VARIABLES AFFECTING SPEAKING FUNDAMENTAL FREQUENCY

Rohima (B)

REG. NO. M9616

A DISSERTA TION SUBMITTED AS PART FULFILMENT OF FINAL YEAR M.Sc. (SPEECH AND HEARING) TO THE UNIVERSITY OF MYSORE

ALL INDIA INSTITUTE OF SPEECH AND HEARING
MYSORE - 570 006

MAY 1998

CERTIFICATE

This is to certify that the dissertation entitled, **"VARIABLES** AFFECTING SPEAKING FUNDAMENTAL FREQUENCY" *is the bonafide work in part fulfillment for the degree of Master of Science (Speech of Hearing), of the student with* ***Register No. M9616.***

Mysore
May 1998

Dr. S.NIKAM
Director
All India Institute of Speech and Hearing
Manasagangothri
Mysore - 570 006
INDIA

CERTIFICATE

This is to certify that this disseration entitled "VARIABLES AFFECTING SPEAKING FUNDAMENTAL FREQUENCY", *has been prepared under my supervision and guidance.*

Mysore
May 1998

Dr. N.P. Nataraja,
Professor and Head
Department of Speech Sciences
All India Institute of Speech and Hearing
Manasagangothri
Mysore 570 006.
INDIA

DECLARATION

This dissertation entitled "VARIABLES AFFECTING SPEAKING **FUNDAMENTAL FREQUENCY",** *is the result of my own study under the guidance of* **Dr. N.P. Nataraja,** *Professor and Head, Department of Speech Sciences, All India Institute of Speech of Hearing, Mysore, and has not been submitted earlier at any University for any other Diploma or Degree.*

Mysore
May, 1998

Reg. No. 9616

ACKNOWLEDGMENT

I would express my gratitude to my guide **Dr. N. P. NATARAJA**, Professor & Head, Department of Speech Sciences, All India Institute of Speech & Hearing, Mysore for his invaluable guidances and help.

I thank **Dr.S.NIKAM,** Director, All India Institute of Speech & Hearing, Mysore for giving me permission to carry out this study.

I thank **Mrs. SREEDEVI** and **Miss LALITHA,** Department of Speech Sciences, for their constant help throughout the study.

I thank all my SUBJECTS for their whole-hearted co-operation.

I thank my **FAMILY,** the invincible force behind all my achievements.

I thank **MARUTHI COMPUTERS,** for their efficient work.

CONTENTS

LIST OF TABLES

INTRODUCTION

"THE SOUNDS OF THE VOICE . . . . . BRING LANGUAGE, SETS THOUGHTS ASTIR, AND KEEPS US IN THE INTELLECTUAL COMPANY OF MAN"

- HELAN KELLER

The faculty of language which forms the basis of communication by speech is known to be specific to humans. This biological innovation is however superimposed on the primitive system of vocal communication of same kind as is used by various other species. Natural speech signals inevitably carry some paralinguistic and extra linguistic information in addition to their linguistic content.

The acoustic properties of speech depends on physical properties of speaker's speech organs such as vocal fold mass and vocal tract length. The acoustic reflections of these variables, which are informative about age and sex of the speaker cannot be removed from speech signal. It is not possible to produce speech without any personal quality (Traunmiller, 1994).

Voice is the vehicle of speech. It is the sound produced by the vibrations of the vocal cords in the larynx by air from the lungs. The importance of voice in speech is very well depicted when one considers the cases of voice disorders. "Voice plays the musical accompaniment to speech rendering it tuneful, pleasing, audible and coherent

essentials insentials to efficient communication by the spoken word (Greene, 1964).

Various studies have demonstrated that pitch of voice carries emotional and attitudal information (Fairbanks, 1940; Uldall, 1960; Lieberman and Michaels, 1962; Scherver, 1979) and as a part of the more general feature of voice quality, serve as a social and regional marker (Trudgill, 1974).

Researchers have shown that fundamental frequency is dynamic and provides important cues regarding the emotional state, type of speech activity, race, sex and physical maturity of the speakers. It has been shown that different emotional states produce distinctive difference in fundamental frequencies (William and Stevens, 1972), Mean F0 is higher for reading than speaking (Hollien and Jackson, 1973), black individual have lower mean Fo than white (Hollien and Maluk, 1962), Fo characteristic which differentiate the sex of speaker are noticeable during piberty when the male Fo drops approximately one octave, but ,less noticeable changes in females (Duffy, 1970; Hollien, Shipp, 1972), that the average Fo for males gradually decrease until the 70's but begin to increase of that age (Saxman and Burg, 1967; Duff, 1970), the average Fo for females begin to decrease during the 30's and continue to decrease gradually with age (Saxman & Burk, 1967).

The present student were undertaken to investigate different variables which may affects speaking fundamental frequency and to study their influence on habitual frequency.

For this purpose, 30 normal bilinguals in Kannada and English, 30 normal bilinguals in Hindi and English, 30 dysphonics and 15 smokers (males) participated in the study.

The variables studied were

1) style of speaking
2) language
3) gender
4) laryngeal pathology
5) smoking

Fundamental frequency in speech was obtained for all the subjects in three different style of speaking; Reading, Narration and Interview. Values obtained were subjected to descriptive statistical analysis and test of significance for each variable was obtained. The present study tested the following hypothesis.

Style of Speaking on a variable:

There was no significant difference between:

1) Reading and Narration in normals
2) Reading and Interview in normals
3) Narration and interview in normals
4) Reading and Interview in dysphonics
5) Reading and narration in dysphonics

6) Interview and narration in dysphonics
7) Reading and narration in smokers
8) Reading and Interview in smokers
9) Narration and Interview in smokers.

Language as variable:

There is no significant difference in SFF obtained between

1) Native language in Hindi and Native language in Kannada.
2) Kannada language and English language in native speakers of Kannada.
3) Hindi language and English language in native speakers in Hindi.

Gender as variable:

There was no significant difference between males and females in

1) Reading style
2) Narration style
3) Dysphonics
4) Native speakers of Kannada
5) Native speakers of Hindi.

Laryngeal pathology as a variable:

There is no significant difference between normals and dysphonics

1) In reading style
2) In narration style
3) In Interview style

Smoking as variable

There is no significant difference between smokers and non-smokers in

1) reading style
2) Narration style
3) Interview style

According to Atkinson (1976) the primary acoustic cue Fo itself interacts in an inseperable way with the phonetic features of voicing, carries information conveying speaker's age, sex and emotion.

Many studies have shown that speaking fundamental frequency (SFF) plays an important role in human communication. Graddol and Swann (1983) suggest that there may be atleast three influences which act on individuals and affect SFF behaviour. The first, from the individual's physical and anatomical desposition, the 2nd, from cultural expectations and third influence has to do with rapid fluctuations in SFF connected with intonation.

Atkinson (1976) showed that there is great deal of variability in SFF between different speakers. In addition, there is eventually as much variability in a single speaker.

As yet it not well documented how far informality (Style of 3peaking), redundancy, personal variation, linguistic variation affect the speaking fundamental frequency. It is also noted by Abberton (1979) and Lariviern (1975) that changes in SFF may affect speaker recognition. therefore, such a study becomes necessary to determine significant variables affecting SFF and to what extent.

Limitations:

1) Age range was limited to 18-25 years in normals.
2) Study was restricted to male smokers.
3) Language effect was studied in normals only.

Implications:

1. Study of langauge effect reflects sociolingustic significance of SFF.
2. Comparative study of normals, dysphonics and smokers accounts for talker's variability in voice identification.
3. Study of effect of style of speaking accounts for variability in speech recognition.
4. Lastly, Speaking Fundamental Frequency can be used as powerful diagnostic tool.

REVIEW OF LITERATURE

Speech is the audible manifestation of language. It is a complex motar act brought about by sophisticated and fine movements of the components of vocal tract and their complex interaction with vocal cord vibration. The speech results by the fine organization co-ordination and modulations between the respiratory, phonatory, articulatory and resonatory system.

Voice is the first sign of life. The most primitive use of voice is for survival. Expression of hunger and pain are often vocal especially by infants. It is an indicator of health sickness, emotion and age.

Expression of emotion is highly vocal, six primary emotions - fear, anger, joy, sadness, suprise and disgust are all expressible vocally.

The role of voice in speech is obvious. Voicing (presence of voice) has been found to be a major distinctive features in almost all language. Voicing provides more phonemes and makes the language broader. Majority of phonemes are voiced including all vowels, semivowels and nasals. In addition, voicing carries the rythm and melody of speech. These are the pattern of pitch, loudness and duration that tie together into syllables, phrases and sentences. Vowels are usually elongated in relation to consonants and become the vehicle for artistic expression.

Voice is more than a means of communication of verbal messages clearly. Voice constitutes the matrix of verbal communication in fusing all parameters of human speech and the unique self one presents the world. Voice has both linguistics and non-linguistic function.

Perkins (1971) has identified atleast five non-linguistic information of voice. Voice can reveal speaker identity i.e. voice can give information regarding sex, age, height and weight of the speaker. Lass, Brong, Ciccolella and Walters (1980) reported several studies which have shown that it was possible to identify the speaker's age, sex, socio-economic status, racial feature, height and weight based on voice.

It is a prevailing notion that there is a relationship between voice and personality i.e. voice reflects the personality of the individual (Starkweather 1961; Fairbanks, 1966; Hutter, 1967 and Titze, 1994). Much of the personality is reflected in the voice, esp. in the context of speech. Images of personality, even the outward appearance, can be judged solely on basis of what is heard (Titze, 1994).

Voice have also considered to be reflecting physiological state of an individual. It is a "window" to many functions performed in the body. For eg: a very weak voice may indicate that the individual may not be keeping good health or a denasal voice may indicate that speaker has common cold. Apart from these, it is a well known fact, that voice basically reflects the anatomical and physiological

conditions of the respiration, phonation and resonatory system i.e. any deviation in any of these system may lead to voice disorders. Hoarseness can be an indicator of a viral infection weakness and tremor can be an early sign of a neurological disease (Titze, 1994).

A recently developed aspect in the area of early identification of disorders is infant cry analysis. It has been found by many investigators (Illinworth, 1981; Indira, 1982; and Venugopal, 1995) that it is possible to identify abnormalities in the neonates by analyzing their cry.

Speaker identification by voice, presently is an immense value in computer technology (development of machines that will respond to speaker commands). In the field of forensic medium (identification of speakers by voice detection) and in defence (availability of classified information), voice identification is widely used.

The quality of voice becomes important for certain professionals for eg. radio, T.V. announcers, actors and singers. Thus voice, has an important role in communication through speech and there is a need for studying voice.

The term voice has been differently defined by different people. "The Random House dictionary lists 25 primary and secondary definitions of voice, the first of which is, the sound or sounds uttered through the mouth of the human beings in speaking, shouting, singing, etc.

Some definitions of voice restrict the term to the generation of sound at the level of the larynx, while others include the influence of the vocal tract upon the generated tone and still others broaden the definition by including aspects of speech like articulation and prosody.

Judson and Weaver (1942) define voice as "laryngeal vibration (Phonation) plus resonance". Further they state that phonation is the production of tone by the laryngeal generator.

The formula P = S.T. has been used by Fant (1960) in which speech sound P is the product of the source S and the transfer function of the vocal Tract T.

"While discussing the production of speech, is an acoustic disturbance, superimposed upon the flow of respiratory air and is caused by a quasi periodic modulation of the airflow due to opening and closing movement of vocal folds" (Fant, 1960).

Michael and Wendahl (1971), after reviewing various definitions of voice define voice as "The laryngeal modulation of the pulmonary airstream, which is then further modified by the configuration of the vocal tract".

Though there are varied definitions of voice. It is a difficult task to define normal voice.

An attempt has been made by Nataraja and Jayarama (1975) to review the definitions of normal voice critically. They have concluded that each of the available definitions of voice have used subjective terms, which are neither defined nor measurable. They have suggested the possibility of defining good voice operationally as one which has optimum frequency as its fundamental (habitual) frequency.

It is apparent that a good voice is a distinct asset and a poor voice may be a handicap. If a person's voice is deficient enough in some respect, that it is not a reasonably adequate vehicle for communication, if it is distracting the listener, one can coniser that as a disorder.

In general the following requirement can be set to consider a voice as adequate as stated by Iwata and Von Leden. (1978).

1. The voice must be appropriately loud.
2. Pitch level must be appropriate. The pitch level must be considered in terms of age and sex of the individual. Men and women differ in vocal pitch level.
3. Vocal quality must be reasonably pleasant. This criterion implies the absence of such unpleasant qualities like hoarsenesses, breathiness, harshness and excessive nasality.

4. Flexibility must be adequate. Flexibility involves the use of pitch and loudness inflection. An adequate voice must have sufficient flexibility to express a range of differences in stress, emphasis and meaning. A voice which has good flexibility is expressive. Flexibility of pitch and flexibility of loudness are not easily separable, rather they tend to vary together to a considerably extent.

Wilson (1962) is of the opinion that good voice should have the following characters.

a) Pleasing voice quality
b) Proper balance of oral and nasal resonance
c) appropriate loudness
d) a model frequency level suitable for his age and sex
e) an appropriate voice inflections involving pitch and loudness.

The production of voice, depends on the synchrony, or the coordination between the systems viz. the respiratory phonatory and resonatory. Voice production involves a complex and precise control by the central nervous system of a series of events in the peripheral phonatory organs. The crucial event essential for voice production is the vibration of the vocal folds. It changes DC air stream to AC air stream converting aerodynamic energy into acoustic energy.

There are two main theories of phonation:

1. Myoelastic - aerodynamic theory and
2. Neurochronaxic theory

These two theories of voice production have dominated much of the literature.

"The myoelastic-aerodynamic theory postulates that the vocal folds are subjected to well established aerodynamic principles. The vocal folds are set into vibration by the air stream from the lungs. The frequency of vibration of vocal cords is dependent upon the length, tension and mass of the vocal cords. These factors are regulated primarily by the delicate interplay of the intrinsic laryngeal muscles" (Luchsinger and Arnold, 1965). The myoelastic-aerodynamic theory was first advanced by Muller in 1843 and later modified by Tondorff (1925) and Smith (1954), but its salient features have remained unchanged through the years (Zemlin, 1981).

This theory is inadequate in explaining the important feature of self-sustained oscillations. The mechanism for continual energy transfer from the aistream to the tissue involves more than the Bernoulli's force alone. Further more, this would apply only to case in which the vocal fold collide. It is known that oscillation can occur without collision. (Stevens, 1977; Titze, 1980; 1983; 1988).

The neurochronaxic theory was proposed by Hussan (1950). This states that each new vibratory cycle is initiated by a nerve impulse transmitted from the brain to the vocal folds by way of the recurrent branch of the vagus nerve i.e., the frequency of the vocal fold vibration is dependent upon the rate of impulses delivered to the laryngeal muscles. Various studies have supported and contradicted both the theories. According to Fant (1960) and Titze (1980), the most commonly accepted one is the myoelastic theory.

Both speaking and singing require an outgoing air stream capable of activating vocal fold vibration. Vocal fold vibration (Phonation) first requires fold approximation. The intrinsic adductors of the larynx approximate the folds in the neutral position, where the natural size/mass and elasticity of the folds determine the rate of vibration; the emitted air flow passes through the approximate opening, blowing the folds tends to bring them back to their neutral position; the Bernoulli effect draws the folds even closer together than when they are in their neutral approximation state; the vibratory cycle repeats itself. (Boone, 1983).

"The D.C. flow of air is converted into A.C. sound pulses, as during the production of sound, the vocal cords are in adducted position. In this position, they vibrate alternately, opening and closing the glottis for very short periods. Actually it is the air current from the lungs that separates the vocal cords and open the glottis. But as the

models suggest that vocal fold oscilalation is produced as a result of asymmetric forcing functions over closing and opening portions of the glottal cycle. For nearly uniform tissue displacements, as in falsetto voice, the asymmetry in the driving forces can result from the inertia of the air moving through the glottis. This inertia can in turn be enhanced or suppressed by supraglottal or subglottal vocal tract coupling. More obvious and pronounced asymmetries in the driving forces are associated with non uniform vocal fold tissue displacements. These are combinations of normal tissue modes and can result in vertical and horizontal phase differences along the surfaces, as observed in chest voice. The range of oscillations increase among various models as more freedom in the simulated tissue movement is incorporated. Of particular significance in initiating and maintaining oscillations are the vertical motions that facilitate coupling of aerodynamic energy into the tissues and allow tissue deformations under conditions of incompressibility. Vertical displacements also can have a significant effect on vocal tract excitation. Control of fundamental frequency of oscillation is basically myoelastic, partially as a result of non linear tissue strain over the vibrational cycle. Titze (1980) has stated that "this places limits on the control of fundamental frequency by 3ubglottal pressure and, forces such control to be inseparably connected with vibration and amplitude, or less directly, with vocal intensity".

AERODYNAMIC CORRELATE:

Not only is it necessary to have an air medium for the propogation of sound waves, but also air must be transported enmasse through various constrictions along the respiratory tract for the purpose of generating sound. The subglottal pressure which builds up when the folds above are approximated develops enough force to blow them apart. This air flow force is opposed both by the static force of the muscles and ligament mass itself and by the Bernoulli effect. The Bernoulli effect is the medial displacement of the vocal folds towards one another due to a vacuum produced in the glottal chink by the air stream. While air flow rate has been constant until the flow reaches the constricting glottis, it then increases its velocity, rushing through what is left of the glottal opening. The resulting vaccum attracts the folds together, and is thus partially responsible for completing their vibratory cycle of being blown apart initially by the outgoing air stream, and then returning to medial approximation. (Boone, 1977).

The air flow is important in bringing about vocal fold vibrations. The subglottal pressure, provides an indication of cord closure as well as information about frequency of vibration of the vocal cords.

Hirano (1980) states, while discussing the aerodynamic tests, that "the aerodynamic aspects of phonation is can be studied by using four parameters".

a) Subglottal pressure,

b) subglottal pressure

c) Glottal impedence and

d) Volume velocity of the airflow at the glottis.

The mean air flow rate varies with the frequency and intensity of voice (Isshiki, 1959; Isshiki & Von Leden, 1964; Yanagihara & Koike, 1967).

Isshiki (1959) noted in electrical stimulation experiments on dogs that pitch was accompanied by increasing air flow alone and that pitch elevation was accompanied by increasing subglottic pressure when air flow remained constant. Ladefoged and McKinney (1963) found "fairly good correlation between subglottal pressure and the logarithm of the frequency of vibration of the vocal cords". Timcke et al. (1958), Von Leden 91961) and Van den Berg (1957) have demonstrated the effect of subglottic pressure on pitch i.e., pitch increases with increased in subglottal air pressure.

Rubin (1963). reported a carefully controlled experiment on thirty eight dogs, in which he found that variations in air flow, within physiological limits, did not alter pitch. His results support the findings of Piquet, Decroix, Libersa and Dujardin (1956), Dunker and Schlosshaver (1958) and Fressard and Vallencien 91957), Rubin (1963) did note, however that the complexity of the frequency and the intensity increased with increases in air flow.

Muller (1843), working with human cadaver larynges and models, noted that an increase in vocal intensity without an increase in pitch had to be accompanied by a decrease in tension of the vocal folds. He also suggested that pitch rose in response to increasing air flow.

Kolman, Gordon, Simpson, and Morton (1975) have studied vocal function by breath flow measurements using pneumotachograph respirometry system in both normal and abnormal groups during quiet respiration, and sustained phonation of /i/, /e/ and /a/ at normal, highest and lowest pitches at comfortable sound pressure level. The vibratory pattern of the vocal folds was obtained using a Laryngograph (Fourcin and Abberton, 1971). Many dysphonic subjects had shown abnormalities in their breathing patterns even during quiet respiration, while others were seemed to be quite normal. (Kelman et al. 1975).

The actual relationship between subglottal air pressure and pitch is confusing because of the diversity in approaches. Although rises in pitch may be accompanied by increase in subglottal pressure, increase in subglottal pressure need not always produce rise in pitch.

Pressman and Kelman (1955) state that the actual variation produced in pitch by pressure changes was relatively small. An increase in subglottic pressure with laryngeal tension held constant, produced a negligible (relatively small) rise in pitch. In addition, pitch changes

were mediated primarily through modifications in glottic tension and mass of the vocal cords.

Liskovius (1846) stated that pitch elevated as the glottic chink narrowed and subglottic pressure increased, and with a constant glottal opening, pitch rose in response to increased air pressure alone.

Aerodynamic and glottographic studies of the laryngeal vibratory cycle by Kitzing, Carlborg and Lofqvist (1982) indicated that the subglottal pressure was higher at onset of vibrations for the hard attract compared with the breathy attack. Fundamental frequency at onset of phonation was almost identical in the two conditions, whereas the open quotient was higher for the breathy than the hard attack.

Voice serves different functions which are varied and plays a major role in speech and hence in communication. Therefore voice needs to be constantly monitored and in the event of abnormal functioning of voice, and immediate assessment should undertaken. Any deviation in voice interms of pitch, loudness, draws attention to the voice itself. The evaluation will lead to the diagnosis which not only identified the voice disorder, but al3o as an indicator for the treatment and the management to be followed. Subjective and instrumental assessment results from the baseline upon which the progress can be evaluated.

The major purpose of clinical evaluation of voice are:

1) to diagnose the etiological diseases.
2) to determine the degree and the extend of the disease
3) to evaluate them
4) to determine pregnosis
5) to monitor change

The ultimate aim of studies on normality and abnormality of voice and assessment and diagnosis of the voice disorder is to enforce the procedure which will eventually bring back the voice of an individual to normal or optimum level.

With regard to diagnosis of voice disorder mainly two methods have been used by many clinicians and researchers. The methods are:

I. Psychoacoustical evaluation (Subjective evaluation)
II. Physioacoustical evaluation (Instrumental evaluation).

I Psychoacoustical evaluation (Subjective evaluation)

It is the assessment of voice samples through listening by the clinician and/or judges. It relies on the identification and discrimination capabilities of varying sound complexes by the listner. Well trained voice clinicians are able to determine the pathologies on the basis of psychoacoustical impression of abnormal voices (Takahashi, 1974; Hirano, 1975). Though this, method of evaluation is relatively time saving and inexpensive, but, it is

subjective. Hence, the inter and intra clinician variabilities are more, which may lead to erroneous diagnostic formulations. It is difficult to measure the degree of disorder and prognosis using this methods.

II Physioacoustical evaluation (Instrumental evaluation)

This method of evaluation uses various measuring techniques using instruments and procedures which may be invasive or non invasive, for the measurement of various parameters of voice. It gives an accurate, precise and quantitative account of the voice. In other words, quantitative account of the voice. In other words, quantitative interpretation regarding the mode of vibration of vocal folds can be obtained. It has an added advantage of uniformity in the diagnostic formulation with respect to the different clinicians and clinical settings. But this method of evaluation may be time consuming and is not an economical method.

Hanson, Gerratt and Ward (1983), suggested that majority of phonatory dysfunctions are associated with abnormal and irregular vibrations of the vocal folds. These irregular vibrations leads to the generation of random acoustic energy i.e., noise, fundamental frequency and intensity variations. This random energy and a periodicity of fundamental frequency.

VARIABLES AFFECTING FUNDAMENTAL FREQUENCY AND SPEAKING FUNDAMENTAL FREQUENCY (SFF):

Fundamental frequency is the single most important correlate of perceived pitch. Many studies indicate that phonetic characteristic of SFF (speaking fundamental frequency) may have social significance. Thus there may be many influences which act on individuals and affect SFF behaviour.

Various studies have shown variability in fundamental frequencies and speaking fundamental frequencies with respect to age, gender, style, pathological condition. Their systematic nature, however may derive from one of two quite different causes. The study of socially significant aspects of voice brings to a familiar debate whether such characteristics are socially learned or biologically determined. (Graddol, 1987).

The evidences of various studies suggests that differences in SFF result from an interaction between physical and natural determinants. (Lass and Brown, 1978; Lieberman, 1967; Majenhski et al., 1972; Guntor and Manning, 1982).

Trudgill (1974) suggests that there must be atleast 3 influences which act on individuals and affects SFF behavior. The first arises from the individual's physical and anatomical disposition. The second influence derives from

the cultural expectations and norms associated with the Spenker's position in society. The third influence has to do with the more rapid fluctuations in SFF connected with intonation.

The sense of a pitch of a person's voice comes from two separate aspects of this process. The most important is probably the basic rate of vibration of the vocal fold, which in turn depends on the length and thickness of the vocal folds. The impression of pitch which comes from this vibration is often fused with the perception of another aspect of vocal timbre, the series of resonances known as formants. This reflects the size and length of the vocal cavities. Hence Lieberman (1972) concluded that pitch of an individual voice would reflect their physical sise.

A speaker is able to control the fundamental frequency of his or her voice but, it is argued, only within the limits dictated by such features as the mass and dimensions of the vocal folds. The precise frequency used at any given moment is affected by further variables such as sub-glottic air pressure and the tension in the musculature that controls the larynx.

The fact that physiological constraints of some kind do affect the Fo of the speaking voice has been shown indirectly by a number of research studies. Helfrich (1979) gives a review of the effects of age on SFF. Gedda, Fiori-Ratti and Bruno (1960) have shown that mean pitches of prepubertal

Siamese twins are more similar than those of ordinary (dizygotic) twins.

Few attempts have also been made to establish relationship between larryngeal dimension's and SFF directly. Evidence from studies of speaker height and weight identification, the claim through out is that listeners can identify weight and height for both female and male speakers with better than chance accuracy (Lass and Davis, 1976; Lass, Phillips & Bruchey, 1980; Walter S. and Maxwell, 1980).

A study done be Graddol and Swann (1983) investigated relationship between speaker's height, weight and bodily built and medium speaking fundamental frequency. Results. showed that there was a significant relationship between speaker height and median speaking fundamental frequency, but no relationship was found between speaker weight and Fo.

There are available evidences which does not seem to support the class that speaker's height and weight are associated with pitch level. A careful study was conducted by Gunter and Manning (1982) who investigated listener's ability to estimate speaker height and weight unfiltered, fundamental frequency filtered, first format filtered and second format filtered speech. The results showed that estimates were not made with significant accuracy and considerably variability was found in estimates between listeners and across conditions.

In view of the evidence that a person's voice is an inherited characteristic which reflects directly the vocal anatomy of its owner, it might seem mutually exclusive to argue that voices are socially learned. According to authors like Liebermern (1967), Spendr (1978), Majewski et al (1972) Social argument does not attempt to refute any of this evidence - they simply suggested that the physiological evidence told only part of the story.

There is some evidence that the fundamental frequency and SFF is considerably affected by non-physical factors. Their influences have been observed from very early age. Lieberman (1967) reported that a 10 month old boy would alter the frequency of his babbling according to which parent was interacting with him.

It has been argued that adult speech shows the effects of a long term accommodation and that speakers adopt SFF setting that are appropriate to their social identity than with physical attributes associated with the sex or built of the speaker. A particularly radical position is to suggest that the differences in SFF between the sexes is itself primarily a social and acquired one. Sopender (1978) claims that the break of voice associated with male puberty does not occur in congenitally deaf people. In practice, men seem to be under some kind of social or psychological pressure to make their voices sound as different as possible from women and vice versa. (Greene, 1980).

Other evidence, that voices are in part socially learned comes from studies from different parts of the world which show that voice quality is culturally variable. Moyewski et al. (1972) found the average SFF of a sample of 103 adult polish males was 137.6 in whereas that of a comparable group of American subjects was 118.91. Difference in physical size was eliminated on a contributing factor, since no relationship between height, weight and SFF was found amongst the polish males. There is some further evidence in a study by Loveday (1981) who examined SFF levels used by Japanese and English Speakers, found considerable discrepancy between them. Such differences in average SFF between speakers from different countries suggest that cultural differences have some influence on SFF.

Age effects on fundamental frequency and speaking fundamental frequency:

The change in voice with age have been the subject of interest to speech scientist. Various investigators dating back to 1939 have provided data on various vocal attributes at successive developmental stages from infancy to old age (Fairbanks, 1940; Snidecor, 1943; Hanky, 1949; Mysak, 1950; Gopal, 1980; Indira, 1982; Rashmi, 1985).

The aging trend for males with respect to the mean Fo is one of a progressive lowering of a pitch level from infancy through middle age followed by a progressive raise in the old age (Mysak, 1966).

The voice of a newborn has been found to be around 400 Hz. (Grutzman and Plates, 1905, Indira, 1982) upto puberty there is little difference between the voice of boys and girls. The voice change is prominent at puberty. In an examination of 60 children between the ages 7 and 8 years, Fairbanks (1950), could find pitch breaks in both sexes.

A longitudinal study of children's voice at puberty was done by Loebell and Karger (1976). The result showed a significant descent of fundamental frequency for all subjects during the lapse studied.

Eguchi and Hirsh (1969) states that "It is well known that the fundamental frequency of children and adult females are higher than those of the adult male". They further said that, children have a fundamental frequency of about 300 Hz even up to the age of 8 to 10 years.

A sex difference is apparent by the age of 13 years which marks the beginning of a substantial drop for male voice, the well known adolescent voice change. The decrement from infancy to adult hood among females is somewhat in excess of an octave, whereas males exhibit on overall decrease approaching octaves (Kent, 1976).

Studies on Indian population have shown that in males the lowering in Fo is gradual till the age of 10 years, after which there is marked lowering in the Fo, which is attributable to the changes in the vocal apparatus at

puberty. In case of females, a gradual lowering of Fo is seen (Georgy, 1973; Usha, 1979; Gopal, 1980; Kushalraj, 1983; and Rashmi, 1985).

Gopal (1980) reported a gradual lowering of the Fo as a function of age for /a/ in both males and females. Fo dropped slightly during the first three weeks of life after which it stabalized for a period of about 5 months.

Beginning with the first year, Fo decreased sharply until three years of age, when it showed a more gradual decline, reaching the onset of puberity at 11 or 12 years of age.

Age effects on Fo of males from seven to twenty years was studied by Usha (1978). The results revealed a gradual decrease in mean Fo from age seven to eleven years. After the age of eleven, a sudden decrease in the mean Fo was observed. The mean Fo decrease from 260.1 Hz to 158.9 at the age of 14. After the age of 14, not much difference was seen in the mean Fo upto the age of 20.

Several investigators have studied SFF as a function of age (Michel, Hollien and Morre, 1965; Bohimi and Hecker, 1970; Hollien and Shipp, 1972; and Kushalraj, 1983). These studies indicated that mean SFF reduced with age upto the end of adolescence in both males and females. A marked lowering took place during adolescence in males. In advanced age, mean fundamental frequency become higher in males, while, mean fundamental frequency was slightly reduced in females in

older age (Bohime and Hecker, 1970;) Sorensen and Horii, 1982; and Stoicheff, 1984).

SFF values according to different studies.

	Troughear & Davis (1979)	Mysak (1959)	Horii (1975)	Schultz Coulton (1975)	Gopal (1986)
Males					
Mean F0 (in Hz)	112	113.2	112.5	117	139.7 (16 to 25 years) 149.7 (56 to 65 years)
Mean age (in years)	33	48.2	54	20-55	
Females					
Mean F0 (in Hz)	195.6	196.6	199.8	208	224.5 (16 to 25 years) 237.5 (56 to 65 years)
Mean age (in years)	28	73	Adult	20-55	

The oldest study done by Gutzman and Platau (1905) showed changes in fundamental frequency as function of age. The voice of new born infants had a pitch around 440 Cps. with the continous growth of the larynx the child's voice gradually changed. This voice change was most prominent at the pubertal age.

The mean SFF of males, age ranging from 20 to 89 years, indicated that there was progressive lowering of the SFF from age, 20 to 40 years with rise in level from age 60 years through the eighties (Holliena nd Shipp, 1972).

A study of pitch level in speech in two groups of females between 65 years and 75 years and between 80 and 94 years indicated no significant difference in the pitch level between the two groups. Thus concluding that the speaking pitch pattern of women probably varies little throughout adult life (Bohime and Hecker 1970).

A detailed study shows changes in SFF as function of age in Indian population as reported by Nataraja and Savitri (1990).

Age in Tears	Fo in Males (Hz)	Fo in Females (Hz)
4-7	233	248
7-1	255	238
11-13	247	240
14-15	177	244
16-25	139	224
36-45	147	243
46-55	148	258
56-65	150	255

Before puberty, there was little difference between the voice of boys and girls. With the onset of puberty the change begin. (Broadnitz; 1959).

Following table shows the fundamental frequency reported by various investigators for males of different ages.

Mean maturity level	Fundamental frequency (CPS)
Frainbanks (1942)	
Infants (9 mon)	556.0 (in Hunger Wails)
Seven years	294.0
Eight years	297.0
Samuel (1973)	
Seven years	268.0
Eight years	280.0
Ten years	248.0
Fourteen years	208
Hanley (1940)	
Adult (24.6 years)	118.6
Mysak (1950)	
Middle age (47.9 years)	110.3
Elder group - I (73.3 years)	124.9
Elder group - II (85.0 years)	142.6

Table 2: Comparison of Fundamental frequencies findings of various investigators for females at different ages.

Mean maturity level	Fundamental frequency (CPS)
Fairbanks **(**1949**)**	
Seven years	273.2
Eight years	286.5
Duffy (1958)	
Eleven years	258.0
Thirteen years	237.7
Fifteen years	229.5
Linke (1953)	
Yonhry adulty	199.8
Me. Glone W. Hollien (1963)	
Group A : 72.6 years	196.6
Group B : 85.0 years	199.8

Suresh (1991) studied the voice as function of age in geriatric population. Subjects age ranged from 35 to 85 years. Results showed that in males, Fo in phonation increases with age while in females, a progressive decreases in Fo was seen with age. Variability measure in Fo in phonation showed an increase with age in both males and females. And in males fundamental frequency in speech increases with age as in Fo in phonation. Kushal Raj (1983) studied the SFF as a function of age, in children between 4 and 12 years. He reported that Fo both in case of males and

females decrease with age. Males showing a sudden decrease around 11 years. No significant difference in Fo was found until the age of 11 years.

Several studies were done on hearing impaired individuals showed that they were unable to control their SFF. Meckfessel and Thorton (1964) reported SFF values in post pubescent hearing impaired individuals which were higher than those obtained in normal hearing individuals. However, in post pubescent hearing impaired males, values obtained by Green (1956) were similar to those of normal hearing males. For hearing impaired females, he reported higher values compared to normal females.

Gilbert and campbell (1980) studied the SFF in three groups of hearing impaired individuals, (4 to 6 years, 8 to 10 years, 16 to 25 years) and reported the values to be higher in the hearing impaired groups when compared to values reported in the literature for normally hearing individual of same age and same sex.

Rajanikanth (1986) reported that when compared to normals the hearing impaired, in general showed a higher fundamental frequency. He also noted that there was a significant difference between male and female and between the two age groups studied i.e. 10-15 years and 16-20 years. Sheela (1988) reported that on the whole, the hearing impaired children exhibited higher average FO than that of the normal hearing group.

Variability in Fo is much greater in hearing impaired, than in normal hearing speakers. (Angelocci, et al., 1964). Shukla (1987) reported that on average the speaking fundamental frequency was higher for deaf adult3, than for normal hearing adult3. A majority of the deaf adults had speaking FO values which fell within the normal range. These findings have also been supported by the findings of other studies done by Ermovick (1965) and Gruanewald (1966).

Gender effects:

Many studies have shown that characteristics changes in voice as function of age is different in males and females. Studies have shown that there is little change in fundamental frequency as a function of age in males upto 14 years, after which a sudden decrease in fundamental frequency was observed and very little change was observed in females with increase in age.

Differences in fundamental frequency between male and female voice are commonly recognized with some authors reporting female Fo to be as 1.7 times those of male (Klatt and Klatt, 1990 and Peterson and Barney, 1952). However others have reported female/male differences of as little as 1.45 (Monsen and Engebreston' 74).

The importance of Fo being a dominant cue for the speaker's sex identification was shown by Lass (1976). The results showed that identification scores were better for the

filtered tape. (FO retained) than for whispered tape. This finding supported Coleman's conclusion that " all listeners were basing their judgements of the degree of maleness or femaleness in the voice on the frequency of laryngeal fundamental than the resonance characteristic of the speaker".

Study done by Eklund and Traunmuller (1997) found that mean values obtained for fundamental frequencies for vowels for men was 109.4 Hz and Women was 209.4 Hz. Loveday (1981) examined SFF used by Japanese female and male speakers, found that there was a considerable discrepancy between Japanese Men and Women.

In another study by Bennet (1979) on preadolescent boys and girls between age of six years one month and seven years 10 months, it was found that Fo was significantly related to listeners sex identification. Certain measures of Fo like mean duration, level inflection, rate of change associated with upward shift were significantly related to perceptual measures of sexual identity.

The fundamental frequency of /a/ for Indian population as reported by other investigations are as follows:

Investigations	Fo in Males (in Hz)	Fo in Females (in Hz)
Sheela (1974)	126	217
Jayaram (1975)	123	225
Nataraja & Jagadish (1984)	141	237
Vanaja (1986)	127	234
Mataraj (1986)	119	223
Anitha (1994)	129	240

In a study done by Sreedevi (1989), fundamental frequency and speaking fundamental frequency showed significant difference between males and females. It was noted that fundamental frequency of female subjects were significantly higher than the males. In the same study, the findings on the speaking fundamental frequency showed that the females used much higher frequency. Similar findings have been reported by Nataraja and Jagadeesh (1984), Gopal (1980), and Nataraja (1986).

In a study of the fundamental frequency of voice and natural frequency of vocal tract on Indian population done by Samuel (1973) showed following results. The fundamental frequency changes in males between 9 and 14 years of ages. Further findings showed that the relationship between Fo and natural frequency varied from age to age and between sexes.

i.e., A difference in relationship was seen between children and adult, and between males and females.

An extensive study was under taken to study Fo of voice in an Indian population, by Abraham (1978). The following are the results of the study.

1) Lowering in the Fo with advancing age was observed in both males and females.

2) In males, vocal mutation seemed to start by the age of 11 and a rapid lowering of fundamental frequency seemed to occur at the age of 14.

3) In females, the vocal mutation seemed to start earlier than in males i.e., at least by the age of 9 and is completed by the age of 12.

4) The voice of adult3 and children are different both in males and females in terms of Fo.

5) After 14 years, the voice of males and females are significantly different in terms of fundamental frequency.

Suresh (1991) studied Fo in phonation in geriatric population. He found that mean Fo in phonation between males and females showed that significant difference exists between subjects of all age groups (35 to 85 years) and in all three vowels (/a/, /i/ and /u/). However, in /i/ age group 75-85 years didnot show significant difference between males and females. The study concluded that males in general show an

increase in Fo after 45 years while female show a decrease in Fo. Also variability in Fo in phonation in males, increases with age while in females, does not show much changes with age.

Graddol and Swann (1983) studied the physical and social interpretation of SFF and contrasted the findings obtained in males and females. Their, findings showed sex differences on various aspects. It was seen that men were using 'natural' SFF (i.e., one which reflects the physical size of their laryrges), whereas women were not. Women use more variable intonation patterns than men. They also found that there was correlation between the median SFF and height only in males and not in females. When compared the absolute singing range of men and women with their mean SFF, it was found that men were less variable than women. (Snidecor' 51).

Many studies were done to account the differences between male and female SFF. Important morphological differences between male and female larynx have been described by Kahane (1978) and Hirhno (1983) on human cadavers.

According to Kahane, the anterior - posterior dimension of male cartilage is approximately 20% larger than that of female. When larynx is fully developed, the female vocal folds has membranous length of about 10mm. and male about 16mm. Combining data from Klatt (1976), and Hirano (1984), an inverse relationship between membranous length and mean SFF was derived for males and females.

Schener et al (1988) showed the type of difference observed in EGG waveform of males and females. It was resonable to conclude that females in more triangular shaped with linearly convergent glottis, whreas male vocal fold have more bulging medial surface.

Even in the evidence of many studies showing that Fo is a dominant use for male - female distinction (Lass et al, 1976; Graddol and Swann, 1983; Coleman et al. , 1972). There are studies which have shown the important role played by formants in sex identification.

A comparision of Fo in speaking in males and females was done by Anitha (1994). Comparing phonation of different vowels and sentences, it was found that in normal males Fo of sentence were lower compared to vowels and in females, Fo of sentence was higher compared to the vowels /a/, /i/ and /u/.

Study done by Gopal (1986) was aimed at examining different acoustic parameters as a function of age and sex in adults ranging in age from 16 to 65 years. The comparision of SFF between males and females was done and findings showed that males used lower SFF when compared to female from 16 to 65 years. There was maximum difference of 110.7 Hz. at 46-55 years and minimum difference of 84.8 Hz. at 16—25 age group between males and females. Further an average difference of 129.7 Hz is seen between males and females in terms of SFF. This difference in frequency of vibrations were attributed to

difference in vocal systems and difference in vibratory patterns of vocal cord in males and females.

Similar finding were obtained by Boheme and Hecker (1970), where results showed that in advanced age, the mean SFF became higher in men. Hollien and Shipp (1971) also reported that from 60 years to 80 years SFF increased in males. In females, many studies have reported a gradual change in SFF with increase in age (Bohme and Hecker, 1970; Kelly, 1978).

STYLE EFFECTS:

The Fo contour of an utterance represents the frequency of Quasi-periodic vibration of the vocal fold during voiced portion of speech. Perceptually, this frequency information plays a major role in judgements of pitch like segment and pause duration, Fo is an attribute of the speech wave that can provide useful information about the nature of speaker's internal processing scheme (Maeda, 1976; Sorenson and Cooper'so).

Maeda, 1976, O'shaighnessy, 1976, have studied style effect like oral reading on the SFF. A sailent feature of Fo contour in single clause declarative sentences consist of a general decline in Fo throughout the sentence. Although many local rises in Fo may be superimposed on this falling contour, the presence of Fo declination occurs with considerable regularity in both oral reading and spontaneous

speech. This decline in Fo is generally attributed to a decrease in lung pressure or/and intra oral pressure during the utterance (Maeda, 1976).

The long utterances are generally accompanied by a high Fo at the beginning of the utterance than that produced for short utterances. This was observed in the study done by Sorenson and Cooper (1980), Where they asked the speakers to read pairs of sentences that varied in length but contained the same word at the beginning of the utterance. The results showed that the peak Fo of the 1st key word in the utterance was indeed significantly higher in the long than the short utterances, by average of 13.5 Hz. They suggested that although, this experiment indicated the existence of speech planning for oral reading, there is no assurance that the effect will also hold good for spontaneous speech.

Fo patterns in Hindi speech utterances were studied by Rajendran and Yegnanarayana (1996). The reading style and conversation style were chosen for this study. Fo contour of Hindi sentences that were seen from the typical declarative sentences Fo set up of about 115 Hz from the onset of the periodicity and assumes the maximum Fo level about 170 Hz at the final syllable of the first word. By the end of the final word of the sentence, Fo tapers off to 110 Hz. Fo contours of the utterance is characterized by valleys and peaks which are also called the vocal minima and vocal maxima

respectively. This declination in Hindi is similar to many other languages.

According to O'hman (1968) and Fujisaki (1991) down trend of Fo is controlled by the laryngeal muscles while according to Collier (1975) it is controlled by subglottic pressure.

Study done by Strik and Boves (1995) showed that in all naturally produced utterances laryngeal muscles affect Fo in addition to subglottic pressure. They conclude that down trend can be explained completely by subglottic pressure, however, it is always possible that other unknown factors also may contribute to the down trend of Fo.

Studies done to investigate the different style effects on the SFF are very few. In one of the studies done by David Graddol and Swann (1983), they compared text of 2 stimulus passage. One dialogue passage with lighting passage. The values for the measure of Fo was obtained for both sexes. The findings showed that the differences in mean SFF between the two passages are significant for both men and women. This difference was attributed to a greater variability and upward inflection in dialogue passage when compared to lighting passage.

In the same study, authors correlated height and median SFF for both the passages. It was found that in male subjects' "dialogue" passage, the correlation between median SFF and speaker's height were not significant. Speakers

height however, showed a significant correlation with median SFF "lighting" passage, in case of males.

LANGUAGE EFFECT:

The contour of speech utterances produced by a normal human being is determined by linguistic factors such as phonology, morphology, syntax and semantics. There are studies which have found differences in average speaking fundamental frequency between speakers from different countries, suggesting that cultural differences and language differences have some influence on SFF. Majewski et al (1972) found the average SFF of a sample of 103 adult polish males was 137.6 Hz, whereas SFF of American subjects was 118.0 Hz.

Rajendran and Yegnanarayana (1996), in their study of Fo patterns in Hindi speech utterances, investigated the Fo contour of a sentence spoken in English by a native speaker of Hindi. They also compared the English utterances of native Hindi speaker to the utterance of native English speakers. Findings showed different Fo patterns for Hindi speakers had a valley followed by a peak in first and second syllables for English speakers, peak followed the valley. Authors concluded that if norms for correction for English is that of the native English speaker, then Fo pattern shown by native Hindi speaker is an "error" and this error is due to the reflection of the grammatical system of first language namely Hindi.

FO AND SINGING

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

Comparison of respiration during quiet breathing and singing, had shown that more air is used in singing as compared to queit breathing. Pressure ranges from high negative pressure during inspiration to relatively high positive pressure during inspiration while singing. Further Proctor (1980) had stated that phonation either for speech or singing doesnot demand high degree of pressure but delicacy of use of breathing mechanisms was required.

In singing the vowels are prolonged since they are especially switched to carry melody, it follows that the rhythmical, dynamic and methodic qualities of specially and singing differ only in regard to quantity and quality.

The attributes of voice are pitch, loudness and quality. And knowledge of pitch, its control mechanism - modulation and maintenance is important for a singer.

Zinkin (1968) had stated that fundamental frequency varied depending upon the shape and volume of the resonating tract and is different for different vowels. Alteration of the shape of the vocal tract shift format frequencies and

singer's use this technique to improve resonances and voice quantity.

Vibrato is an essential characteristic of singing voice. The artistic quality of 3inging is frequently judjed by the presence of vibrato in the voice. Winckel (1971) believed that vibrato is due to fluctuating activity in the vocal musculature, Large (1973) suggested that its combined laryngeal and respiratory mechanism with laryngeal factor as having dominant role in the production of vibrato.

Range of pitch used for singing by most singers is two to two and half octave. Luchsinger (1965) studied the voice of a female singer and found the range as four and half octave. Fairbanks (1945) commented that child's singing ranges varied very little in boys and girls over the middle octave at the age of 7 years and at 8 years the voice range in slightly extended.

According to Boone (1971) "related to production of voice pitch range of any individual is voice register". It appears that a particular register characterizes a certain pattern of vocal cord vibration with the vocal cords approximating in a similar way throughout the pitch range. Once the pitch range reaches its maximum limit the folds adjust to new approximation contour, which produce an abrupt change in vocal quality. Van Den Berg (1959) classified and described registers as chest, midvoice and falsetto. From the perceptual view point voice register is confined to the

similar sound of the individual voice at various pitches. Klein (1967) had stated that the lower tones had been called the chest register and the higher tone had been called as upper register or head register.

Moses (1954) considers "register, as that refers to physical acoustic event which results from an energentic change within the muscular co-ordination of the vocal cords. Thus physiologically the maximum range of pitch was determined by the length and shape of the singer's vocal folds, shape of the vocal tract and ability to coordinate muscle for phonation. Sundberg (1979) studied the role of Fl and Fo control in male and female singing. He found that Fo control was affected when Fl was damped out, more so among males than females.

Bloothooft and Plomp (1986) found that irrespective of the mode of singing the sound level of the singers formants remained constant upto Fo = 392 Hz when Fo values crossed 392 Hz, a variation on sound level ranging from 9 to 14 dB was found.

Studies have been conducted to determine the relation between vowels and Fo. Bloothooft and Plomp (1985) found that vowel configuration were similar for male and female singers upto an Fo = 220 Hz. Beyond this spectral variations were observed. They also found that relation between the average sound level of singer formants and Fo to be vowel

dependent. Benolken and Swanson (1990) studied the effect of pitch related change on the perception of sung vowel.

Fugisaki (1981) and Suderburg (1982) found that the Fo changes in music were best explained when they used a logarithmic scale rather than a linear scale was based on physical laws, so they found to adequately represent the dynamic characteristic of Fo.

In a study by Ragini (1989) the fundamental frequency was measured in reading, reciting and singing conditions. The following results showed that mean Fo was found significantly different in all three conditions. It was found that in singing a higher Fo (261.95 Hz) had been used than in other conditions. It was also observed that variability of fundamental frequency in singing (SD 40.53) had been more when compared to other two conditions.

FUNDAMENTAL FREQUENCY AND SPEECH RECOGNITION:

The chain of events from conception of a message in the speaker's brain to arrival of the message in the listeners brain is called speech chain. In many applications of speech processing a part of the chain is implemented by a stimulation device. In automatic speech of speaker recognition, an algorithm takes the listener's role in deciphering speech waves into either the underlying textual message or a hypothesis concerning the speaker's identify.

The most basic problem of speech recognition is how to reconstruct the discrete linguistic components from the overlapping and interwoven cues in the acoustic signal. There also many variation encountered in the speech like linguistic variation, personal variation (Bristoro, 1986) style variation which will affect the acoustic correlate.

In actual fact, the effectiveness of every recognizer is determined by the appropriateness of its response. Input utterances may be considered equivalent if they have same intended responses or different if they should yield different responses. This producers "equivalence classes" of spoken inputs which changes with talker, speaking rate, the recording environment, style of speaking and variabilities in details of pronunciation.

In the speech production point of view, this input - output signal processing is well understood by the communicative "source" of the speech signal and also the Individual can capture essential aspects of the man in which speech was produced by the human vocal system (Eg: rate of vibration of vocal cords, vocal tract resinous, co-articulatory movements etc).

Acoustic parameters of speech recognition can be mainly divided into time - domain and spectral parameters.

Time domain parameters include peak amplitude and peak-to-peak measures. Large wave form peak are produced by the

periodic excitations of the human vocal tract by puffs of air from the vocal cords and the time interval between successive excitation peaks provide the pitch period the reciprocal of the pitch period is the fundamental frequency of the voice which is used for prosodic analysis. Within each pitch period, there are succession of progressively smaller peaks, indicating the resonance characteristic of the human vocal tract as a resonating tube for vowel - like sounds, the peak count in each pitch cycle can be the cue to the frequency of the dominant formant.

In frequency domain, voice fundamental frequency can be found from the spacing between the harmonics or from central analysis vowel detection is also reliabily accomplished, based on energy region of each syllable nucleus and presence of voice. The prosodic fractures of vowel energy, duration of formants and fundamental frequency provide confirming cues to vowel identify.

Many authors tend to agree that duration of utterance and fundamental frequency as important variables among the variables in the process of speech recognition.

A study was under taken by Ashok Kumar (1989) to find out effect of variation in fundamental frequency on speech recognition. In order to find the effect of variation, were made to utter the digits at habitual pitch and pitches higher and lower than habitual pitch of the subjects. Number of currently recognized digit at different pitch levels were

shown using three different recognition methods i.e., cosh measure, minimum prediction residual method and linear prediction coefficient. Results indicated that, at habitual pitch both cosh measure and linear prediction co-efficient yields good results. The digits are recognised 80% to 90% by these 2 methods out habitual pitch. But as the pitch was varied, the percentage of recognised digit went down. Thus showing that recognition of digits is affected by varying the pitch. Same study also showed that at low pitch were very poorly recognised (about 40%). Better results was obtained at higher pitch level with respect to low pitch level. (Ashok Kumar, 1989).

Studies on speaker recognition (Abberton, 1970; Lariviere, 1975, Atal, 1972) have suggested fundamental frequency as an important parameter in speaker recognition tests. It was not obvious what measures of fundamental frequency were likely to be the most appropriate. But authors had claimed that it could be concluded that change in fundamental frequency may affect speaker recognition.

FUNDAMENTAL FREQUENCY AND SUPRA SEGMENTALS:

Supra segmentals can be described as variations larger than individual segments, overlaid upon a word, phrase or sentence. They include intonation, stress, rhythm and juncture, primary prosodic parameters and the psychological attributes of sound pitch, loudness and duration; which have a primary relationship with the physical dimensions of

fundamental frequency, amplitude and time respectively (Crystal, 1969).

Stress is the perception of some linguistic unit as emphasized or prominent in contrast to surrounding units. Fry (1958) studied the relative role of each acoustic correlate involving stress. He concluded that fundamental frequency tended to dominate duration and duration tended to dominate intensity. Stressed segments are perceived as louder, longer and higher in pitch than the unstressed segments, (Fry, 1958). In English stressed morphomes have a characteristic energy curve. The force of articulation rises sharply at the beginning, culminates in the stressed syllable and tapers off towards the end (Kurath, 1964).

One of the primary studies regarding the acoustic cue/cues was relevant for the perception of stress in English was by Scott in 1939 who found that fundamental frequency as important in every stress. Bolinger (1958) also supported this view. Study done by Morton and Jassem (1965) showed that fundamental frequency produced a greater effect than intensity or duration in the perception of stress.

Westin, Buddenhagen in Obrecht (1966) in their study showed that frequency specifically the frequency of the first syllable, overriding opposing cues of pitch quantity and intensity in the final syllable provides the primary cue for identification of stress.

Summarizing the findings on English stress, William (1986) stated that there was a fair degree of consensus as to the acoustic correlate of stress in English. The primary cue to stress was a change in fundamental frequency (Fo) within a syllable and the next most important cue was a step change in to between a stressed syllable and a neighbouring syllable, the stressed syllable usually having higher Fo. For Lieberman, (1960) the measure of peak amplitude was more reliable than duration, while Fry (1958) also noted that in the case of changes in Fo within a syllable more than the actual shape and extent of the Fo change, its occurrence was more important.

Fry (1958), studied the relative role of pitch, loudness, tempo and change in formant pattern in using stress. His findings showed that fundamental frequency tended to dominate followed by duration inturn followed by intensity.

Intonation is described as the patterned variation of pitch over linguistic units of different length. The changing Fo perceived as the intonation contour of a phrase or sentence is particularly effective in expressing differences in attitude and meaning.

Study conducted by Hutten (1968), showed correlation between the acoustic variables and degree of emotion. Degree of perceived emotions was found to be highly and positively correlated with Fo range and Intensity range.

Physiological correlate of rising intonation was showed by Liberman (1967). He claimed that rising intonation resulted chiefly from increased cricothyrind muscle activity, lengthening of vocal folds for faster vibrations.

Changes in pitch, according to Woolbert (1977) carried significant emotional information, for example, the widest ranges were usually seen in anger and narrowest in grief.

The intonation contours occur in various forms in different linguistic contexts. At the elemental and segmental levels, namely the phonemes and words, one finds enough support in the literature which points to the more or less consistent fractures of Fo (Lehiste and Peterson, 1961; Silverman, 1986). This however does not remain the same at phrase or sentence level (O'shaughnessy in Allen, 1983). The declination phenomena of Fo in discourse was accepted as a universal phenomenon by many investigators (O'shanghnessy, 1979; nmeda, 1981).

Proponents of "rise-fall" dichotomy view (Lehiste and Peterson, 1961; Mohr, 1971, Abramson and Lisker, 1985) claimed that the Fo fell after voice in stops but rose after voiced stops. They also stated that the direction of post release Fo was contextually invariant. The "FO rise" view (Silverman, 1986) on the other hand claimed that the onset frequency of post release Fo was raised after all stops, if they were phonologically voiced. According to this view, Fo contour was a combination of segmental perturbation added on

to a smooth underlying intonation contour, i.e. the direction of post release Fo depended not only on segmental phonetic features but also on the prosodic structure (Silverman, 1986).

Cooper, Scares, Ham and Dorman (1983) determined the influence of speaking rate and emphatic stress on patterns of Fo. They reported that Fo peaks were higher in fast speakers and in fast rate of speech emphatic stress, was associated with an increase in Fo on the emphasized word and a lowering of Fo on the neighbouring word.

Intrinsic Fo difference between vowels was also extensively studied by various investigators (Peterson and Barney 195), Mohr, 1971; Atkinson 1973 and Honda 1981). All of them have reported that the fundamental frequency in high vowels was higher than that of the low vowels, in unchanging intonational contexts. Some investigators had observed that the magnitude of intrensic Fo (IFo) difference varied from language to language (Ladefoged, 1964; Lehiste, 1970).

Ladd and Silverman (1984) tested for IFo effects in paragraph of connected speech as well as in carrier phrases. They investigated IFo in specific context in which they controlled the sentence position, nuclear stress and high/low Fo in speakers range. The results indicated that the low Fo, rather than low stress or phrase final position, accounted for decrements in intrinsic Fo effect. Shandle (1985) pointed that there was an interaction between sentence position and

4

intrensic Fo differences. The results of his study showed that the Intrinsic Fo differences were generally small in sentence final, unaccented positions.

Fo in phrases and sentences:

Commenting on the patterns of Fo in English, O'shangnnessy and Allen (1983), observed that a typical Fo contour of an English utterance would be viewed as the composite result of a set of heirachial patterns (associated with sentence, phrase, word and phoneme). The Fo pattern described were as follows:

1) **Utterance level:** This was considered a prototypical pattern of a sentential utterance, the highest level of Fo contours which could be related to breath group effects.

2) **Phrase level:** A cumulative Fo pattern when the effects at the clause or phrase level were considered.

3) **Word level:** Depicted the additional efforts of Fo emphasis at the word level.

4) **Phoneme level:** A typical, complete Fo contour, including all levels of Fo efforts, the phonemic effects were manifested in the continuity break of the curve, representing unvoiced section of speech.

In other words, O'shanghnessy and Allen (1983) stated that the sentence level determined the overall Fo shape. They pointed that the overall pattern of Fo in a breath

group. For English utterances other than Yes/no questions, started on a relatively low level, rose rapidly on the 1st emphasized syllable and then gradually declined to reach a very low level. In Ye3/No question, Fo differed from the typical pattern by falling less after the initial rise and rising rapidly at the very end to the highest level in the utterance (O'shaughnessy, 1979).

With reference to phrase level, which was the second hierarchial level, O'shanghressy and Allen (1983) agreed with Lee (1956), Olive (1975), who reported that certain points of the utterances were often marked by Fo changes at major syntactic breaks. They further stated that within the normal gradual Fo fall of the breath group, such breaks were indicated by discontinities in the Fo pattern, such as a sharp Fo fall, followed by a rise on the final voiced phone before the break.

Delattre et al (1965) had pointed to the fact that this "Continuation rise" Fo pattern was used to signal to the listener that the sentence was not yet complete because Fo fall to a low level indicated finality.

The effects of modality operators such as sentential adverbs, modals, negatives and quantifiers on a Fo pattern. Recorded sentences and paragraphs were analysed for the Fo feature. It was found that the important words in each sentence were marked intonationally with rises or sharp falls in Fo compared to gradually falling Fo unemphasized words.

These emphasis duration were measured in terms of Fo variations from the norm. It was found that the Fo variations were larger.

1) In the beginning of the sentences
2) In longer sentences
3) In syllables surrounded by unemphasized syllable
4) In contrastive contents

Other results showed that embedded clauses tended to have lower Fo and negative contractions were emphasized on this first syllables. Individual speakers differed in overall Fo levels. It was al3o seen that the Fo vowels changed in paragraphs, with emphasis going to contextually new information (O'sharghnessy and Allen, 1983).

Two major differences between Yes/No questions and other sentences was studied by O'shanghnessy and Allen (1983). These differences were

a) The middle of the utterance exhibited only a very slightly falling declination, with Fo remaining above 140 Hz after the early emphasis rises.

b) Fo increased sharply on the last word to the highest level in the utterance, rather than falling to the lowest level as in other sentences.

A series of experiments were conducted by Cooper and Sorensen (1977) to determine the extent to which speakers

syntactic loading influenced the Fo contours in the region of syntactic boundaries. The results showed that the fall rise patterns were more pronounced at the boundaries between two nonjoined clauses.

In a study, O'shaughnessy (1979) examined the pattern of Fo extracted from natural speech of male speakers reading isolated sentences. Fo contour as function of time exhibited systematic behavior with regard to sentence type, Syntactic construction and word type. He suggested that the basic Fo movements of rise fall can be considered the fundamental linguistic parameter which constituted the Fo feature pattern. Rises and falls, which were controlled by the speakers and perceived by the listener were related closely with the perception of phomemes with stress, syntactic boundaries, certain phrases and sentence type (Ohala, 1970; Klatt, 1973). The level Fo (relativeity flat or slightly falling Fo), rises and the fall in Fo were described as linguistically relevant Fo patterns.

Declination refers to the fact that the pitch of the voice is most commonly lower at the end of a sentence than it is at the beginning (Cruttenden, 1981). In long stretches of continuous speech, there is a global tendency for the Fo never to decline with time, despite successive local rise and falls (Vaissiere, 1983). This phenomenon was observed in a number of languages, in English (Magno - Caldognetto, 1978), in Italian (Fujisaki, 1979), in Japanese (Hombert, 1974).

Highlighting the general properties of Fo contours in unmarked sentences in a number of langauges, Vaissiere (1983), observed some common tendencies. They are

1) A tendency for Fo values to fluctuate between the plateau and the baseline, which delimited the speaker's Fo range.

2) A tendency for the Fo range to diminish a function of time.

3) A tendency to start sentences with a large sentence initial rise in Fo, located on one of the first syllables.

4) A tendency to repeat a succession of Fo rises (R) and lowering (1): a pair of opposing movements indicazing a prosodic word.

5) A tendency for the highest value of Fo to be located on the first prosodic word of the sentence.

Although the declination pehnomenon was reportedly found in many languages, there was lack of agreement regarding the universal nature of this phenomenon in speech. Umeda (1982) tried to verify the statement that the down drift Fo was an universal phenomenon. In a study, the Fo of sentences in different modes of speaking i.e., short unrelated sentences, an essay and free conversation were studied, the results indicated that the Fo pattern becomes complex as the complexity of the nontextual information increased.

It was noted that declination was observed in situation where the meaning of the sentences was not expressed well by the talker or was not specified by nontext or a gradual preparation for sentence termination was made. He also felt that "mechanical" or "bored" reading should be avoided if possible. Thus it is noted from the literature that intonation gestures, namely rise and fall contour movement in segments differs from words to paragraphs and Fo declination phenomenon is well noted.

Many studies have been reported on the emotive intonation patterns (Pence, 1964; Chapellez, 1964; Fo'nagy and Magdics, 1963; Manjula, 1979; Nataraja, 1985). Fo'nagy and Nagdics (1963) described emotive intonation patterns in Hungarian. They concluded that:

1) Joy was denoted by an increase pitch range.
2) Tenderness was expressed by a non fluctuating higher pitch level.
3) Longing was denoted by a narrow pitch range.
4) In case of surprise, the voice suddenly glided up or down to a high level within the stressed syllable.
5) Anguish was denoted by an extremely narrow pitch range.
6) Sarcasm was devoted by a stressed syllable sliding to a low level.

Nataraja (1985) found the following patterns for emotions in Kannada.

1) Joy - High - mid - high
2) Sarcasor - mid - low
3) Disappointment - High - mid - high - mid
4) fear - mid low

Following are the analysis of emotion expressed in Hindi (Nataraja, 1981)

1) Anger - Mid - low mid
2) Joy - High - mid - high - mid
3) Jealousy - mid - low
4) Neutral - mid - low - low
5) Mercy - mid - low - mid

The same study also analyzed the intonation patterns in other 2 language, the pitch pattern were as following.

Emotions	Gujarathi	Tamil
1) Anger	Mid-low-high-low	mid-low-mid
2) Joy	mid low-mid-low	high-mid-high-mid
3) Jealousy	mid-low	mid-low
4) Neutral	mid-low-mid	mid-low-low
5) Mercy	mid-low	mid-low-mid

Thus above studies show that change in pitch have some emotional significance and it is also agreed by a number of researchers that Fo contours may play a role in the perception of intonation of sentences.

In Dysphonics:

SFF has been found to be different in dysphnocis than in normals (Sawashima, 1968; Cooper, 19 75; Murray, 1978; Murray and Bonerty, 1980).

Beck and Schnerdor (1926) demonstrated that any part of the larynx might be sight of congenital or acquired malformation vocal disturbances and particularly expected when the vocal cords are affected. Any irregularity in length, breadth, thickness, muscular development, asymmetry in physical properties of the vocal cords affects the acoustical quality of the voice.

Languaite and Waldrop (1964) state that, "there is a general agreement in the literature that vocal nodules are produced by using a pitch that is too high and contact volurs by using a pitch that is too low. Other types of laryngal pathologies, such as polyps, Polypoid degeneration and chronic laryngitis although not associated especially with use of wrong pitch, are thought to be primarily the result of vocal abuse.

Luchsinger and Arnold (1965) observed that many patients with nodules used an unnaturally low speaking pitch. They also note that many patients with nodules had histories suggesting that prior to dysphonia they habitually used an unnaturally low speaking pitch which might have contributed to the development of the lesion.

Various disorders of larynx interfere with approximation, tension and vibration of the vocal cords may lead to hoarseness. Many authors have discussed hoarseness as a major deviant quality found in patients with voice disorders (Van Riper and Irwin 1958, More, 1971). They also observed that a growth on the vocal folds lowered the pitch and affected the quality of voice. Hoarseness has been described in terms of physiology involved at the level of larynx. Thus interms of the acoustical correlate of the vibrating structure behaviour, there may be variations (Seth and Guthrie, 1935).

Hanson, Gerratt and Ward (1987) suggested that majority of phonatory dysfunction are associated with abnormal and irregular vibration of vocal folds leading to generation of random acoustic energy, ie.., noise, fundamental frequency and intensity variation. This random energy and aperiodicity of Fo is perceived by human ears as hoarseness. Hence the spectral, intensity and Fo parameters are more appropriate in quantifying phonatory dysfunction.

The frequency related parameters are the most rugged and sensitive in anatomical and physiological changes in dysphonics larynx (Hanson, Gerratt, and Neard, 1981).

Van Leden et al. (1960) reported that, in pathological condition, there is variation in the vibratory pattern, accompanied by transient pressure charges across glottis which are reflected acoustically as disturbance in Fo and

amplitude patterns. Swashima (1968) reported a rise in mean fundamental frequency in case of sulus vocals and fall in mean Fo due to disturbances in mutation in males.

Michel (1968) had studied the difference in mean fundamental frequency between vocal fry harshness and normal voice. Ten adult males recorded a standard passage in their normal voice and then in vocal fry. A second group whose voice had been clinically, diagnosed as harsh, recorded the passage in their usual harsh voice. The results of the study indicated that vocal fry could be differentiated from clinical harshness and normal phonation on the basis of mean fundamental frequency.

Jayaram (1975) had made an attempt to compare some of the parameters of voice between normal and dysphonics, In his study, a significant difference emerged in habitual frequency between normals and dysphonics, showing that study of fundamental frequency had important clinical implication. Similar results and conclusions were obtained in the study done by Cooper (1974).

A study was undertaken by Fritzell et al., (1989), to determine the Pitch changes following the surgery for oedematous vocal folds. The results showed that in all patients there was an upward shift in fundamental frequency as a result of operation. This showed that measurement of the fundamental frequency was a simple method to monitor post operative changes in case of voice in vocal fold edema.

Susheela (1989) undertook study to draw a conclusion regarding the usefulness of aerodynamic and acoustic measurements in case of laryngeal lesions. The results showed significant differences in fundamental frequency, phonation duration between pre and post operative measures.

Divya (1996) studied fundamental frequency of dysphonics before and after therapy. The findings showed that comparison of Fo before and after therapy among dysphonics reveated differences. In all cases, there was a decrease in Fo following therapy. The differences were statistically significant for vowel /u/ and not significant for vowels /i/ and /a/.

Cooper (1975) had compared fundamental frequencies in dysphonic patients before and after vocal rehabilitation. He had reported that one fifty out of one fifty five patients were using low pitch before therapy. After therapy they were free of hoarsness. From the measurements of fundamental frequencies obtained, it was posited that the use of pitch below the optimal level is a major factor in initiating or contributing to most types of dysphonics.

In a study by Biswajit Das (1995), the phonation of /a/, /i/ and /u/ and spontaneous speech production of normals and dysphones were analysed. The finding showed a higher mean and SD values of fundamental frequency for dysphonics in both the conditions when compared to normals. He also found that dysphonics had mean values of "highest Fo" for the sentence

was highest when compared to the mean value of /a/, /i/ and /u/. However mean value of "lowest Fo" of sentence was lowest when compared to /a/, /i/ and /u/.

EFFECTS OF SMOKING ON SFF:

SFF of human voice is a measure which has often been used to asses the condition of larynx. Study done by Lorensen and Horii (1982) showed significantly low Fo values for smokers than non-smokers. This result was particularly true for male subjects in oral reading and spontaneous speech task. This study did not show statistically significant difference in females. They explained this by saying that predominance of younger female subjects would tend to skew the data towards non-smokers. Second explanation may be that the length of the time and amount smoked had affected the results. They also found that males smoked heavily than females.

Gilbert and Weisner (1974) investigated effects of cigarette smoking on SFF for female smokers. They found that women who smoked had a lower Fo than women nonsmokers. The results of their study was significant in reading passage but not in spontaneous speech. The authors also suggested that low Fo values of female smokers may have been result of thickness of vocal folds and connective tissue caused by cigarette smoking.

Ryan etal (1955) compared microscopic section from the larynges of smokers and non-smokers. They found that surface

epithelium hyperplasia. They also found that smokers showed greater degree of round. Cell infiltration, edema and squamous cell metaplasis. Auerbach etal (1970) should that epithilial thickening of the true vocal folds was greater in smokers than ex-smokers and non-smokers.

The above studies provided histopathological evidence for lowering of the SFF that was seen in the smokers compared to non-smokers.

According to the literature, there seems to be a definite variation in speaking fundamental frequency (SFF) and the source of variation has been studied. Yet data in some areas are limited. This present study was aimed at investigating presence of significant relationship between the speaking fundamental frequency (SFF) variability and following variables.

1) Style of speaking
2) Gender
3) Langauge
4) Laryngeal pathology
5) Smoking.

METHODOLOGY

The objective of the present study was to find fundamental frequency in speech and to study the effect of following variables on it.

1) Language effect (Kannada, Hindi, English)

2) Gender effect

3) Style effect (Interview-Narration and Reading)

4) Effect of Laryngeal Pathology

5) Effect of Smoking

Subjects:

SI.No.	Subjects	Number M	Number F	Age Range (Yrs)	Criteria for Selection
1)	Normals				General: No apparent speech and hearing or ENT problem
a)	Native Speakers of Kannada	15	15	17-24	Kannada as 1st Language
b)	Native Speakers of Hindi	15	15	17-24	Hindi as first language. Both groups: Minimum of 5yrs of experience in speaking English.
2)	Dysphonics	15	15	25-50	Diagnosed as case of voice disorder after routine otolaryngological, speech and audiological evaluation.

				No therapeutic intervention was undertaken.
3)	Smokers	15	18-25	History of smoking habitually for one year or more.

EXPERIMENT 1:

Purpose: To obtain samples of spontaneous speech through interview mode.

Subjects: All subjects who participated in this study were given this task.

Material: Five questions were designed for this tasks. They were,

1) What is your place of birth?
2) Where did you study?
3) Which language do you speak at home?
4) What are the other languages you know?
5) Which of these language you are fluent in?

Instruction:

Just before recording, subjects were instructed as follows.

"I would like to record your speech sample. Now I am going to ask you some questions, for which you have to answer in complete sentences. Questions will be asked in English and you will have to answer in English language".

Procedure:

Experimenter interviewed each subject informally and responses were recorded, using sony deck TCFX 170 with unidirectional microphone kept at a distance of 6 inches from

the speakers's mouth. All recordings were done in 3ound treated room.

Experiment II:

Purpose: Aim of this experiment was to elicit spontaneous speech through narration mode.

Subjects:

Subjects		Language (of narration)
1) Native speakers of Kannada	-	Kannada
	-	English
2) Native speakers of Hindi	-	Hindi
	-	English
3) Dysphonics	-	Only Kannada
4) Smokers	-	Only English

Material:

For English story narration; a well known short story (See Appendix - 1) was selected.

For Kannada story narration: English story which was selected for narration was translated.

For Hindi story narration: Hindi translation of English short story was used.

Instruction:

The material were given to the subjects twenty four hours before recording and were instructed as follows.

"You are provided with short story. You have to read and retell the story the next day. You will not be allowed to read from the card".

Just before the recording was to take place, subjects were instructed as follows.

"You have to now narrate the stories that were given the previous day. Retell the stories in your own words. The written version of the story will be available as a memory aid, but you should not read from the card".

Procedure:

Same procedure as in experiment I was undertaken.

Experiment III:

Purpose:

To obtain samples of formal reading style.

Subjects:

Samples of reading style were obtained from all subjects. Language in which the reading passage sample was obtained were similar to narration mode.

Instruction:

For reading passage, subjects were instructed as follows: "You have to read this passage given to you".

Procedure:

Procedure is similar to one used in Experiment .

Experiment IV:

All subjects were asked to phonate /a/ for three times.

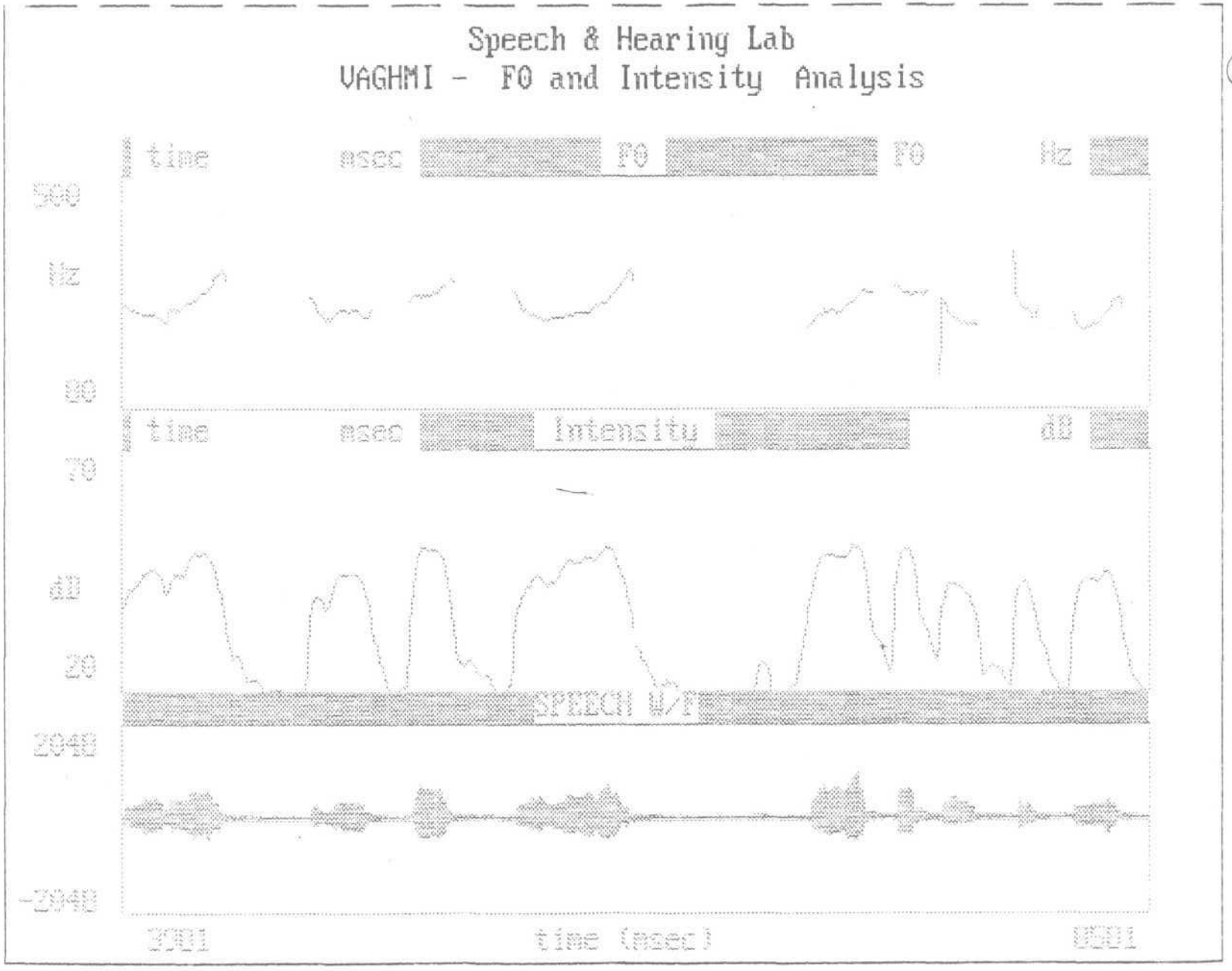
Acoustic analysis:

The analysis was carried out using the following steps.

The recorded speech sample were digitized using speech interface unit of VSS (16 bit A/D converter) at a sampling rate of 16 KHz using the programme, 'record' or VSS software. Before digitizing, each sample was passed through the anti-alaising filter at 3.5 KHz with the rate of 48 dB per octave. Digitized data was stored on the hard disk of the computer (HC, LPC - AT 386).

The software package, "VAGHMI" of voice and speech system (VSS) was used to extract fundamental frequency and intensity readings of the sample. The extraction of fundamental frequency (FO) and intensity (10) was done using INTON programme of VSS software.

PHOTOGRAPH SHOWING THE INSTRUMENTATION FOR ACOUSTIC ANALYSIS OF SPEECH


Speech & Hearing Lab
VAGHMI - F0 and Intensity Analysis
time
msec
F0
F0
Hz
500
Hz
80
time
msec
Intensity
dB
70
dB
20
SPEECH W/F
2048
-2048
2001
time (msec)
6001

(1)

73(a).

A window size of 30 millisecond in case of speech sample of males and 20 milli sce in case of speech sample of females were used.

STATISTICAL ANALYSIS

Following acoustic analysis, the data was subjected to descriptive statistical analysis and the mean, mode, standard deviation and range were obtained for speaking fundamenatal frequency.

The values obtained were further subjected to the Mann Whitney U test (SPSS programme) to find whether there was any significant influence of variables undertaken on speaking fundamental frequency (SFF).

RESULTS AND DISCUSSION

The present study is aimed at finding out different variables affecting speaking fundamental frequency and their influence on the habitual frequency of the individual.

Variables undertaken were Gender, Language, Laryngeal Pathology, Smoking and Style of speaking: Reading, narration and interview.

Descriptive statistics like Mean, Mode, Standard deviation and range were obtained and their implications have been discussed. The test of significance was administered to investigate whether there was any significant relationship between SFF and variables undertaken.

The results obtained were as follows.

Style of speaking as a variable:

Speaking fundamental frequency (SFF) was obtained for 3 speaking style: reading, narration and interview. Fundamental frequency of /a/ was determined in order to compare with fundamental frequency obtained in speech.

The study of the table 1.1 and graph 1.1 clearly show that highest mean SFF was obtained for reading style (161.23 Hz) and lowest for phonation of /a/ (118 Hz) and narration falling in between with mean SFF value of 130.02 Hz. This was noticed in both males and females. The mean values for reading varied from 140.2 Hz to 179.3 Hz in males and 248.6

TABLE 1.1: Mean, Mode, S.D and Range of SFF across different style of speaking in Native speakers of Hindi.

Sl. No.	Style	Mean		S.D.		Range		Mode	
		M	F	M	F	M	F	M	F
1)	Reading	161.23	262.98	10.00	9.40	39.10	28.80	142.0	248.06
2)	Narration	130.02	235.32	6.9	14.41	15.70	50.30	135.2	215.0
3)	Phonation /a/	118.00	218.90	23.90	9.65	36.20	30.90	123.6	212.1

Fig 1.1 Comparison of SFF across different style in Hindi Native Speakers

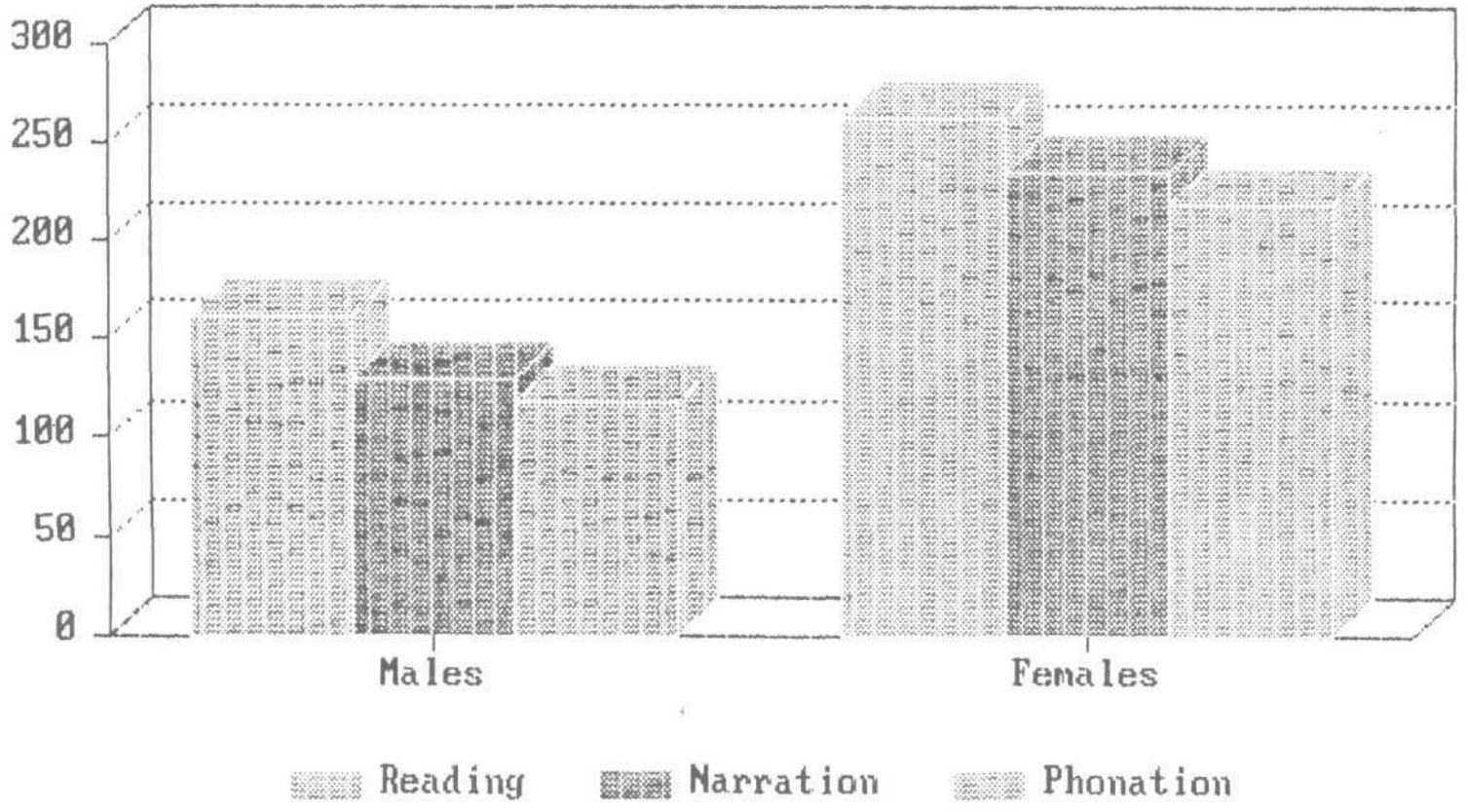
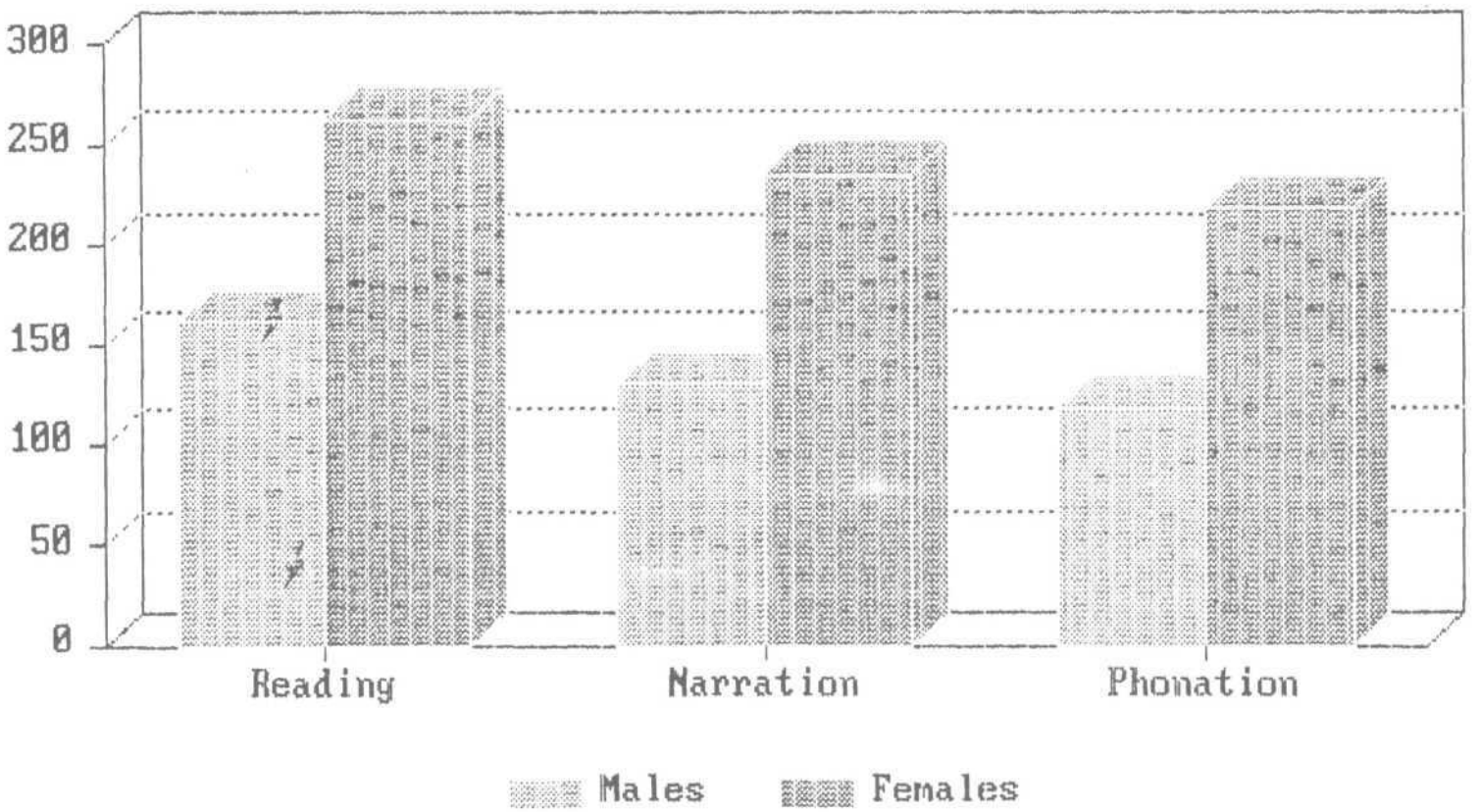


Fig 1.2. Comparison of SFF across Males and Females in Hindi Native Speakers



Hz to 277.4 Hz in females. While in narration, it varied from 145.5 Hz to 161.5 Hz in males and 215.5 Hz to 265.3 Hz in females. Range and S.D values indicated that variability was high in narration and least in reading in females whereas in males variability was found to be higher in reading style and least in narration style.

Table 1.1 shows the mode values obtained in native speakers of Hindi langauge. These values in the present study indicates the frequently used frequency - the habitual frequency. The male speakers of the present study habitually used 142.0 Hz, 135.2 Hz and 123.6 Hz for reading, narration and phonation respectively while in females the mode values were found to be 248.6 Hz, 215.0 Hz and 212.1 Hz in reading narration and phonation respectively.

The test of significance revealed that there was statistically significant difference between reading style and narration style in both males and females at 0.05 level of significance. The comparision of SFF values of reading and narration to Fo value of /a/ showed that significant difference were observed for reading and phonation, whereas, phonation and narration revealed no significant difference. The gender effect was investigated and it was found that there was significant difference between males and females in all three modes i.e., speaking, narration and phonation, with females showing higher SFF values compared to males as expected. This is clearly seen in the graph 1-2.

TABLE 1.2: Mean, Mode, S.D and Range of SFF across different style of speaking in Native speakers of Kannada.

Sl. No.	Style	Mean		S.D.		Range		Mode	
		M	F	M	F	M	F	M	F
1)	Reading	155.30	265.40	7.54	7.37	31.10	28.60	140.2	249.8
2)	Narration	132.60	238.15	7.98	9.16	33.10	28.50	121.2	237.0
3)	Phonation /a/	117.08	225.40	6.13	8.53	21.00	30.60	114.0	224.0

FIG 1.3 Comparison of SFF across different style in Kannada Native Speakers

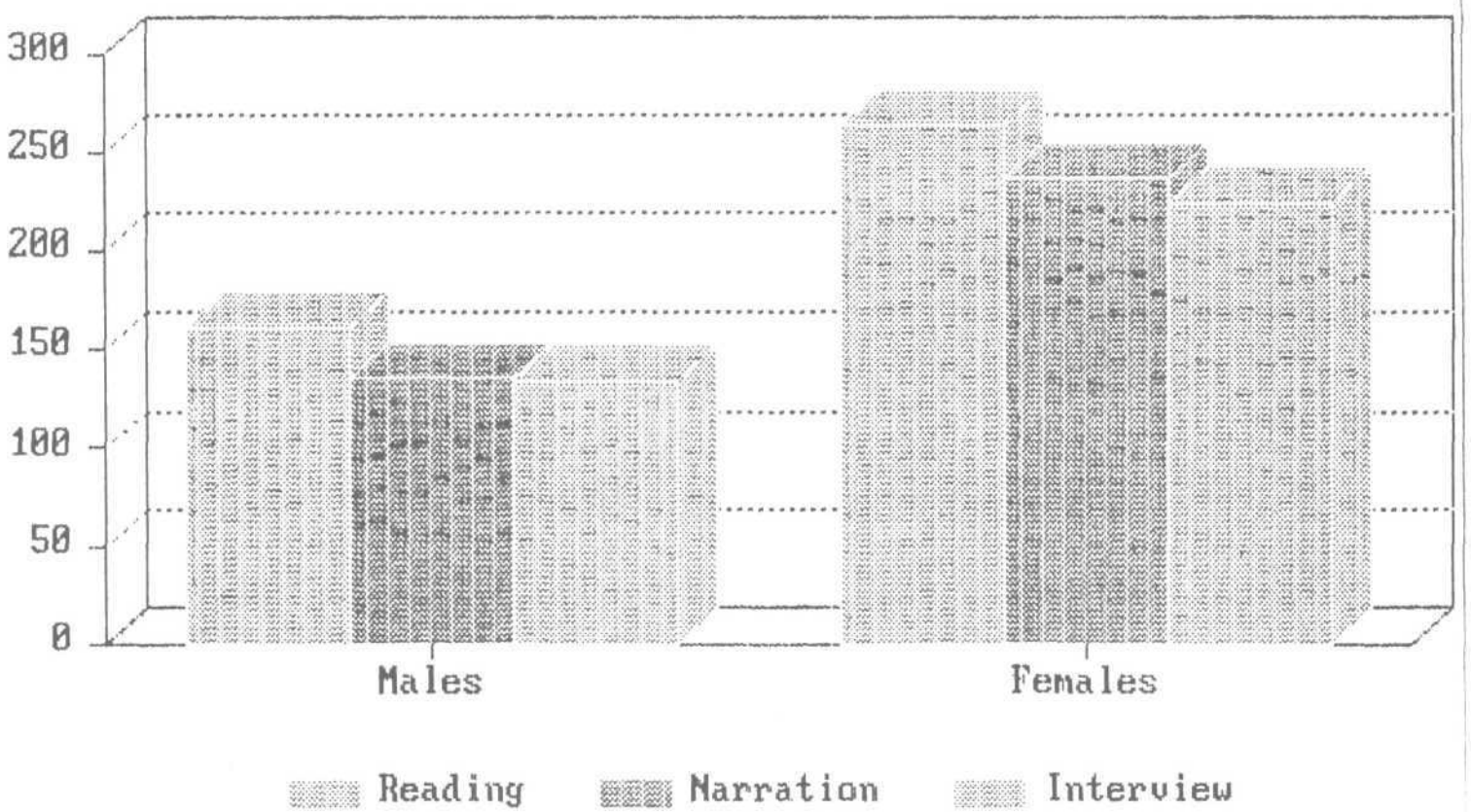


Fig 14 Comparison of SFF across males and females in Kannada Native Speakers

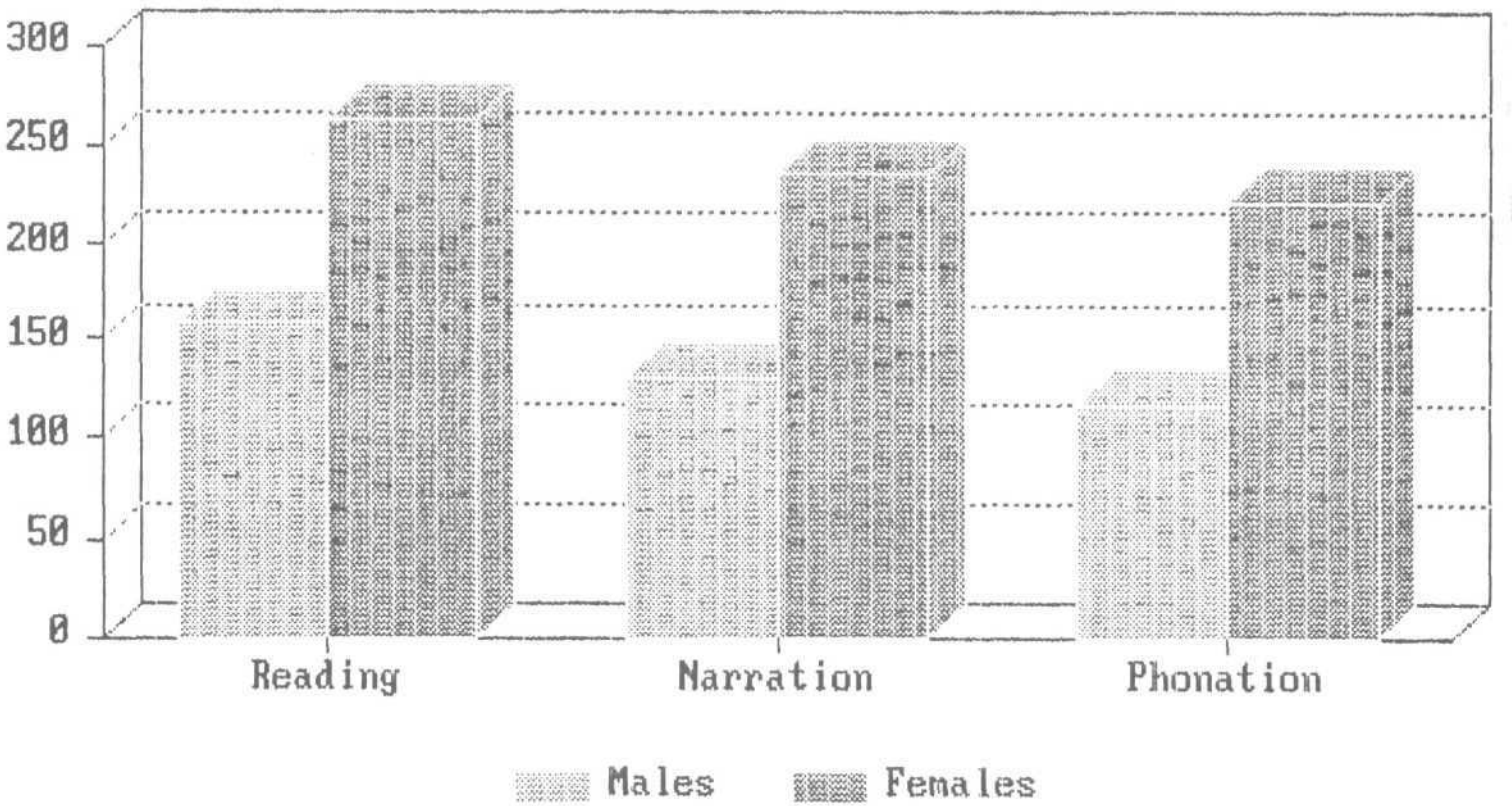
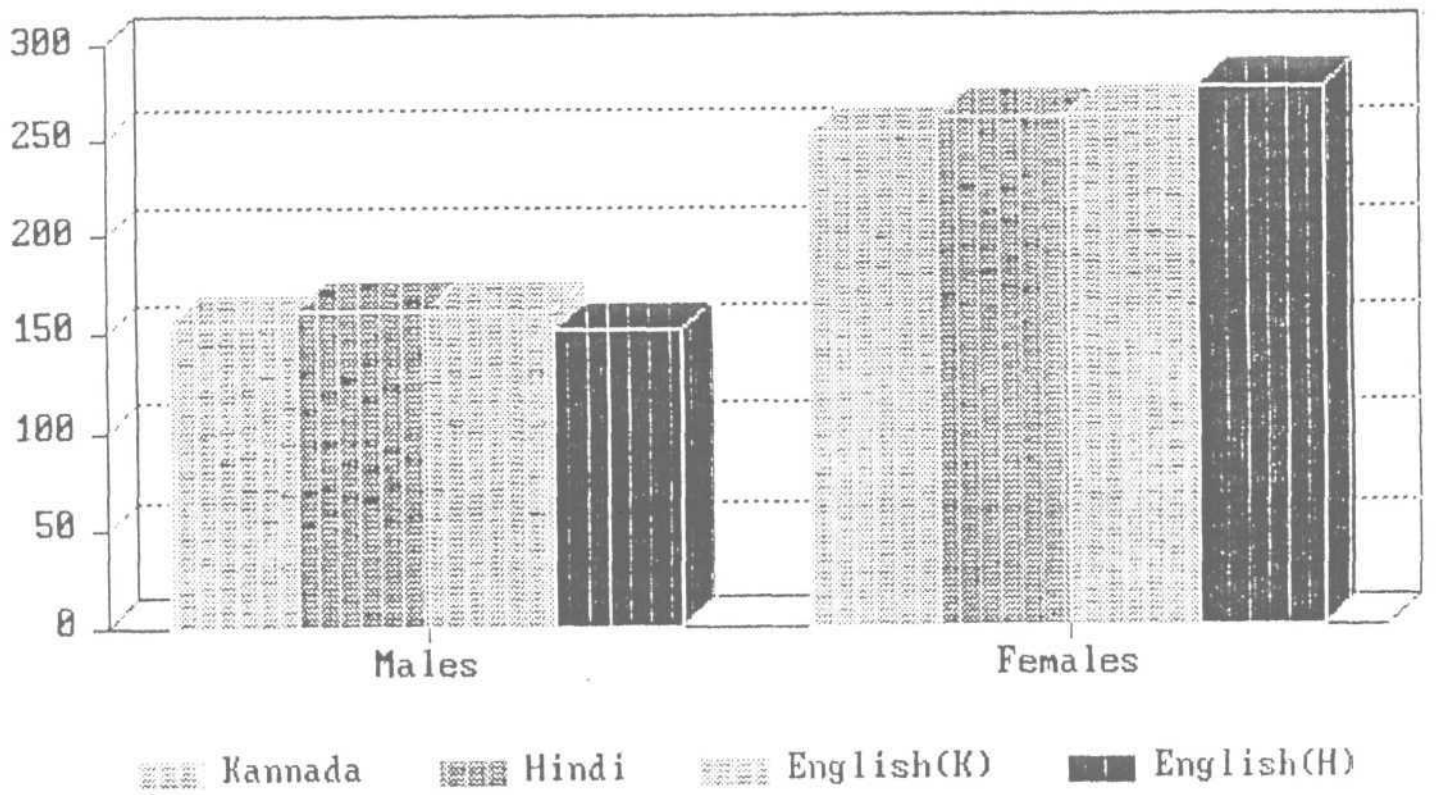


Table 1.2 and graph 1.3 depict the following results. Mean and mode values the found to be highest for reading and least for phonation with narration falling in between. Range and standard deviation values indicated less variability in reading and narration style for both males and females. In females, mode values for reading narration and phonation was found to be 249.8, 237.0 and 224.2 Hz respectively. In males, values obtained were 140.2 Hz, 121.2 Hz U4.0 Hz for reading, narration and phonation respectively. These values indicated that male and female speakers used higher habitual frequency in reading when compared to narration. The study showed statistically significant differences between reading and narration style and reading and phonation while no such differences were obtained for narration and phonation.

Graph 1.4 shows mean difference in SFF obtained in males and females in reading, narration and phonation. The habitual frequency of females was found to be significantly higher (249.8 Hz) than males (140.2 Hz) for reading style. For narration style the habitual frequency was found to be 237.0 Hz and 121.2 Hz in males.

Statistically significant gender differences were obtained in reading and narration style. Graddol & Swann (1983) studied gender effect on Reading & Dialogue task and found statistically significant gender differences.

FIG 2.1 Comparison of SFF across different Languages in Reading style



LANGUAGE AS VARIABLE:

One of the aims of the present 3study was to investigate whether SFF values differed with language. SFF values across 2 native languages i.e. Hindi and Kannada and first and second language among the native speakers (i.e. Kannada and English/Hindi and English) were compared and following results were obtained.

Table 2.1 shows mean, mode, S.D. and range of SFF for reading style in Hindi, Kannada and English language read by the native speakers of Hindi and Kannada. Graph 2.1 pictorially depicts the mean SFF values across different language for males and females.

Study of the Table 2.1 and Graph 2.1 shows that in males SFF mean values are higher in native speakers of Hindi (161.3 Hz) when compared to native speakers of Kannada (155.6 Hz). In female subjects, higher SFF values were obtained in Kannada speakers (277.2 Hz) followed by when Hindi speakers (263.0 Hz) on reading English passage. Lowest SFF values was obtained in native speakers of Kannada on reading Kannada passage (252.4 Hz).

The range and SD values did not show much variability in SFF values while reading Kannada and Hindi passages were compared. Also, test of significance did not reveal statistically significant difference between the reading Kannada and Hindi passages.

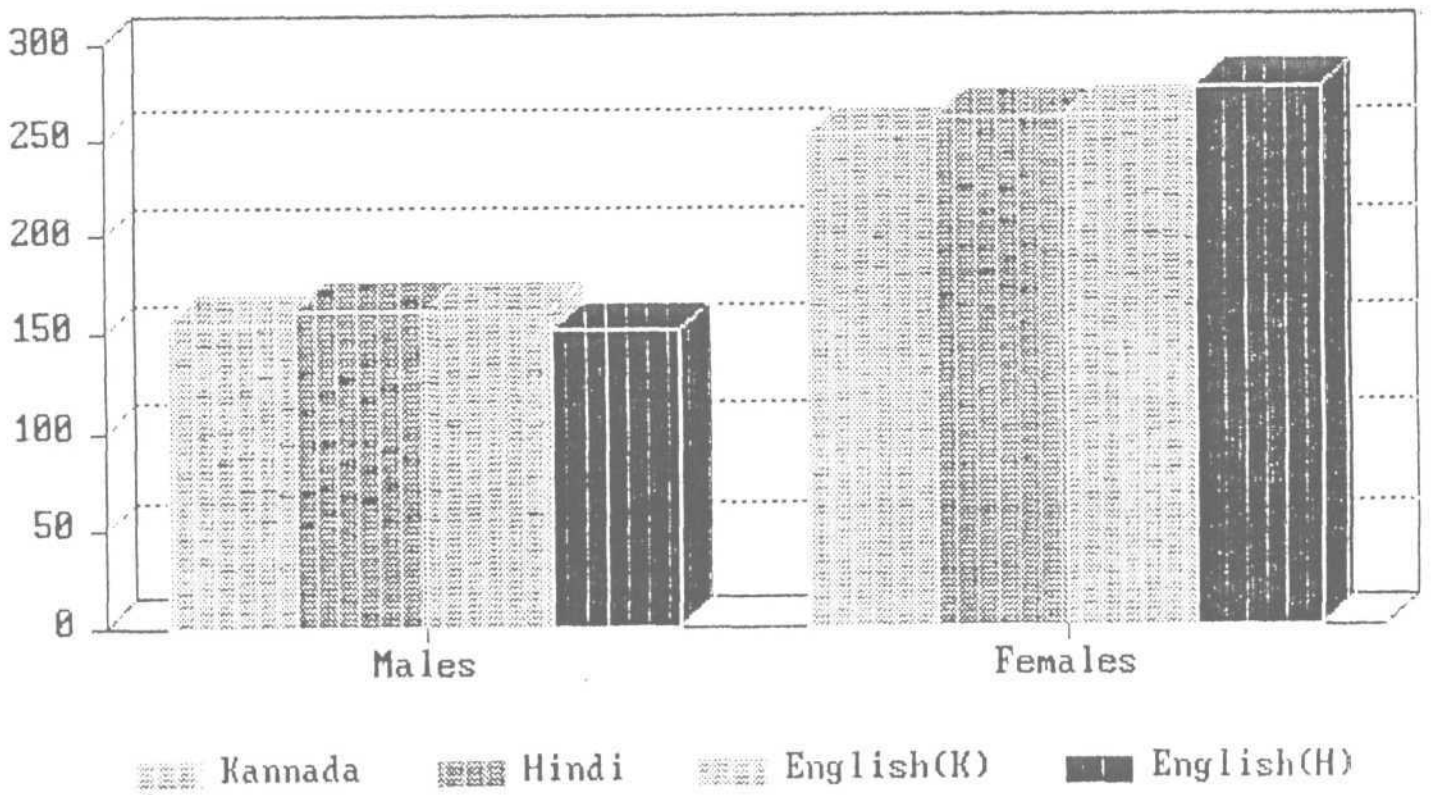
TABLE 2.1: Mean, Mode, S.D and Range of SFF for reading style across different languages.

Sl. No.	Style	Mean		S.D.		Range		Mode	
		M	F	M	F	M	F	M	F
1)	Kannada	155.60	252.40	7.54	9.54	31.10	29.60	140.2	242.8
2)	Hindi	161.30	261.20	11.00	9.40	39.10	28.80	141.2	248.6
3)	English(H)	162.30	263.00	8.92	10.42	33.80	34.20	159.2	241.2
4)	English(K)	151.10	277.20	11.90	8.61	44.10	31.40	143.2	259.6

(H) : Native speakers of Hindi

(K) : Native speakers of Kannada

FIG 2.1 Comparison of SFF across different Languages in Reading style



These results may have two implications:

1) Native speakers of Kannada and Hindi did not vary in their style of speaking across the languages i.e Kannada and Hindi.

2) There may be some convergence taking place in the phonological system of northern Indo European language ie; Hindi and southern Dravidian language ie; Kannada

Study of mode values from table 2.1 suggests that the Habitual frequently did not vary significantly across native language (i.e. Kannada and Hindi) across in both males and females.

Mean SFF values for reading English passage in both native speakers of Kannada and Hindi are shown in Table 2.1 and graph 2.1. The results show that in males, the native speakers of Hindi obtained higher SFF values (162.3) when compared to native speakers of Kannada. (151.1.H2), whereas in females, mean SFF values were found to be higher in native speaks of Kannada (277.2 Hz) than natives speakers of Hindi (263.0 Hz) But theses differences were not statistically significant.

In reading English passage male native speakers of Kannada showed high variability (S.D = 11.9, Range 44.1) when compared with male native speakers of Hindi (S.D = 8.92, Range = 33.8). In females, more deviation was seen in native

speakers of Hindi (S.D =10.42) Than native speakers of Kannada (S.D =8.61) in reading English passage.

The habitual frequency as denoted by mode values in Table 2-1 was found to be higher in male Hindi, speakers (159.2) when compared to male Kannada speakers (140.2) in reading English passage. In females, mode values for reading English passage did not vary significantly.

Mode values (Table 2.1) obtain in the present study indicated that male hindi speakers used higher habitual frequency (159.2Hz) when compared to male Kannada speakers (140.2Hz) in reading English passage. However, in females, Kannada speakers had higher habitual frequency (259.6Hz) than hindi speakers (241.2Hz) in reading English Passage.

It was observed that female Kannada speakers varied their habitual frequency significantly across Kannada (242.8Hz) and English (259.6Hz) whereas in female Hindi speakers comparable values for both Hindi reading (161.3) and English reading (162.3). An interesting finding that was noticed in the present study was that, a marked variation in mean and mode values for passage reading across English and Kannada languages was found only in female Kannada speakers. In females mean value of SFF for Kannada reading was 252.4 Hz, while English passage reading it was found to be 277.2 Hz. Whereas in males, the mean values for Kannada and English passage reading were found to be 155.6 Hz and 151.1 Hz respectively. Mode values in females were found to be

259.6 and 242.8 hz and in males, 143.2 Hz and 140.2 Hz for English and Kannada passage reading respectively.

No significant difference was obtained between Kannada and English reading in males, however in females, statistically significant differences were noticed. This implies that there may be an interaction between language and gender.

By studying the mean values of SFF from Table 2.2 and Graph 2.2, it is clearly observed that mean SFF values did not vary significantly with language. Test of significance also revealed that SFF values obtained in native speakers of Kannada and native speakers of Hindi for narration was not statistically different.

Mode values (Table 2.2) of SFF obtained in male, varied across languages in narration style. In males, Highest value was obtained in case of English narration (145.7Hz) in native speakers of Hindi. The least value was obtained in English narration (111.3Hz) in native speakers of Kannada. This result indicated that in the present study, male Hindi speakers used higher habitual frequency when compared to male Kannada speakers in narration task.

In females, SFF values was found to be highest for Kannada narration (23 7.0Hz) and least for English narrations (211.7 Hz) in native speakesr of Kannada. In native speakers of Hindi,the highest value was obtained for English narration

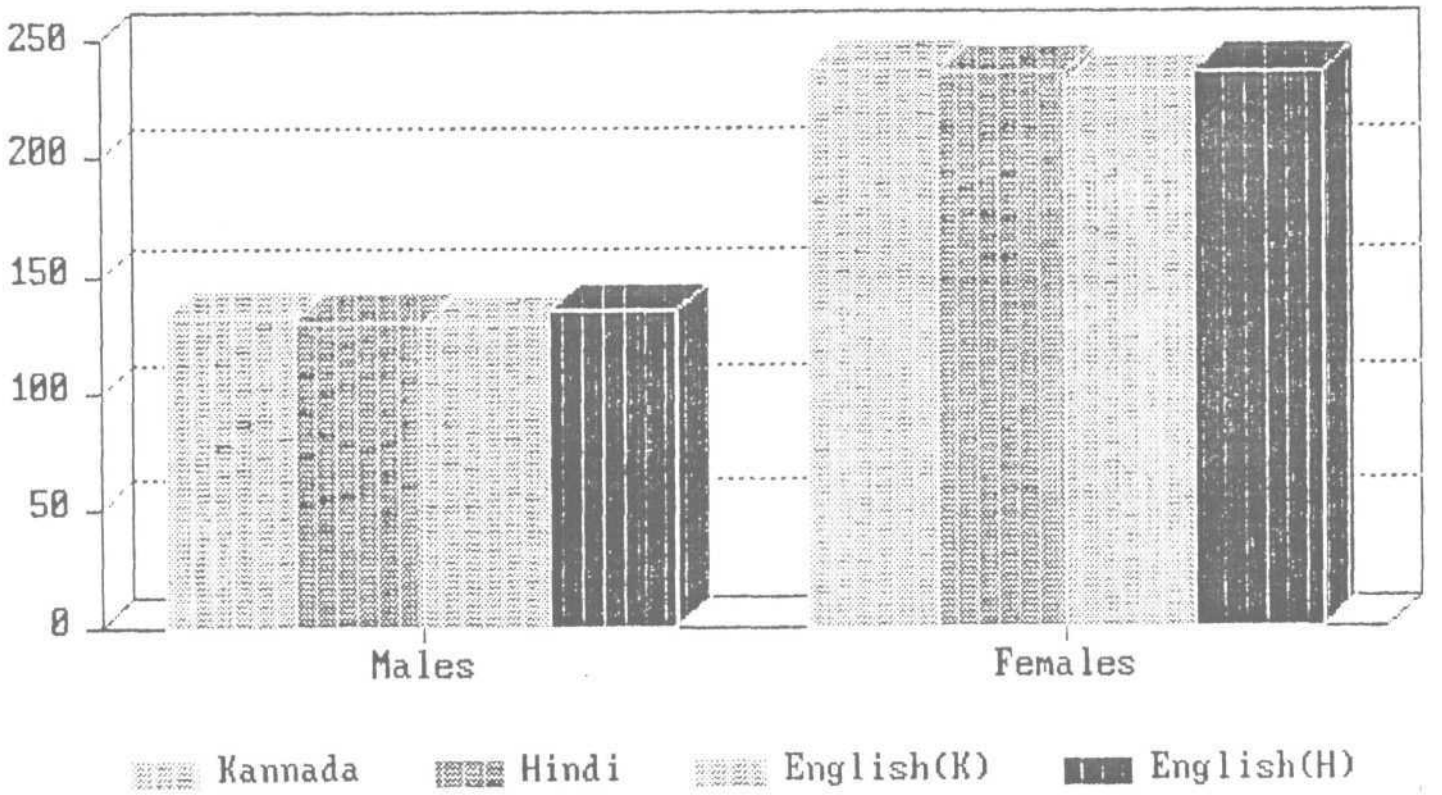
TABLE 2.2: Mean, Mode, S.D and Range of SFF for narration style across different languages

Sl. No.	Style	Mean		S.D.		Range		Mode	
		M	F	M	F	M	F	M	F
1)	Kannada	132.02	238.80	7.98	9.16	33.10	28.50	121.2	237.0
2)	Hindi	130.02	235.30	8.63	14.41	32.70	50.30	135.2	215.0
3)	English(H)	135.40	236.20	11.69	10.41	35.10	35.00	145.7	230.3
4)	English(K)	129.09	230.80	12.03	11.35	39.90	43.90	111.3	211.7

(H) : Native speakers of Hindi

(K) : Native speakers of Kannada

FIG. 2.2 Comparison of SFF across different Languages in Narration



(236.2Hz) and least for Hindi narration (215.0Hz). Results in the present study suggested that female Kannada speakers used higher habitual frequency when comapred to Hindi speakers on narration task in their native language. On English narration task Hindi speakers used higher habitual frequency when compared to Kannada speakers.

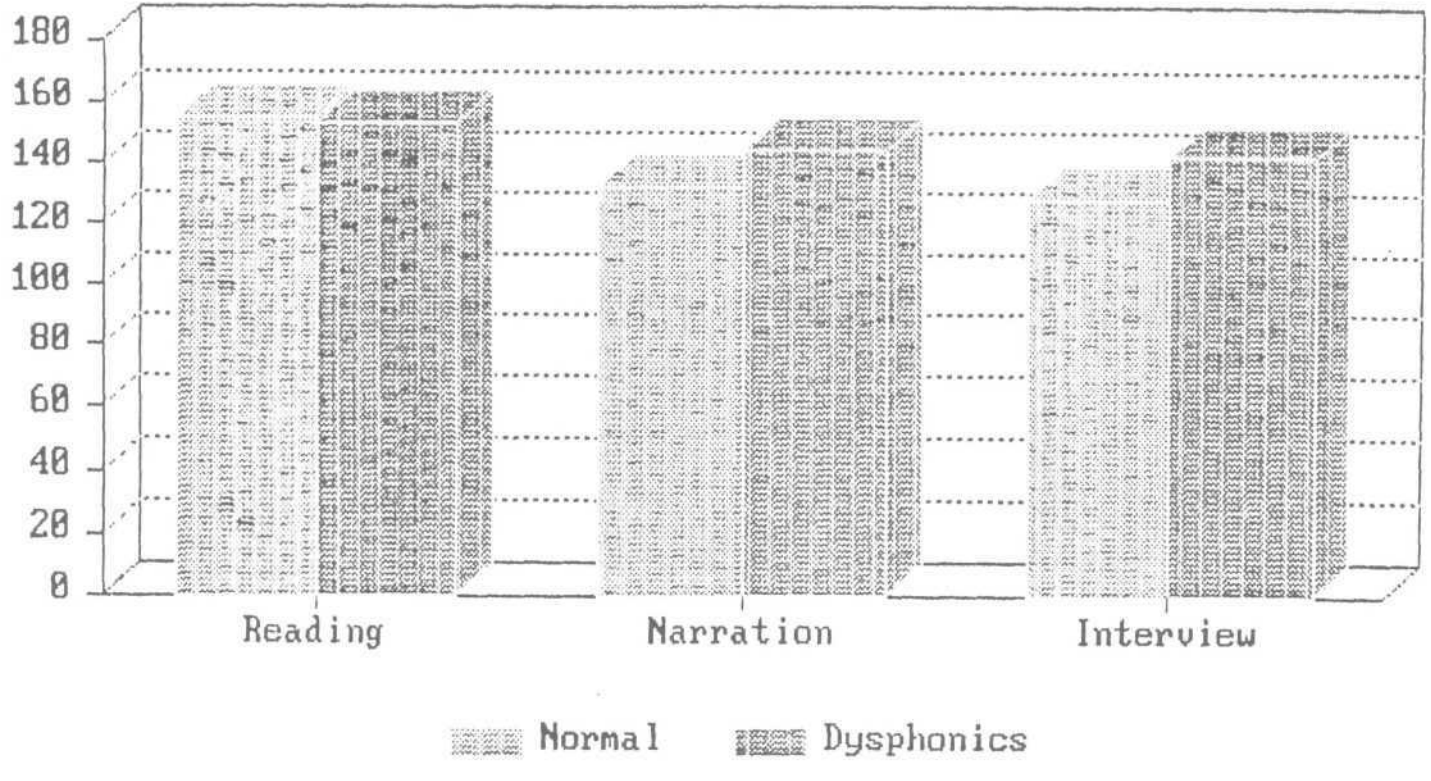
EFFECT OF LARYNGEAL PATHOLOGY:

Table 3.1. and Graph 3.1 show the mean values of SFF in normal and dysphonic males across different style of speaking. Mean SFF values obtained in dysphonic3 were higher than normal in interview and narration style. Fo of /a/ was observed to be higher in dysphonics when compared to normals. The mean values in dysphonics varied in the following manner, interview 122.4 Hz to 163.1 Hz Narration 127.0 Hz to 163.4 Hz and reading 130.1 Hz to 169.3 Hz.

Range and standard deviation values were found to be higher in dysphonics compared to normals thus indicating a high variability. However variability across different 3tyle of speaking was observed to be less in normals as well as in dysphonics.

Mode values shown in Table 3.1 indicates that male dysphonics use high habitual frequency across different styles of speaking when compared to normals. Similar mode values across different style of speaking in dysphonics show

Fig 3.1. Comparison of SFF across Normal and Dysphonic males



that they do not vary their habitual frequency with different style of speaking.

A significant difference was noted between normal males and dysphonic males in interview and narration mode. However no such differences were found between normals and dysphonics in reading style. On phonation tasks there was significant difference between normal and dysphonic males.

Table 3.2. shows the mean, mode, S.D. and range of SFF in normals and dysphonics across different styles of speaking in females. Study of Graph 3.2. and Table 3.2 show that mean values of SFF was lower than normals in reading, narration, interview and phonation. Mean values varied from 199.3 to 248.1 in reading style, from 200 to 242.1 in narration and 193.1 to 236.4 in interview style. Variability in SFF values were found to be higher in dysphonics than in normals.

The range and S.D. values were observed to be markedly higher in dysphonics when compared to normals indicating large deviations and variability.

Mode values (table 3.2) showed that dysphonic females used very low habitual frequency for all three styles of speaking. No marked variations in mode values were noted across different styles of speaking indicating that these subjects did not vary their habitual frequency in different styles of speaking.

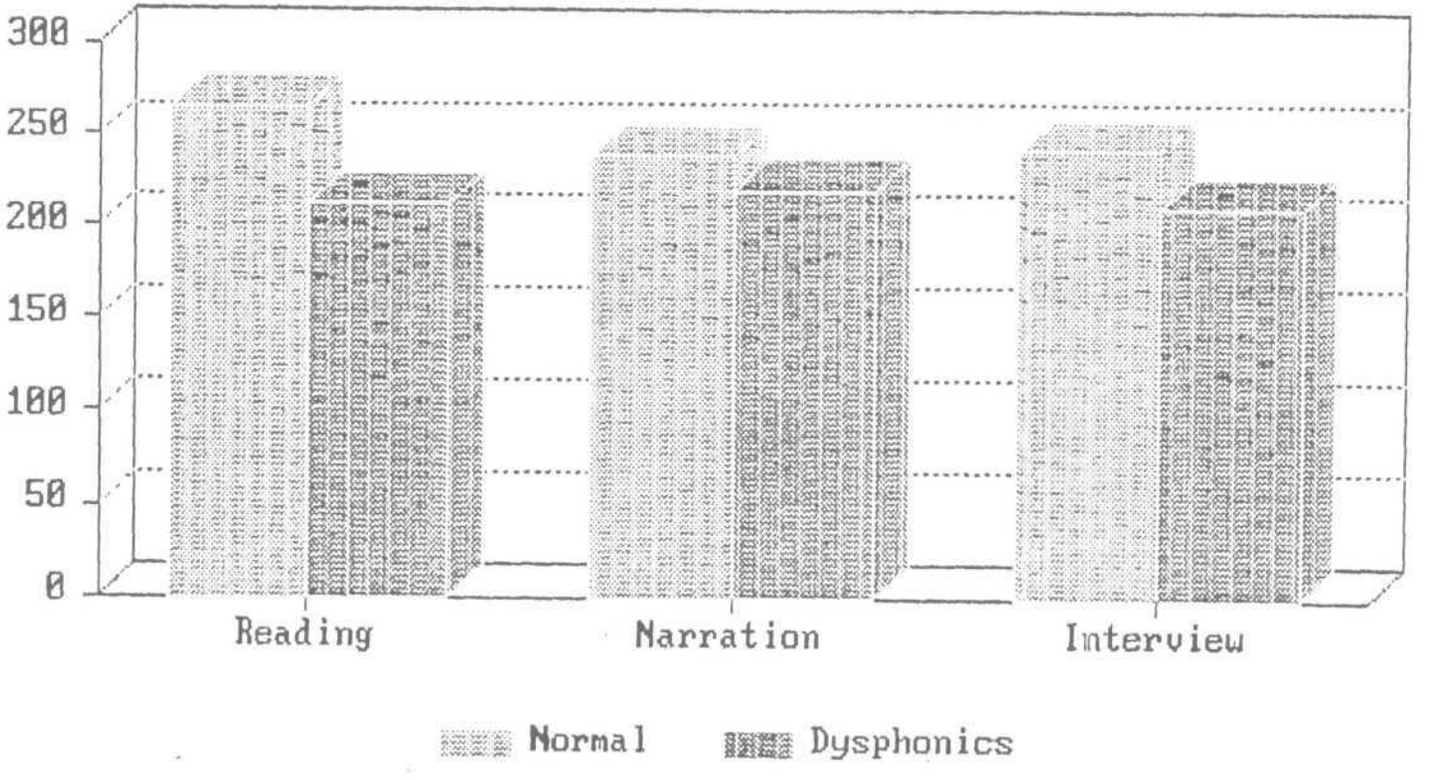
TABLE 3.2: Mean, Mode, S.D and Range of SFF in female normals and dysphonics.

Sl. No.	Style	Mean		S.D.		Range		Mode	
		M	F	M	F	M	F	M	F
1)	Reading	265.40	211.36	7.37	13.83	28.60	48. 10	259.3	199.4
2)	Narration	238.15	219.16	9.16	12.96	28.50	42.00	240.2	200.1
3)	Interview	241.50	209.65	8.69	11.80	29.60	42.30	238.1	199.2
4)	Phonation of /a/	236.0	228.4	11.1	12.1	26.3	42.7	229.2	223.6

Nls : Normals

Dys : Dysphonics

FIG3.2 Comparison of SFF across Normal and Dysphonic females



Test of significance revealed significant differences between normals and dysphonics in all three modes of speaking. There was no significant difference in normals and dysphonics in phonation. In females significant differences between normals and dysphonics was noticed in more than one style of speaking when compared to males. In males, difference was more evident in phonation than in speech, but in females, difference was marked in speech than in phonation. Thus, in males, fundamental frequency of phonation had important clinical implication as reported by studies done by Jayaram, (1974); Cooper, (1975); Nataraja and Jagadeesh, (1984). According to the present study in females, fundamental frequency in speech or speaking fundamental frequency would be potential tool in diagnosis of dysphonics.

EFFECT OF SMOKING:

Table 4.1, shows mean, mode, SD and range of SFF across smokers and non-smoker in different style of speaking. The Results showed that mean values of SFF for all smokers were lower when compared non-smokers.

The mean values in Table 4 and Graph 4 shows that SFF obtained in smokers were significantly lower when compared to non-smokers in all three styles of speaking; reading, narration and phonation. The mean values in smokers varied from 99.9 Hz to 131.2 Hz for interview; 102.3 Hz to 136.2 Hz for narration and 103.3 Hz to 147.2 Hz for reading style.

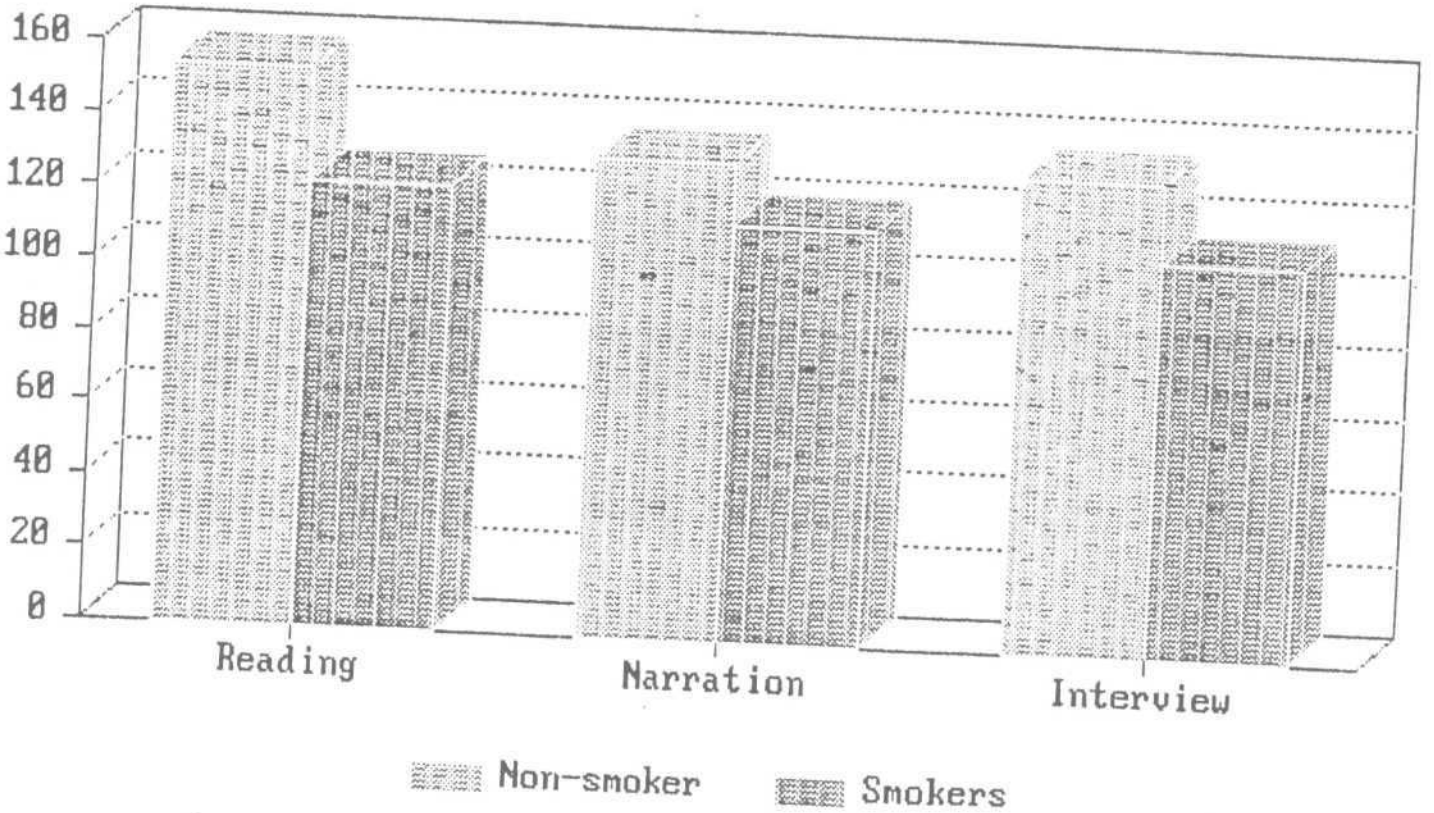
TABLE 4. : Mean, Mode, S.D and Range of SFF in smokers and non-smokers

Sl. No.	Style	Mean		S.D.		Range		Mode	
		N.S	S	N.S	S	N.S	S	N.S	S
1)	Reading	154.6	123.00	8.49	11.82	33.2	43.80	157.8	103.3
2)	Narration	132.6	115.60	11.99	9.92	44.0	33.90	130.2	102.3
3)	Interview	131.6	109.10	8.04	9.39	34.0	31.30	131.4	101 .4
4)	Phonation								
	/a/	116.3	112.4	7.14	11.2	23.06	42.0	121 .2	118.3

N.S. : Non-smokers

S : Smokers

Fig. 4. Comparison of SFF across male smokers and non-smokers



Mode values in the present study indicated that all smokers used low habitual frequency when compared to non-smokers in reading, narration and interview.

Test of significance showed that there was statistically significant difference between smokers and non-smokers in three different style of speaking. There was no statistically significant difference between smokers and non-smokers in phonation of /a/. This result was true for all 3 style of speaking. Similar results have been obtained by Soresen and Horri (1982). Thus SFF can help differentiating smokers from non-smokers or any changes in laryngeal condition.

SUMMARY AND CONCLUSIONS

Fundamental frequency is the single most important correlate of perceived pitch. According to Lover and Trudgill (1979), pitch and voice Quality are generally regarded as "informative" rather than "communicative". SFF indicates membership of a group i.e. age, sex (Abercrombie, 1967), to identify individual voices, it has been successfully used in speaker recognition (Steffen-Batog et al., 1970), as diagnostic tool in speech pathology (Fourcin and Abberton, 1976, Hirano, 1981) and many other prosodic and paralinguistic information.

Inter and Intra individual differences in pitches have been widely noted. The sources of variations as documented in literature can be biological or social. (Graddol and Swann 1983).

This present study was undertaken to investigate the effect of following variables on speaking fundamental frequency.

1) Style of speaking
2) Language
3) Gender
4) Laryngeal pathology
5) Smoking.

Two types of bilingual i.e 30 normal (Kannada speaking and English speaking and 30 normal Hindi speaking and

English speaking, 30 dysphonic3 and 15 smokers (Males), were given four tasks. Interview, narration, reading and phonation of /a/. The SFF were determined for each speech samples for all subjects using computer programmes. Mean, mode, standard deviation and range was calculated and test of significance for each variables was obtained.

From the present study following conclusions are drawn.

Effect of Style of Speaking;

In normals:

1) SFF values varied across narration, reading and interview, with reading being highest, interview being lowest and narration falling in between and this was noticed in both males and females.

2) There was significant difference between reading and narration in all normal males and females.

3) There was significant difference between reading and interview in all normal males and females.

4) There was no significant difference between narration and interview in normal males and females.

5) There was no significant difference between reading and narration in dysphonics.

7) There was no significant difference between narration and interview in dysphonics.

8) There was no significant difference between reading and interview in dysphonics.

9) There was no significant difference between reading and narration in smokers.

10) There was no significant difference between narration and interview in smokers and

11) There was significant difference between reading and interview in smokers.

Language effect:

The results indicated that the mean and mode values did not vary markedly for different styles of speaking across different languages. An exception to this, was seen for English language in native speakers of Kannada. The test of significance revealed the following.

1) There was no significant difference between Kannada language and Hindi language in reading style in normal males and females.

2) There was no significant difference between the native language and English language in native speakers of Hindi for reading style in normal males and females.

3) There was no significant difference between the native language and English language in native speakers of Kannada for reading style in males.

4) There was significant difference between the native language and English language in native speaker of Kannada in reading task in females.

5) No significant differences were obtained between Kannada and Hindi language in narration mode in males and females.

6) No significant differences were obtained between the native languages and English language for narration in males and females.

3) Gender Effect:

Mean and mode values for SFF were compared across males and females in normals and dysphonics.

Test of significance showed the following:

1) There was significant difference between males and females in reading, narration and interview style.

2) There was significant difference between males and females across all languages studied in reading style.

3) There was significant difference between males and females across all languages in narration style.

4) In dysphonics, there was no significant difference between males and females in reading style.

5) In dysphonics there was no significant difference between males and females in interview style.

6) In dysphonics, there was significant difference between males and females in narration style.

Effect of Laryngeal Pathology:

From the results of the present 3tudy, it was concluded that dysphonic males use high habitual frequency for speech and dysphonic females used low habitual frequency when compared to normal males and females respectively. No variations in their SFF was noticed in different style of speaking. Test of significance showed that,

1) there was no significant difference between normal and dysphonic males in reading style.

2) there was no significant difference between normal and dysphonics males in narration style.

3) there was significant difference between normal and dysphonic males in Interview mode.

4) there was significant difference between normal and dysphonic females in all three different style of speaking reading, narration and interview.

Effect of Smoking:

All smokers in the presents study showed markedly low SFF values in all 3 styles of speaking when compared to normals. Present study concludes that SFF is a potential too in demarkating smokers and non-smokers.

Teat of significances showed,

1) Significance difference between smokers and non-smokers in reading style.

2) Significance difference between smokers and non-smokers in in narration style.

3) Significance difference between smokers and non-smokers in in Interview style

CONCLUSION:

In the present study, it was noticed that speaking fundamental frequency and habitual frequency varied with the style of speaking. Reading, narration and interview in normal males and females. However, no such marked variations were observed in dysphonics and smokers. When language as a variable was investigated, it was observed that subjects did not vary their SFF and habitual frequency across Hindi and Kannada language. Among Kannada native speakers, there was significant variation in SFF and habitual frequency when English and Kannada passage reading was compared, esp. in females, however no significant variation was seen in males, implying that there may be some interaction between language and gender. Study of smokers and dysphonics revealed that SFF was very sensitive to changes in laryngeal condition and thus can be used as a potential tool for screening and diagnosis.

IMPLICATION

1) The present study accounts for the variability in speech recognition and speaker identification

2) Study reflects on social signifiance of 3peaking fundamental frequency.

3) Speaking Fundamental Frequency can be used as the powerful tool for screening and diagnosis.

BIBLIOGRAPHY

Abramson and Lisker, (1985). Cited in Fo segmental cues depend on intonation: The case of the rise after voiced stops by K.Silverman. Phonetica, 43, 76-91.

ATAL, B.S. (1972). Automatic speaker recognition based on pitch contours. Journal of the Acoustical society of America, 52, 1687-1697.

Atkinson, J.E. (1976). Inter and Intra speaker variability in Fo. Journal of Acoustic Society of America, Vol. 60 (2), 434-342.

Bennett, (1979). Acoustic correlate of received sexual identity in preadolescent children's voices, Journal of Acoustic Society of America, 66(4), 989-1000.

Benolken, M.S. and Swanson, L.E. (1990). The effect of pitch related changes on the perception of sung vowels. Journal of Acoustic Society of America, 87(4), 1781—1785.

Bloothooft, G. and Plomp, R. (1986). The sound level of the singers formant in professional singing. Journal of Acoustical society of America, 79(6), 2028-2033.

Bhome, G. and Heckar, G. (1970). Gerontologische untersuchungen uber stimmumfang and sprechstimmlage. Folia, Phoniatrica, 22, 176-184.

Bohme and Hecker (1970). Cited in Clinical examination of voice, Hirano, M., springer-verlag Wien, N.Y. 1981.

Bolinger, D.L. (1958). Cited in prosodic system and intonation in English by D. crystal. Cambridge University Press, Cambridge, 1969.

Boone, D.E. (1983). The voice and voice therapy (1st ed) Prentice-Hall Inc., Englewoodcliffs, N.J.

Borden, G.J. and Harris, K.S. Speech science primer: Physiology, Acoustics, and perception of speech. William and Wilkins, Baltimore, 1980.

Bristow, G. (1986). Electronic speech recognition. Techniques Technology and Applications, Willins professional and Technical bocks, London.

Cooper, W.E. and Sorenson, J.H. (1977). Fundamental frequency contours at syntactic boundaries. Journal of Acoustical society of America, 62, 683-692.

Cooper, M. (1974). Spectrographic analysis of fundamental frequency and Hoarseness before and after vocal rehabiltation. Journal of speech and hearing disorders, 39, 286.

Crystal, D. (1969). Prosodic systems and intonations in English. Cambridge University Press, Cambridge.

Cruttenden, A. (1986). Intonation, Cambridge University Press, Cambridge.

Diehl, R.L., Lindblom, B., Hoemeke, K.A. and Famy, R.P. (1996). On explaining certain male - females differences in the phonetic realization of vowel categories Journal, of phonetic, 24, 187-208.

Fry, (1958). Cited in Acoustic phonetics - A course of basic reading by Fry, D.B. (Ed.). Cambridge University Press, Cambridge, 1976.

George, S. (1973). A study of fundamental frequency of voice and natural frequency of vocal tract on an Indian population of different age ranges. Unpublished master's dissertation. AIISH, University of Mysore.

Gilbert, H.R. and Cambell, M.I. (1980). Speaking fundamental frequency in three groups of hearing impaired individual. Journal of Communication Disorders, 13, 195-205.

Gopal, H.S. (1980). Relationship for locating optimum frequency in the age range of 7 to 28 years. Unpublished master's dissertation, AIISH, University of Mysore.

Gopal, N.K. (1986). Acoustic analysis of the speech in normal adults. Unpublished master's dissertation, AIISH, University of Mysore.

Gordon, M.T., Morton, F.M., and Simpson, I.L. (1978). Airflow measurements is diagnosis, Assessment and Treatment of Mechanical dysphonia. Folia phoniatrica, Vol. 30, 161-174.

Gould, W.J., Quantitative assessment of voice function in microlaryngology. Folia phoniatrica, 27 (13), 190-200.

Graddol, D. and Swann, J. (1983). Speaking fundamental frequency: Some physical and social correlates. Language and speech, Vol.26, Part 4, 1983.

Graddol, D. (1987). Voices of authority—the sexual politics of human voice. CIAL occasional papers in communication no.4, 1987.

Hanson, R.J. (1982). A two state model of FO control. Journal of Acoustic Society of America, 64, 534-544.

Hanson, D.G., Gerrat, B.R. and Ward, H.P. (1983). Glottographic measurement of vocal dysfunction - A preliminary report. Annals of otorhinolaryngology, 92(5), 413-419.

Hirano, M. (1981). Clinical examination of voice. Disorders of human communication, 5, Springer, Wien.

Hirano, M. (1975). Phonosurgery - Basic and Clinical investigations. Otologic (Fukuoka), 21, 239-240.

Hollien, H., and Shipp, T. (1972). Speaking Fundamental frequency and chronological age in males. Journal of Speech and Hearing Research, 15(1), 155-159.

Hudson and Holbrook (1981). A Study of the reading FO vocal and of young black adults. Journal of speech and hearing, 24(2), 197-201.

Hudson, A.I. and Holbrook, A. (1981). A study of the reading fundamental vocal frequency of young black adults. Journal of speech and hearing research, 24(2), 197-201.

Iwata, S., and Von Leden, H. (1970). Phonation quotient in patients with laryngeal diseases. Folia phoniatrica, 22, 117-128.

Jndson, L.S.V. and Weaner, A.J. (1965). Voice science 2nd edn., Meredith publishing company. Great Britain, 1965.

Kelman, A.W. (1981). Vibratory pattern of the vocal folds. Folia phonetricia, 33, 73-99.

Ladd, D.R., and Silverman (1984). Cited in interaction of vowel FO and prosody by steel-Phonetica, 43, 92-105.

Ladefoged (1964). Cited in interaction of vowel F0 and prosody by steel. Phonetica, 43, 92-105.

Lankkanen, A.M. (1996). Physical variation related to stress and emotional state: a preliminary study. Journal of phonetics, 24, 313-335.

Lass, N.J. (1976). Speaker sex identification from voiced, whispered on filtered isolated vowel. Journal of Acoustic Society of America, 59 (3), 675-681.

Lass, N.J. and Brown, W.S. (1975). Correlation study of speakers heights, weights, body surface area and speaking fundamental frequencies. Journal of Acoustic society of America, 63, 1218-1220.

Lehiste, (1970). Cited in crystal, T.H. and House, A.S., Segmental durations in connected speech signals: Preliminary results. Journal of Acoustic Society of America, 72(3), 1982, 705-716.

Lehiste, (1972). Cited in Klatt, D.H., Linguistic uses of segmental duration in English: Acoustic and perceptual evidence. Journal of Acoustic Society of America, 59(5), 1976, 1208-1221.

Luchsinger and Arnold, (1965). Voice, speech and language. Wordsworth publishing Comm. Inc. California.

Lushsinger and Arnold, (1965). Cited in Boone, D.R., the voice and voice therapy, Prentice Hall, Inc., Englewood Cliffs, N.J., 1971.

Manjula, R. (1979). Intonation in Kannada, some Aspects. A dissertation submitted to the University of Mysore in Part fulfillment of Master's Degree.

Meckfessel (1964). Cited in Gilbert, H.R. and Campbell, M.I., Speaking fundamental frequency in three groups of hearing impaired individuals. Journal of Communication Disorders, 13, 1980, 195-205.

Michel, J.F., and Mendhal, R., Correlation of voice productions. In Travis, E. (Ed.) Handbook of speech pathology and Audiology, Prentice Hall Inc., Englewood Cliffs, N.J., 1971, 465-480.

Mohr,(1971). Cited in Fo segmental uses depend on intonation. The case of the rise after voiced stops by K. Silverman. Phonetica, 43, 76-91.

Morton and Jassem (1965). Cited in supra segmentals by I.Lehisti. The MIT press, Cambridge, 1970.

Mysak, E.D. (1959). Pitch and duration characteristics of older males. Journal of Speech and Hearing Research 2, 46-54.

Nataraja, N.P. and Jayaram, M. (1982). A new approach to the classification of voice disorders. Journal of All India Institute of Speech and Hearing, 12, 21-28.

Nataraja, N.P. (1981). Intonation in four Indian languages under five emotional conditions. Journal of All India Institute of Speech and hearing, 12, 22-27.

Nataraja, N.P. and Jagadish, A. (1984). A vowel duration and fundamental frequency. Journal of All India Institute of Speech and hearing, 15, 72-81.

Nataraja, N.P. and Savithri, S.R. (1990). Cited in Rashmi, M. "Acoustic aspects of the speech of children" unpublished master's dissertation. University of Mysore, 1985.

Nittrouer, (1990). Acoustic measurements of men's and women's voice, a study of context effects of Conversation. Journal of Speech and Hearing Research, 33, 761-775.

Olive. (1975). Cited in linguistic modality effects on fundamental frequency in speech by O'shanghnessy and Allen. Journal of Acoustical society of America, 74(4), 1155-1171.

O'Shaugghnessy, D. (1981). Study of french vowel and consonant durations. Journal of Phonetics, 9, 385-406.

O'shaugghnessy and Allen, J. (1983). Linguistic modality effects on fundamental frequency in speech. Journal of Acoustic Society of America, 74(4), 1155-1171.

Peterson, G.E. and Barney, H.L. Control method used on study of the vowels. Journal of Acoustic Society of America, 24, 1952, 175.

Rajenderan and Yognarayan. (1996). Word boundary hypothesization for continuous speech in Hindi, based on FO patterns. Speech communication, 18(1), 21-46.

Ragini, M. (1989). Acoustical parameters of voice in singing. Unpublished master's dissertation in part fulfillment to the University of Mysore.

Samuel, G. (1973). A stud of Fundamental frequency of voice and natural freqency of vocal tract on an Indian population of different age range. Unpublished master's dissertation, All India Institute of Speech and Hearing, University of Mysore.

Shadle (1985). Cited in interaction of vowel F0 and prosody by steel-phonetica, 43, 92-105, 1986.

Silverman, K. (1986). FO segmental cues depend on intonation. The case of the rise after voised stops. Phonetica, 43, 76-91.

Sorensen and Horii. (1982). Cigarette smoking and voice fundamental freqency. Journal of Communication Disorders, 15, 135-144.

Strick, H. and Boves, L. (1995). Downtrend in FO and Subglottic pressure. Journal of phonetics, 23(2), 203-220.

Suresh, T. (1991). Acoustic analysis of voice in genetic population. Unpublished master's dissertation, All India Institute of Speech and Hearing, University of Mysore.

Swashima, M. (1968). Movements of larynx in articulation of Japanese Consonants. Annual Bulletin 1, Research Institute of Logopedics and Phoneatrics, University of Tokyo, 2, 11-20.

Syrdal and Gopal, H.S. (1986). A perceptual model of vowel recognition based on the auditory representation of American English vowels, Journal of Acoustic Society of America, 79 (4), 1086-1101.

Timcke, R.H. (1958). Laryngeal vibrations, measurements of the glottic wave part-I, the normal vibratory cycle Arch of otolarynglogy, 68, 1-19.

Titze, I.R. (1980). Comments on the Myoelastic -Aerodynamic theory of phonation. Jounal of Speech and Hearing Research, 23(3), 495-510.

Traunmiiller, H. (1994). Conventional, Biological and Environmental factors in Sp. communication. A modulation theory. Phonetica, 51, 170-183.

Umeda, N. (1981). Influence of segmental factors on fundamental frequency in fluent speech. Journal of Acoustical society of America, 70, 350-355.

Usha, A.A. (1978). A study of fundamental frequency in an Indian population. Unpublished master's dissertation, Mysore, 1978.

Vaissiere, J. (1983). Language independent prosodic features in prosody: Models and measurements by A.Cutler and D.R. Ladd (Ed.) Springer-verlag, Berlin.

Van Riper, C. and Irwin, J.V. (1955). Voice and articulation. Prentice Hall Inc., N.J., Englewood Cliffs.

Vonleden, H. (1960). Laryngeal vibrations: Measurements of the glottal wave. Part III The pathologic larynx. Archives of otorhinolaryngology, 71, 16-35.

Westin, Buddenhagen and Obrcht (1966). Cited in supra segmentals by I. Lehiste. The MIT Press, Cambridge, 1970.

Williams, B. (1986). An acoustic study of some features of welsh prosody. In intonation in discourse by C.Johns-Lewis (Ed.). College Hill Press Inc. San Diego.

Wilson, D.K. Voice problems in Children. 2nd Edn., The Williams and Willins Company, Baltimore, 1979.

Zemlin, W.R. Speech and Hearing Science, Englewood Cliffs, Prentice Hall Inc., N.J., 1968.

APPENDIX - I

MATERIAL USED FOR ENGLISH STORY NARRATION

Who will bell the cat ?

Once upon a time, there lived many rats in an old house. One day, the cat attacked the old house and ate some rats. To put an end to this, Worried rats called upon a meeting. In the meeting, all rats put forth thier ideas. One clever rat told that if a bell was tied to the cat's neck, their would be sounds upon its entrance. Having heard the sound, all rats could run for life. But then, there was a problem. "Who would tie the bell to the cat's neck ?" . Just then, cat attacked the old house and all rats ran for life.

APPENDIX - II

MATERIAL USED FOR KANNADA STORY NARRATION

ಬೆಕ್ಕಿಗೆ ಗಂಟೆ ಕಟ್ಟುವವರು ಯಾರು?

ಒಂದಾನೊಂದು ಕಾಲದಲ್ಲಿ, ಹಲವು ಇಲಿಗಳು ಒಂದು ಹಳ್ಳಿಯ ಮನೆಯಲ್ಲಿ ವಾಸವಾಗಿದ್ದವು. ಒಂದು ದಿನ, ಒಂದು ಬೆಕ್ಕು ಈ ಹಳ್ಳಿಯ ಮನೆಗೆ ಮುತ್ತಿಗೆ ಹಾಕಿ ಕೆಲವು ಇಲಿಗಳನ್ನು ತಿಂದುಬಿಟ್ಟಿತು. ಇದಂದ ಗಾಬರಿಗೊಂಡ ಇಲಿಗಳು, ಏದನ್ನು ಕೊನೆಗೊಳಿಸಲು ಒಪ್ಪಂದಕ್ಕೆ ಕರೆದವು. ಈ ಒಪ್ಪಂದದಲ್ಲಿ ಎಲ್ಲಾ ಇಲಿಗಳು ತಮ್ಮ ಬುದ್ಧಿಯ/ಕಲಿಕೆಗಳನ್ನು ಮುಂದಿಟ್ಟವು. ಒಂದು ಬುದ್ಧಿವಂತ (ಶತುರ) ಇಲಿಯು ಬೆಕ್ಕಿಗೆ ಗಂಟೆ ಕಟ್ಟುವುದರ ಬಗ್ಗೆ ಯೋಚಿಸಿತು. ಏದು ವಿನಂಬುತ್ತ ಕೇಳಿತು, ಗಂಟೆಯನ್ನು ಬೆಕ್ಕಿನ ಕುತ್ತಿಗೆಗೆ ಕಟ್ಟಿದರೆ ಅದು ಬರುವಾಗಲೆಲ್ಲಾ ಶಬ್ದ ಏಳುತ್ತದೆ /ಬರುವುದು. ಈ ಶಬ್ದವನ್ನು ಕೇಳಿ ಎಲ್ಲಾ ಇಲಿಗಳು ತನ್ನ ಪ್ರಾಣವನ್ನು ರಕ್ಷಿಸಿಕೊಳ್ಳಲು ಓಡಬಹುದು ಎಂದು ಏದೆ. ಏಲ್ಲಾ ಒಂದು ತೊಂದರೆ ಇತ್ತು. "ಬೆಕ್ಕಿಗೆ ಗಂಟೆ ಕಟ್ಟುವವರು ಯಾರು? ಏಷ್ಟರಲ್ಲಿ, ಬೆಕ್ಕು ಮತ್ತೆ ಈ ಹಳ್ಳಿಯ ಮನೆಯ ಮೇಲೆ ಮುತ್ತಿಗೆ ಹಾಕಿತು. ಈಗ ಎಲ್ಲಾ ಇಲಿಗಳು ತನ್ನ ಪ್ರಾಣವನ್ನು ರಕ್ಷಿಸಿಕೊಳ್ಳಲು ಓಡಿದವು.

APPENDIX - III

MATERIAL USED FOR HINDI STORY NARRATION

"कौन बाँधेगा घंटी"

एक पुराने घर में बहुत सारे चुहे रहते थे। एक दिन एक बिल्ली आकर कुछ चूहों को खा जाती है। सभी चुहे उससे तंग आकर एक सभा बुलाते हैं। सभी चुहे अपने अपने विचार पेश करते हैं। एक चूहे को घंटी के बारे में ख्याल आया। उसके अनुसार अगर बिल्ली के गले में घंटी बांध दी जाए तो, कभी भी बिल्ली के आने पर घंटी की आवाज़ से सब भाग सकते हैं। पर अब समस्या यह थी कि बिल्ली के गले में घंटी कौन बांधेगा? तभी बिल्ली आती है और सभी चूहे अपनी जान बचा कर भाग जाते हैं।

APPENDIX - IV

MATERIAL USED FOR HINDI PASSAGE READING

"ताजमहल"

ताजमहल भारत की सुन्दरतम इमारतों में से एक है। बादशाह शाहजहां ने अपनी पत्नी मुमताजमहल की याद में इसे बनवाया था। ताजमहल आगरा में यमुना के तट पर बना है। ताजमहल को बनाने में भारत के अतिरिक्त अन्य देशों के चुने हुए राज और कारीगरों का भी हाथ है। सतत वर्ष तक लगातार बनते रहने के बाद, यह सन् 1648 में बन कर तैयार हुआ। कहा जाता है कि इस पर कुल साढ़े चार करोड़ रुपये की लागत लगी है। सारी इमारत संगमरमर की बनी है। इसमें कीमती हीरे भी जड़े हुए हैं। देखने में यह इतना आकर्षक है कि विदेशी पर्यटक इसे देखे बिना नहीं जाते हैं।

APPENDIX - IV

MATERIAL USED FOR HINDI PASSAGE READING

"ताजमहल"

ताजमहल भारत की सुन्दरतम इमारतों में से एक है। बादशाह शाहजहां ने अपनी पत्नी मुमताजमहल की याद में इसे बनवाया था। ताजमहल आगरा में यमुना के तट पर बना है। ताजमहल को बनाने में भारत के अतिरिक्त अन्य देशों के चुने हुए राज और कारीगरों का भी हाथ है। सतत वर्ष तक लगातार बनते रहने के बाद, यह सन् 1648 में बन कर तैयार हुआ। कहा जाता है कि इस पर कुल साढ़े चार करोड़ रुपये की लागत लगी है। सारी ईमारत संगमरमर की बनी है। इसमें कीमती हीरे भी जड़े हुए हैं। देखने में यह इतना आकर्षक है कि विदेशी पर्यटक इसे देखे बिना नहीं जाते हैं।