The variation in mean word duration in singing was minimum and it was maximum in reading. Thus it was concluded that the word duration almost doubles in singing when compared to reading or reciting condition.

The mean difference in mean word duration of all the five female subjects was compared between - reading and reciting; reciting and singing; singing and reading conditions using Mann-Whitney U test.

In female group, the mean difference in mean word duration between,

TABLE-4.7

Subjects	Reading		Reciting		Singing	
	Total word duration	Mean Wd, durn	Total word duration	Mean Word duration	Total word duration	Mean Word duration
1.	798	88.67	759	84.33	1836	204
2.	749	83.22	724	80.44	1867	207.44
3.	692	76.89	623	80.33	1883	209.22
4.	816	90.67	832	92.44	1820	202.22
5.	814	90.45	813	90.33	1805	200.56
Mean	773.8	85.98	770.2	85.57	1842.2	204.69
SD	53.12	5.9	50.35	5.59	32.38	3.6

Table 4.7: The total word duration and mean word duration (in centi seconds) for each female subject in Reading, Reciting and Singing Conditions.

a) Reading and reciting conditions was not statistically significant, hence the auxilary hypothesis stating that "there is no significant difference between reading and reciting conditions in female group, when then mean word duration is compared" was accepted.

b) Reciting and singing conditions was statistically significant, hence the auxilary hypothesis stating that "there is no significant difference between reciting and singing conditions, in female group, when the mean word duration is compared" was rejected.

c) Reading and singing conditions was statistically significant, hence the auxilary hypothesis stating that "there is no significant difference between resding and singing conditions in female group, when the mean word duration is compared" was rejected.

These resutls further confirm the earlier findings regarding vowel duration in case of females i.e., the words were also prolonged in singing when compared with reading and reciting.

The range of mean word duration of male group ranged from,

i) 78.22 c.secs. to 95.56 c.secs in reading.

ii) 85 c.secs. to 99.78 c.secs. in reciting.

iii) 188 c.secs. to 196.78 c.secs. in singing, condition.

Table 4.8

Subjects	Reading		Reciting		Singing	
	Total word duration	Mean Word duration	Total word duration	Mean Word duration	Total word duration	Mean Word duration
6.	816	95.56	887	98.56	1692	188
7.	788	87.56	898	99.78	1771	196.78
8.	704	78.22	765	85	1755	195
9.	724	80.45	769	85.34	1681	186.78
10.	739	82.11	796	88.44	1702	189.11
Mean	763	84.78	887	91.42	1720.2	191.13
SD	63.47	6.94	887	7.21	40.17	4.46

Table 4.8: The total word duration and mean word duration (in Centi Seconds) of each male subject in Reading, Reciting and Singing conditions.

The above table indicates that the mean word duration was highest in staging and it was lowest in reading. Whereas the variation of mean word duration was minimum in singing and maximum in recitation.

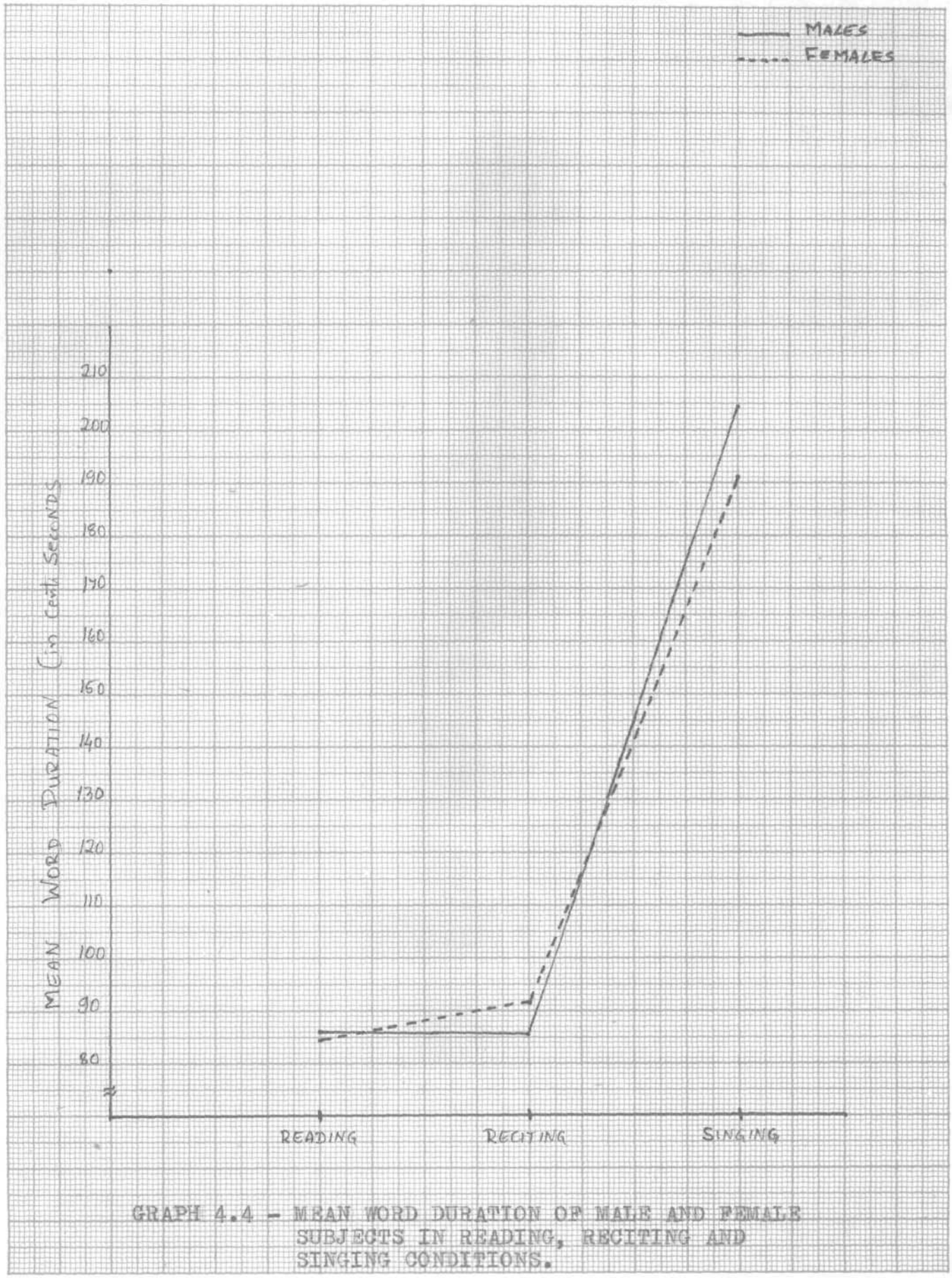
The mean difference in mean word duration of all the male subjects was compared between reading-reciting and reciting-singing and singing-reading conditions using Mann-Whitney U test.

In the male group, themean difference in mean word duration between,

i) Reading and reciting conditions was statistically insignificant, hence the auxilary hypothesis stating that "there is no significant difference between reading and reciting conditions in male group, when the mean word duration is compared" was accepted.

ii) Reciting and singing conditions was significant statistically, therefore the auxilary hypothesis stating that "there is no significant difference between reciting and singing conditions, in male group, when the mean word duration is compared" was rejected.

iii) Reading and singing conditions was significant statistically, hence the auxilary hypothesis stating that "there is no significant difference between reading and singing conditions, in male group, when the mean word duration is compared" was rejected.



GRAPH 4.4 - MEAN WORD DURATION OF MALE AND FEMALE SUBJECTS IN READING, RECITING AND SINGING CONDITIONS.

Similar to female group, male group also had revealed a similar trend i.e., the word were prolonged in singing thus confirming the prolongation of vowels in singing. Thus it was concluded the vowels were prolonged in singin when compared to reading and reciting both in case of females and males. Further it was also observed that all the subjects, both males and females had taken more time to complete the stranza in terms of sining than in either reading or reciting.

The 't' test was applied to compare the mean differe-nces in mean word duration between male and female subjec in reading, reciting and singing conditions.

The mean difference of mean word duration between male and female groups,

a) in reading was 1.2 c.secs. and this was statistically insignificant at 0.05 level (t=0.29), hence the auxi-lary hypothesis "there is no significant difference between male and female group in reading condition when the mean word duration is compared" was accepted.
b) in reciting it was 5.85 c.secs. and this mean difference was statistically not significant at 0.05 level (t=l.43). Therefore the auxilary hypothesis stating that "there is no significant difference between male and female group in reciting condition when the mean word duration is compared" was accepted.

c) in singing it was 13.56 c.secs. and this mean difference was statistically significant at 0.01 level (t=5.30), hence the hypothesis stating that "there is no significant difference between male and female group in singing when the mean word duration is compared" was rejected.

It is surprising to note that there was a statistically significant difference between sales and females interms of word duration in singing eventhough there is no such durational differences were found in reading and recitation.

Thus the overall findings indicate a significant difference between reading and singing and recitating and singing, only interms of vowel duration and word duration. A similar trend is seen in case of females also. Therefore it was concluded that in singing the vowels were prolonged both by males and females and this was found to be the main factor which differentiates reading and reciting from singing. However it was also noticed that there was an increase in the fundamental frequency in singing, both in case of females and males, when compared to reading and reciting, which was not statistically significant. Similarly the range of fundamental frequency used in singing was greater than in reading and reciting both in case of males and females. However this was not statistically significant.

In summary, it was concluded that all the parameters studied i.e., fundamental frequency, range of fundamental frequency, vowel duration and word duration show an increase in singing than in other two conditions. Thus these acoustical and durational factors play an important role in differentiating between singing and other forms of speech and this further warrants studies to seek more details in these aspects.

Thus this study shows thetrends in changes in the acoustical parameters in singing.

This study has also provided the methodology that can be used for further investigations of acoustical parameters like the vowel spectra, he rhythm patterns and other factors.

CHAPTER - V

SUMMARY AND CONCLUSION

The present study was undertaken to investigate the acoustic parameters of voice in singing.

This was done by measuring and comparing the following voice parameters in reading, reciting and singing conditions-

1.Fundamental Frequency.

2.Range of Fundamental Frequency.

3.Vowel Duration.

4.Word Duration.

Ten trained singers in classical music, 5 females and 5 males, with minimum training of 5 years were taken as subjects. The recording material was one of the popular kannada poem which could be easily used for singing. The first stranza of this poem was selected forthe acoustic analysis.

The subjects were instructed to read the poem first, then to recite and later to sing in a particular tune, after practicing it. The model was provided to the subjects earlier.

The above three performances were recorded using a high speed spool tape recorder, in a a sound treated room.

The sample was fed to PZ-100 and the mean fundamental frequency, range of fundamental frequency and the mean word duration were measured.

The duration of the vowels /a/, /i/, /u/ were obtained using the High Resolution Signal analyzer (B & K).

The collected data was analysed statistically. The 't' test and Mann-Whitney U test were used to knew the significance of mean difference of the above mentioned voice parameters in reading, reciting and singing condition.

Conclusions:

The following conclusions were drawn from the present study.

1. In female group, when the mean fandamental frequency was compered, there was no difference between,
   i) Heading and reciting conditions.
   ii) Reciting and singing conditions.
   iii) Singing and reading conditions.
2. In male group, when the mean fundamental frequency was compared, there was no difference between,
   a) Reading and reciting conditions.
   b) Reciting and singing conditions.
   c) Singing and reading conditions.
3. There was difference between male and female subjects in reading condition when fundamental frequency was compared.
4. There was difference between male and female group in reciting condition when fundamental frequency was compared.

5. There was no difference between male and female subjects in singing condition, when fundamental frequency was compared.
6. There was no difference, in female group, when the range fundamental frequency was compared between,
   i) Reading and reciting conditions.
   ii) Reciting and singing conditions and
   iii) Singing and reading.
7. In male group, when the range of fundamental frequency was compared, there was no difference between,
   i) Reading and reciting conditions.
   ii) Reciting and singing conditions and
   iii) Singing and reading conditions.
8. There was no difference between male and female group, in reading condition, increasing condition and in singing condition, when the range of fundamental frequency was compared.
9. There was no difference between reading and reciting conditions, in female group when the duration of vowels /a/, /i/, /u/ was compared.
10. In female group, when the duration of vowels /a/, /i/ /u/ was compared between reciting and singing condition significant difference was observed.
11. There was difference between singing and reading conditions, in female group, interms of duration of vowels /a/, /i/, /u/.

12. There was no difference between male and female groups in reading condition, in reciting condition and in singing condition when the vowel durations of /a/,/i/, /u/ was compared.
13. There was no difference between reading and reciting conditions, in female group, when the mean word duration was compared.
14. In female group, when the mean word duration was compared, there was difference between,
    i) Reciting and Singing condition and
    ii) Singing and reading conditions.
15. In male group, there was no difference between reading and reciting conditions when the mean word durations was compared.
16. When the mean word duration was compared in male group, there was difference between,
    a) Reciting and singing conditions and
    b) Singing and reading conditions.
17. There was no difference between male and female group in reading and in reciting condition when the mean word duration was compared.
18. There is difference between male and female group in singing condition when the mean word duration was compared.

Thus, this study shows the trend in changes in the acoustical parameters in singing.

Implication:

This study provides information regarding,

a) the changes in fundamental frequency, range of fundamental frequency, vowel duration and word duration with respect to reading, reciting and singing conditions in both males and females respectively.
b) the differences in the above parameters between males and females in all the three conditions.

Limitation:

1. Sample was small.
2. The acoustic parameters considered in this study were,
   - Fundamental Frequency.
   - Range of fundemental frequency.
   - Vowel duration.
   - Word duration.

Recommendations:

1. The study should be carried on large scale.
2. Further investigations of acoustical parameters like vowel spectra, the rhythm pattern and other factors in singing should be carried out.

BIBLIOGRAPHY

Anderson, V.A., "Training the speaking voice", Oxford University Press, N.Y., 1942.

Balasubramanian, T., "Duration of Vowels in Tamil" J. Phonectics, 9, 1981, (151 - 161).

Barnwell, (1971) cited in Klatt, D.H., "Linguistic uses of Segmental duration in English; Acoustic and perceptual evidence". JASA., 59, 1976, (1208 - 1221).

Bloothooft, G., & Plomp, R. "Spectral analysis of sung vowels: I- variation due to differences between vowels singers, and modes of singing. JASA., 75, 1984, (1259-1264).

Boomer & Dittman, (1962) cited in Crystal, T.H. & House, A.S. segmental durations in connected speech signals: Prelimanary results. JASA., 72(3), 1982, (705-716).

Boone, D., "The voice and voice therapy". second edition., Prentice Hall, Inc., Englewood Cliffs, N.J. 1977.

Bosma J.F. Anatomic and physiologic development of the speech apparatus in nervous system. In Tower,D., (Ed) Human communication and its Disorders. Vol. 3, Raven Press, N.Y., 1975.

Bunch, M.A., "Dynamics of singing voice" Springer, N.Y., 1982.

Bunch M.A., & Sonninen, A. "A survey of research on covered and open voice qualities"., NATSB*, .Oct.,1977, (216-330).

Butenschn & Borchgrevink: Voice and Song, 1982.

Cleveland, T.F., "Acoustic properties of voice timber types and their influence on voice classification", JASA., 61, 1977, (1622 - 1629).

Coker et al (1973) cited in Klatt, D.H., "Linguistic cues of segmental duration in English; Acoustic and perceptual evidence". JASA., 59, 1976, (1208-1221).

Coleman, R.O., "A comparison of the contributions of two voice quality characteristics to the perception of maleness and femaleness in the voice". JSHR., 19, 1976, (168-180).

Collins M., Rosenbek, J.C., & Wertz, R.T., "Spectrographic analysis of vowel and word duration in apraxia of speech". JSHR., 26, 1983, (224-230).

Cooper, (1975) cited in Klatt, D.H., "Linguistic cues of segmental duration in English". JASA., Vol. 59, No. 5, 1976.

Cowan, (1936) cited in Hudson, A., & Holbrook, A., "Astudy of reading fundamental vocal frequency of young black adults. JSHR., 24(2), 1981, (197-202).

Critchtey, M., (1975) Langage in E.H. Lenneberg & E, Lenneberg (Eds.,) Foundations of Language devolopment., Vol. one, N.Y., : Academic press, 1975.

Crystal and House, "Segmental durations in connected speech signals: preliminary results". JASA., 72(3), 1982, (705-716).

(Curry, T., "The pitch characteristics of the adolecent male voices"., Speech Monograph, 7, 1940, (48-62).

Datta, Ganguli & Dutta Majumder, "Speech and Music-A Review on quantitative studies." J.A.S.I., 9(4) 1983, (56-69).

Disimoni, F.G. "Effect of vowel environment on the duration of consonants in the speech of 3-6 & 9 years old children". JASA., Vol. 55, No.2, 1974, (362-363).

Disimoni, F., "Evidence for a theory of speech production based on observations of the speech of children". JASA., 56, 1974, (1919-1921).

Dmitriev, L. & Kiselev, A. "Relationship between the formant structure of different types of singing voices and the dimensions of supraseglottic cavities". Folia Phoniat, 31, (1979), (238-241).

Duffy, R. "The vocal pitch characteristics of 11, 13, & 15 year old female speakers". Doctoral Dissertation, State university of Iowa, 1958.

Fairbanks, G. "Voice and Articulation Drill Book". Harper and Row, N.Y., 1940.

Fairbanks & Pronovast (1939) cited in Hudson, A. & Holbrook, A. "A study of reading fundamental vocal frequency of young black adults". JSHR., 24(2), 1981, (197-202).

Fitch & Holbrook, (1970) cited in Hudson, A.I. & Holbrook, A., "A study of the reading fundamental vocal frequency of young black adults"., JSHR., 84, 1981, (197-201).

Fonagy, Fonsgy, J. & Dupuy, P. "Duration as a function of sound pressure level". J. phonetics, 8, 1980, (375-378).

Freeman, F.J. Prosody in perception production, and pathologies, Chap, 26, in speech language and Hearing, Vol. II, Lass, N.J., (Ed) W.B. Saunders company 1982.

Gaitenby,(1965) cited in Klatt, D.H. "Linguistic uses of segmental duration in English:Accoustic and perceptual evidence". JASA., Vol. 59, No. 5, 1976, (1208-1221).

Goldman - Eisler, (1968) cited in Crystal, T.H., and House, A.S., "Segmental durations in connected speech signals: Preliminary results". JASA., 72(3), 1982, (705-716).

Goldman - Eisler, (1961) cited in Klatt, D.H., "Linguistic cues of segmental duration in English: Acoustic and perceptual evidence". JASA., 59(5), 1976, (1208-1221).

Gopal, H,S., "Relationship for locating optimus frequency in the age range of 7 to 25 years. unpublished Master's Dessertation University of Mysore, 1980.

Greene "The voice and its disorders" Pittman medical publishing company, III Edition, London. (1972).

Greene, M. "The voice and its disorders", Pittman medical publishing company, 2 London, 1964.

Grosjean & Deschampe, (1975) cited in Crystal, T.H. and House, A.S., segmental durations in connected speech signals: preliminary results. JASA., 72(3), 1982, (705-716).

Gupta, J.P., "Acoustic factors in musical phonation". A study in off-pitch phenomenon. An unpublished Masters Dessartation, University of Mysore, 1984.

Haggard, (1973) cited in Kkatt. D.H., "Linguistic cues of segmental duration in English. Acoustic and Perceptual evidance". JASA., 59(5), 1976, (1208-1221).

Han, (1966) cited in Crystal, T.H., & House, A.S., segmental durations in connected speech signals: Preliminary results. JASA., 72(3), 1982, (705-716).

Hanley, (1951) cited in Hudson, A. & Holbrook, A., "Study of reading fundamental vocal frequency of young black adults". JSHR., 24(2), 1981, (197-202).

Harris & Umeda, (1974) cited in Crystal, T.H., & House, A.S. segmental durations in connected speech signals: Preliminary results. JASA., 72(3), 1982, (705-716).

Harris, M.S. & Umeda, N. "Effects of speaking mode on Temporal Factors in speech". JASA., 56, 1974, (1016-1018).

Hirano, M. "Clinical Examination of voice". Springer-Verlag Wien, N.Y., 1981.

Hollien etal. Experimental data on "Singer's Formant"s JASA., 64, 1978, (171).

Hollien & Jackson

Hollien & Paul (1969) cited in Hudson, A. & Holbrook, A. "A study of reading fundamental vocal frequency of young black adults". JSHR ., 24(2), 1981, (197-202).

Hollien, H. & Shipp, T. "Speaking fundamental frequency and chronologic age in males". JSHR., 15(1), 1972, (155-159).

Homma, Y. "Durational relationship between Japanese stops and vowels". J. Phonetics, 9, 1981, 273-281.

House, (1961) cited in Wardrip-Fruin, C. "On the status of temperal cues to phonetic categories: preceding vowel duration as a cue to voicing in fundamental stop consonants". JASA., 71(1), 1982, (187-195).

House & Fairbanks, (1953) cited in Klatt, D.H. "Linguistic cues of segmental duration is English: Acoustic and perceptual evidence". JASA., 59(5), 1976, (1208-1221).

Hudson, A.I. & Holbrook, A. "A study of the reading fundamental vocal frequency of young black adults". JSHR., 24(2), 1981, (197-201).

Huggeins, (1964) cited in Klatt, D.H., "Linguzistic cues of segmental durations in English: Acoustic and perceptual evidenc". JASA., 59(5), 1976, (1208-1221).

Judson, L.S. & Heaver, A.T.. "Voice Science" II Edition Appleton-century crofts, N.Y., 1965.

Kent, R.D., Motor skill components of speech development, presented at the 1980 Annual concention of the American speech-language-Hearing Association, November 21-24, Detroit, Michigan, 1980.

Kent, R.D. & Forner, L.L. "Speech segment durations in sentence recitations by children and adults" J. Phonetics 8, 1980, (157-168).

Klatt, D.H. "Linguistic cues of segmental duration in English; Acoustic and perceptual evidence". JASA., 59(5), 1976, (1208-1221).

Klatt, D.H. "Linguistic cues of segmental durations in English: Acoustic and perceptual evidence". JASA., 59(5), 1976, (1208-1221).

Klatt, D.H. "Interaction between two factors that influence vowel duration". JASA., 54(4), 1973, (1102-1104).

Klatt, (1971), cited in Klatt, D.H. "Linguistic of segmental durations in English: Acoustic and perceptual evidence". JASA., 59(5), 1976, (1208-1221).

Klein "Singing Technique" Princeton, New Jersey, Toronto, London.

Kushal Raj, P. "Acoustic analysis of speech of children". An unpublished Master's Dessertation, University of Mysore, 1983.

Large, J. "Acoustic study of register equalization in singing". FP. 25, 1973, (39-61).

Large, J. & Iwata, S. "Aerodynamic study of vibrato and voluntary "Straight tone" pairs in singing"., Fp., 23, 1971, (50:65).

Lass &Deem, (1972) cited in Crystal, T.H. & House, A.S., Segmental duration in connected speech signals; Preliminary resutls. JASA., 72(3), 1982, (705-716).

Lehiste, (1970) cited in Crystal, T.H. & House, A.S., "Segmental durations in connected speech signals: Preliminary results". JASA., 72(3), 1982, 705-716.

Lehiste, (1976), cited in Klett, D.H. "Linguistic cues of segmental duration in English:- Acoustic and perceptual evidence." J.A.S.A. 59(5), 1976, (1208-1221).

Lehiste,(1975), cited in Klatt, D.H. "Linguistic cues of . segmental duration in English:- Acoustic and perceptual evidence." J.A.S.A., 59(5), 1976, (1208-1221).

Lehiste,(1972) cited in Klatt, D.H. Linguistic cues of segmental duration in English; Acoustic and perceptual evidence. JASA., 59(5), 1976, (1208-1221).

Lindblom,(1975) cited in Crystal, T.H. & House, A.S. "Segmental durationsin connected speech signals: Preliminary results". JASA., 72(3), 1982, 705-716.

Lindblom & Repp (1973) cited in Xlatt, D.H. Linguistic cues of segmental duration in English: Acoustic and Perceptual evidance". JASA., Vol. 59, No, 5, 1976, (1203-1221).

Luchsinger, R. & Arnold, G.E. Voice-Speech-Language, Wadworth, California, 1965.

Lyberg, B. "Some observations on the vowel duration and the fundamental frequency contour in swedish utterences". J. Phonetics, 9, 1981, (261-272).

Martin, (1970) cited in Klatt, D.H. "Liinguistic cues of segmental duration in English: Acoustic and percep-tual evidence". JASA., 59(5), 1976, 1208-1221.

Michel, J.F., Hollien, H. & Moore, P. "Speaking fundamental frequency characteristics of 15, 16 & 17 year old girls". Language speech, 9, 1965, (46-51).

Moses, P.J. "The voice of Neurosis" Grune & Stratton Inc. printed in U.S.A., (G.B.).

Mysak, E.D. "Pitch and duration characteristics of older sales". JSHR. Vol. 2, 1959, (46-54).

Nadoleizny, (1923) cited in Bunch, M. "dynamics of the singing voice". Springer-Verlag Wien, N.Y., 1982.

Nataraja, N.P. & Jagadeesh "Vowel duration and fundamental frequency" paper presented at the ISHA conference, 1984.

Nataraja, N.P. & Jayaram, M. "a new approach to the classification of voice disorders". J. All India Institute of Speech and Hear. 12, 1982, (21-28).

Noote Boom, S.G. "The phonetic feature of vowel length in dutch". Language speech, 15(4), 1972, 301-306.

Ohala, J. Aspects of the control and production of speech. VCLA., working papers phonetics, 15, 1970, (1-192).

Oller, (1973) cited Klatt, D.H. "Linguistic cues of segmental duration in English: Acoustic and perceptual evidence". JASA., 59(5),1976, (1208-1221).

| O'shanghnessy, D. "Study of French vowel and consonant durations". J. Phonetics, 9, 1981, 385-406.

Paramenter & Trevin, (1936) cited in Klatt, D.H. "Linguistic cues of segmental duration in English: Acoustic and perceptual evidence". JASA., 59(5), 1976, 1208-1221.

Perkin, S.W.H. vocal function: Assessment and therapy in Travis, L.E. (2 ed) Hand Book of Speech pathology & Audiology. Prentice-Hall, N.J., 1971.

Peterson & Lehiste, (1960) cited in Shoup, J.E., Lass, N.J. and Kuehn, D.P. "Acoustics of speech" in Lass N.J. etal, (Eds). Speech, Lang. & Hearing, Vol. I W.B. Saunders company, Philadelphia, 1982.

Plomp, r. Pitch of complex tone. JASA., 41, 1967, (1526-1533).

Proctor, D.F. "Breathing, Speech and song". Springer-Verlag Wien, New York, 1980.

Rajapurchit, B.B. "Acoustic characteristics of Kannada". CIIL., Mysore, 1982.

Suderberg, J. "The Acoustics of singing voice". Scientific American, Vol. 236, (3), 1977, (82-91).

Suderberg, J. Articulatory interpretation of the "Singing formant". JASA., Vol. 55, No. (4), 1974, (838-843).

Suderberg, J. Formant structure and articulation of spoken and sung vowels. FP. 22, 1970, (28-48).

Usha, A.A. "A study of fundamental frequency in an Indian population, unpublished Master's Dissertation, Mysore, 1978.

Vandenberg, J. Register problem. 155, 1968, (129-139).

Vandenbe rg Mysoelastic- aerodynamic theory of voice production. l. 1958, (227-244).

Vennard, W. "Singing the mechanism and technique 1962". Edward Brotehrs Inc. Ann. Arbor, Wichigraz, 1962.

Van Riper and Irwin "Voice and Articulation Pittman Medical publishing company limited, London, 1958.

Walsh, T. & Parker, F. "Vowel length and 'voicing' in a following consonant". J. Phonetics, 9, 1981, 305-308.

Wardrip-Fruin, C. "on the status of temporal cues to phonetic categories: preceding vowel durations a cue to voicing in final stop consonants". JASA., 71(1), 1982, 187-195.

Williams & Stevens, (1972) cited in Hudson, A. & Holbrook,A. "A study of reading fundamental vocal frequensy of young black adults". JSHR., 24(2), 1981, (197-202).

Williams & Stevens, (1972) Cited in Klatt, D.H. "Linguistic cues of segmental duration in English: Acoustic and perceptual evidence". JASA., 59(5), 1976, (1208-1221).

Winckel, F. Music, Sound and Sensation - A modern Exposition. Dover Pub. N.Y. , 1967.

Zimmerman, (1867) cited in Bosma, J.F. Anatomic and physiologic development of the speech apparatus in nervous system. In Tower, D.(Ed) Human communication and its disorders, Vol. 3. Ravan press, N.Y., 1975.

Zinkin Mechanism of speech Mouton and Co, Hague, Netherlands, 1968.

APPENDIX

1. Definition of Terms
2. Settings and description of the instruments used in this study.
3. Photographs of the instrumetns used in this study.

Appendix I

Definition of Terms:

1. Fundamental Frequency:

The mean frequency of the speech stimulus displayed.

2. Frequency Range in Speech:

The difference between the highest and the lowest frequency for the speech stimuli.

3. Vowel Duration:

The duration from the beginning of the vowel to the beginning of the following stop as shown by the High Resolution Signal Analyzer. It is measured in mili seconds.

4. Word Duration:

The duration from the beginning of the word to the end of the word. It is measured in centi seconds.

Appencix II

Pitch Analyzer PM - 100

The Pitch Analyzer is a microprocessor controlled device which has been designed for use in a wide range of speech and language applications.

Various pitch and intensity traces, as well as, the digital data are displayed on a TV monitor. The frequency and/or intensity carves say be transfered to output printing devices in an analog or digital form either on a Mingograph or an X-Y plotter.

The operating range of the instrument is from 70-1000 Hz.

In this unit is a level of 47 dB is equal to the agdiotelephony standard of 0 dB. This, inturn, is approximately an audiometer level of 130 dB.

The sample duration ranges from 1 to 9 seconds.

Allows entry of data into the upper or lower half of the screen, and is provided with two cursors - an upper and a lower cursor, which may be moved independently.

High Resolution Signal Analyzer Type 2033.

The High Resolution Signal Analyzer (B & K 2033) consists of a combined transient recorder and Fourier analyzer. The transient recorder has a 10 K sample memory (1K = 1024) and is equipped with an extremely

flexible trigger allowing the 2033 to analyze both continuous and transient data. The transient recorder combines with the Fourier Analyzer to give the 2033 two modes of operation - base band mode and High Resolution mode.

It has a large 11" screen for display of time function, instantaneous or averaged spectrum, ratio* of spectra, or spectrum comparison.

Frequency Range: 11 base band full scale frequencies from 10 Hz to 20 KHz in 1-2-5 sequence.

Dynamic Range: Full displaced spectrum dynamic range greater than 70 dB.

Triggering: Internal and external triggered operation with flexible pre- and post trigger time delay (from 0.0 to 64 K samples).

Averaging: Linear, exponential or store max. averaging over 1-2048 spectra with automatic elimination of overloaded input data.

Scan Analysis and Scan Average: Unique scan analysis for speed up/slow down of events. Scan average producing a 400 line averaged spectrum of hole of 10 K time function. Invaluable to analyse long transient and nonstationary signals.

Wude angle zoom: Built-in non-destructive zoom with possibility of measuring a 4000 line spectrum (wide angle

zoom). The zoom transformation takes only about a second.

Storage: Protected memory for storage of displayed spectra or spectra entered digitally.

Spectrum Comparison: Slow and fast alternate display of input and stored spectra.

Cursor: Versatile cursor function for indication of time or frequency and level of selected line.

Appendix 3.1 : Pitch Analyzer - P-M. 100

Appendix 3.2 : High Resolution Signal Analyzer- B & K.2033