ACOUSTIC ANALYSIS OF THE SPEECH OF THE HEARING - IMPAIRED

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Rajanikanth B.R.

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Dedicated to

All those,

who served to train me,

And those,

whom, I am trained to serve.

<u>CERTIFICATE</u>

This is to certify that this dissertation entitled: ACOUSTIC ANALYSIS OF THE SPEECH OF THE HEARING-IMPAIRED is the bonafide work in part fulfilment for degree of M.Sc, (Speech and Hearing) and of the student with Register Number 8407.

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CERTIFICATE

This is to certify that this Dissertation entitled: ACOUSTIC ANALYSIS OF THE SPEECH OF THE HEARING-IMPAIRED has been prepared under my supervision and guidance.

N.P.Nataraja
Header & HOD.
Speech Sciences.

DECLARATION

I hereby declare that this dissertation entitled ACOUSTIC ANALYSIS OF THE SPEECH OF THE HEARING IMPAIRED is the result of my own study under the guidance of Mr.N.P. Nataraja, Reader and Head of the Department of Speech Sciences, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any university for any other diploma or degree.

Mysore REGISTER NO.8407.

Dated: May 1986.

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INTRODUCTION

Recent investigations have indicated that only about 20% of the speech output of the deaf is understood by the "person on the street". This lack of intelligibility has been associated with some frequently occuring segmental and suprasegmentalerrors. The correlation between the errors and overall speech intelligibility is less clear (Tony Gold, 1980).

Speech is unique to man. Its presence has made all the difference between man and the lower beings. A poor speech development may not only hamper effective communication but also the overall development of the individual.

Among the many variables affecting speech development, hearing level is perhaps the most important (Ling, 1976).

Knowledge of speech production abilities of hearing-impaired individuals is in many ways of potentially of greater value to educators than knowledge of an individuals hearing ability (Moinsen, 1978).

With the current advance in technology, it is possible to overcome the lack of auditory feedback in hearing-impaired by providing a variety of other feedbacks through the other sensory modalities as well as through amplification of sounds.

But before this one has to know the different characteristics and parameters of the speech of hearing-impaired; a proper understanding of which will help in deciding the selection of the different aspects of speech for providing an effective feedback.

But a review of literature indicstes that most of the studies conducted in the past decades studies based on subjective evaluations, where a normal listener was used as an analytica tool (Hudgins and Numbers, 1942; Penn, 1955; Calvert, 1962; Martony, 1965; DiCarlo, 1968; Levitt, 1971; Mangan, 1961; Nober, 1967; Markides, 1970; Smith, 1975; McGarr, 1978; and Geffner, 1980).

Thus, inspite of a long history of speech rehabilitation of the hearing handicapped, it is surprising to note that there are comparitively very few studies investigating the objective parameters (Monsen, 1974, 1976; Gilbert, 1975; McClumpha, 1966; and Calvert, 1962) and specifically the acoustic characteristics of the speech of the hearing-impaired.

Hence, the present study was planned to carry out acoustic analysis of the speech of the hearing impaired.

Purpose of the study:

This study aimed at obtaining the acoustic characteristics of the speech of the hearing-impaired.

Of the different acoustic parameters listed by Hirano (1980), 10 parameters were selected for the present study as they reflect the condition and functioning of respiratory, phonatory and resonatory systems. They have also been studied in the normal population below 15 years (Rashmi, 1985) and above 15 years (Gopal, 1986, Vanaja, 1986).

Fifty-three subjects both males and females, age ranging from 10-20 years were considered for this study. All the subjects had hearing loss of 60 dB or more in their better ear. They had no other abnormalities.

Three trials of maximum phonation duration of /a/, /i/ and /u/ were recorded for all the subjects. Using the data on vowel phonation, the following were determined.

1. The maximum phonation duration
2. The fundamental frequency
3. Frequency and Intensity range
4. Rise and Fall time

Recordings of 3 repetitions of the sentences "idu papu", "idu koti", and "idu kempu banna" were made for all subjects. These were analyzed to obtain.

1. Speaking fundamental frequency
2. Frequency and Intensity range of speech
3. Duration of vowel /i/ in "idu"
4. The Intensity levels of harmonics.

Apart from the latter two measurements, which were made on the High Resolution Signal Analyzer (B&K 2033), all other measurements were made using Pitch Analyzer (PM-100).

The obtained data were subjected to statistical analysis.

Hypothesis: It was hypothesized that (1) "there is no significant difference between the hearing-impaired males and females" and (2) "no significant difference exists in each of the sexes as a function of age" in the following parameters.

1. Maximum phonation d-eviration
2. Fundamental frequency of phonation
3. Frequency range in phonation
4. Intensity range in phonation
5. Rise and Fall Time in phonation
6. Speaking fundamental frequency
7. Frequency range in speech
8. Intensity range in speech
9. Vowel duration
10. Intensity at different harmonics.

Auxiliary hypothesis:

A. Maximum phonation duration:

1. There is no significant difference between the male and females for maximum phonation duration.
2. No significant difference exists for maximum phonation duration as a function age in males.

3. No significant difference exists for maximum phonation duration in females, as a function of age.

II. Fundamental frequency of phonation:

1. There is no significant difference between the males and females for fundamental frequency of phonation.
2. No significance difference exists for fundamental frequency of phonation as a function of age in males.
3. No significant difference exists for fundamental frequency of phonation in females, as a function of age.

III. Frequency range in phonation:

1. There is no significant difference between the males and females for frequency range in phonation.
2. No significant difference exists for frequency range in phonation as a function of age in males.
3. No significant difference exists for frequency range of phonation in females, as a function of age.

IV. Intensity range in phonation:

1. There is no significant difference between the males and females for intensity range in phonation.
2. No significant difference exists for intensity range in phonation as a function of age in males.
3. No significant difference exists for intensity range in phonation in females, as a function of age.

V. Rise time in phonation:

1. There is no significant difference between the males and females for rise time in phonation.
2. No significant difference exists for rise time in phonation as a function of age in males.
3. No significant difference exists for rise time in phonation in females, as a function of age.

VI. Fall time in phonation:

1. There is no significant difference between the males and females for fall time in phonation.
2. No significant difference exists for fall time in phonation as a function of age in males.
3. No significant difference exists for fall time in phonation in females, as a function of age.

VII. Speaking fundamental frequency:

1. There is no significant difference between the males and females for speaking fundamental frequency.
2. No significant difference exists for speaking fundamental frequency as a function of age in males.
3. No significant difference exists for speaking fundamental frequency in females,as a function of age.

VIII. Frequency range in speech:

1. There is no significant difference between the males and females for frequency range in/speech.

2. No significant difference exists for frequency range in speech as a function of age in males.
3. No significant difference exists for frequency range in speech in females,as a function of age.

IX. **Intensity range in speech:**

1. There is no significant difference between the males and females for intensity range in speech.
2. No significant difference exists for intensity range in speech as a function of age in males.
3. No significant difference exists for intensity range in speech in females, as function of age.

X. **Vowel duration:**

1. There is no significant difference between the males and females for vowel duration.
2. No significant difference exists for vowel duration as a function of age in males.
3. No significant difference exists for vowel duration in females, as a function of age.

XI.**ά .ratio:**

1. There is no significant difference between the males and females for of-ratio.
2. No significant difference exists force-ratio as a function of age in males.
3. No significant difference exists for of-ratio in females, as a function of age.

Limitations of the study:

1. The study was limited to the age group 10-20 years only.
2. The study consisted of hearing-impaired children attending a school which emphasized more on total communication than oral-aural approaches.
3. The study was limited to only 10 parameters.
4. Correlation between different parameters were not determined.
5. The sample studied were limited to 3 vowels and 3 sentences only.

Implications of the study:

1. The results of this study would help in better understanding of speech of the hearing-impaired.
2. The measurement of these parameters would help in providing better description of voice and speech of the hearing-impaired.
3. The information obtained from the present study can be used to plan therapy for the hearing impaired.

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REVIEW OF LITERATURE

"Speech may be viewed as the unique method of communication evolved by man to suit the uniqueness of his mind. By its great flexibility, it permits man to produce a variety of signals commensurate with the richness of his imagination. At the same time, the ability to think in terms of causality and purposiveness (time blending) enables man to expand enormously his use of reciprocal communication for the coordination of social activities".(Eisenson,J., Amer, J.P., and Irwin, J.V,1963).

Speech is a complex motor activity and any disorder during the developmental stages of speech might come in the way of the development of motor control.

Among the many variables affecting speech development, heav-ing level is perhaps the most important (Ling, 1976).

Speech is normally controlled through hearing. Nowhere is this clearly shown than in the way a baby learns to talk. All the needs is time. Time for added experiences, time to learn new words through hearing them and time to master vocal control by hearing his own speech (Carhart, 1970).

Because it is natural for the ear to be the channel through which one learns to talk, a serious impairment in hearing will hinder a child's normal development of speech.

The most obvious example of the role played by hearing in acquisition of spoken learning is furnished by the child who is deaf by birth. Unless special training is undertaken, such a child never learns to talk. His deafness closes for him the door through which he would normally acquire both knowledge of speech and control of the speech organs.

Any substantial loss of hearing which exists at birth or occurs soon thereafter will hinder both learning development and the establishment of adequate speech habits. Two factors are responsible - First, the hearing loss reduces sharply the number of listening experiences that the child has and thus slows down the process of learning speech and languages. Second, losses of certain types make it difficult for the child to distinguish some of the elements in speech. No child will learn to produce distinct sounds which he does not hear, unless of course, he has been given special guidance.

Mousen (1978) states that knowledge of speech production abilities of hearing impaired individuals is in many ways of potentially greater value to educators than knowledge of an individuals hearing ability (Rebb, Hughes and Frese, 1985).

While an analytical approach is undoubtedly necessary in order to make tractable the task of studying deficient speech, a problem approach to training may be bound to yield only limited success. Perhaps the most distinguishing characteristics of speech is its integrity and it may be that, training techniques will continue to produce disappointing results until methods are developed that will provide a child with an ever present visual or tactile representation of his own or other peoples speech that is as rich as the representation that the hearing person gets by ear. But exactly what information should be coded are the questions that are yet to be answered. Until they are answered an analytic approach to training is possibly the only path that is open (Nickerson, 1977).

With the advent of high technology it is now possible to develop a great variety of training displays designed to convey information about many aspects of speech. Before this technology can be used with maximal effectiveness, however more information is needed about the characteristics of the speech of the deaf persons and in particular, about how the abjective parameters of speech relate to its perceptual properties.

Descriptions of the speech of hearing impaired individuals have, for the most part been based on perceptual evaluations (Hudgins and Numbers, 1942; Penn, 1955; Calvert, 1962; Martony, 1965; Di Carto, 1968; Levitt, 1971). Investigators who have been concerned with this area have used such terms as hypernasality, hyponasality, gross misarticulations, faulty stress and faulty intonation to describe the speech6f hearing impaired. These confusions may be the result of subjective methods used in the part to evaluate the speech of hearing impaired individuals.

A few investigators have used objective methods to study the speech of hearing impaired (Benson, 1957; McClumpha, 1966; Huntingdon, 1968; Gilbert, 1975; Hutchinson, and Smith, 1976). These studies indicated that in general there is no set of characteristics that best typifies the speech of hearing impaired individuals.

The nature of sound generated in chiefly by the vibratory pattern of the vocal folds. It can be specified both in terms of acoustic and psychoacoustic terms. Acoustic parameters include fundamental frequency, intensity, waveform, or acoustic spectrum and their time-related variations.

Analysis of such acoustic parameters have been considered to be useful in drawing a voice profile. Hirano (1981) has pointed out that the acoustic analysis of voice signal may be one of the most attractive methods for assessing phonatory function or laryngeal pathology because it is non-invasive and provides objective and quantitative data. Many acoustic parameters, derived by various methods have been reported to be useful in differentiating between the pathological and the normal voice.

Few studies of these acoustic parameters have been carried out for the normals in the Indian population. (Kushal Raj, 1984; Rashmi, 1985).

But there is no study so far studying these acoustic parameters in the hearing impaired population.

Hence there is a need for the study of acoustic parameters in the speech of the hearing-impaired. This will not only help in understanding of the speech of hearing-Impaired but also helps in deciding the goals in therapy and increasing the effectiveness of the therapy.

Therefore the present study aims at investigating some of the acoustic parameters (fundamental frequency in phonation and speech, mean frequency and intensity range in phonation and speech, rise and fall time in phonation, maximum phonation duration,harmonics distribution and vowel duration) of the speech of the hearing impaired).

Further the review of literature, that follows, would show the importance of these parameters in understanding better the speech of the hearing impaired. The review also reveals the lack of studies of these parameters (especially some of them) in the hearing impaired population.

Fundamental frequency:

The fundamental frequency often loosely called the pitch of the voiced speech sounds varies considerably in the speech of a given speaker and the average or characteristic fundamental frequency varies over speakers.

Of the three major attributes of voice, the underlying basis of speech, namely pitch, loudness and quality, ".... both quality and loudness of voice are mainly dependent upon the frequency of vibration. Hence it seems apparent that frequency is an important parameter of voice". (Anderson, 1961).

Pitch is the psychophysical correlate of frequency. Although pitch is often defined in terms of puretones, it is clear that noises and other aperiodic sounds have more or less definite pitches. The pitch of a complex tone, according to Stevens and Davis (1935) depends upon the frequency of its dominant component, that is, the fundamental frequency in a complex tone. Plomp (1967) states that even in a complex tone, where the fundamental frequency is absent or weak, the ear is capable of perceiving the fundamental frequency based on periodicity of pitch. Emrickson (1959) is of the opinion that the vocal cords are ultimate determiners of the pitch and that the same general structure of the cords seem to determine the range of frequencies that one can produce.

The factors determining the frequency of vibration of any vibrator are mass, length and tension of vibrator. Thus mass, length and tension of vocal cords determine the fundamental frequency of voice.

There are various objective methods to evaluate the fundamental frequency of the vocal cords. Stroboscope procedure, (pardue pitch meter. High speech cinematography, Electroglottography ultrasonic recordings, stroboscopic laminggraphy (STROL), Capstrum pitch detection, the 3M plastiform magnetic tape viewer. Spectre—graphy, Digi Pitch, Pitch computer and High Resolution Signal Analyzer and others.

The changes in voice with age and within the speech of an individual have been the subject of interest to speech scientists. Various investigators dating back to 1939 have provided data on various vocal attributes at successive developmental stages from infancy to old age. Fairbanks (1946, 49); Curry (1940); Sridecor (1943); Hanky (1949), Mysak (1950), Samuel (1973), Usha Abraham (1978), Gopal (1980) and Kusnal Raj (1984) are some of them.

The voice of a new born has been found to be around 400Hz (Grutzmann and Plateau, 1905, Indira, 1982). The fundamental frequency drops slightly during the first three weeks or so, but then increases until about the fourth month of life, after which it stabilizes over a period of five months. Beginning with first year, fundamental frequency decreases sharply until about 3 years of age, when it makes a more gradual decline, reaching to the onset of puberty at 11 or 12 years of age. A sex difference i.e. apparent by the age of thirteen years,which marks the beginning of a substantial drop for male voices, the well known adolescent voice change in the case of females. The decrement in fundamental frequency from infancy to adulthood among females is somewhat in excess of an octave, whereas males exhibit an overall decrease approaching two octaves (Kent, 1976).

The fundamental frequency values are distinguished by sex only after the age of eleven years, although small sex differences might occur before that age (Kent, 1976).

Studies on Indian population have shown that, in males, the lowering in fundamental frequency is gradual till the age of 10 years, after which, there is a sudden marked lowering in the fundamental frequency, which is attributable to the changes in the vocal apparatus at puberty. In the case of females, a gradual lowering of fundamental frequency is seen (George, 1973; Usha, 1979; Gopal,1980; Kushal Raj, 1983).

Average fundamental frequency decreases with increasing age until adulthood for both males and females. The average drop of females is roughly 75Hz (from about 275-300Hz)to about 200-225Hz) during the time from prepubescence to adulthood. For males the drop over the same period is likely to be about 150Hz (275-300Hz to 100-150Hz) about l00Hz of which may occur abruptly as a result of the adolescent voice break. (Curry, 1940; Fairbanks, 1940).

Of course for any given age, average individual fundamental frequencies span over a considerable range, but about 90% would be expected to be with $\pm$ 30-40Hz of thepopulation norms (Fairbanks, 1940; Fairbanks, Wiley and Lassman, 1959; Hollien and Paul, 1959).

The fundamental frequency varies in the speech of an average speaker over a range of 1-1½ octaves (Fairbanks 1940). It is used to indicate stressed and unstressed vowels, to add emphasis to what is being said and to carry information about the structure and meaning of a sentence.

Linguistic and semantic information is carried by pitch in several ways. A falling pitch is used, for example, to signal the end of the final stressed vowel in a declarative sentence. At a major syntactic break within a sentence such a fall is followed by a rise in pitch to indicate that the sentence is to continue. For certain types of questions, a pitch rise occurs in the final stressed syllable. Also, messages beyond the words - sometimes subtle, sometimes prignant. can be conveyed by the way the utterance is inflected.

The difficulties that the deaf speaker has with pitch are of 2 general types: in appropriate average pitch and improper intonation. Intonation problem in turn can be divided into 2 major types: monotone voice and excessive or erratic pitch variation.

Several investigators have noted that deaf speakers are apt to have a relatively high average pitch or to speak in falsetto voice (Angelocci, Kopp, and Holbrook, 1964; Boone, 1966; Engleberg, 1962; Martony, 1968). There is some evidence that this problem is greater for teenagers thanfor preadolescents and that it is particularly troublesome for adolescent boys (Boone, 1966). Angelocci, Kopp, and Holbrook (1964) suggest not only that fundamental frequency of deaf are higher than that for hearing speaker: on the average; but also that the average fundamental frequency for different speakers spans a wider range.

Deaf speakers often tend to vary the voice pitch much less than do hearing speakers and the resulting speech has been described as flat or monotone (Calvert, 1962; Hood, 1966; Martony, 1968).

A particular problem is that of inappropriate or insufficient pitch change at the end of a sentence (Sorenson, 1974). A terminal pitch rise such as occuring at the end of some questions may be even more for deaf to produce than a terminal fall (Phillips et al., 1968).

Pitch problems vary considerably from speaker to speaker. Whereas insufficient pitch variation has been noted as a problem for some speakers excessive variationhas been reported for others. (Martony, 1968). Such variation are not simply normal variations that have been somewhat exaggerated but rather pitch breaks and erratic changes that do not serve the purpose of intonation.

Some of the abnormal pitch variation in the speech of deaf may result from attempts by speakers to increase the amount of proprioceptive feedback that he receives from the activity of producing speech. Martony (1968) and Willemain and Lee (1971) have observed that deaf speakers sometimes tend to begin a breath group with an abnormally high pitch and then to lower the pitch to a more normal level.

Angelocci, Kopp and Holbrook (1964) found that fundamental frequency varied more from vowel to vowel when the vowels were produced by same deaf speakers than for 1st and 2nd formant frequencies, attributing their type of abnormal pitch variation of effects by the deaf speakers to differentiate vowels by varying fundamental frequency and amplitude rather than frequency and amplitude of formants. "In physiological terms, he achieving vowel differentiation by excessive laryngeal variation with only minimal articulatory variations".

It appears that mean fundamental frequency and its variants in deaf speakers is Belated in a complex manner to fundamental frequency in hearing speakers. Abverations of fundamental frequency contour may be a more characteristic abnormality of deaf speech than abnormalities of mean fundamental frequency its variance. . . . . . .fundamental frequency affects perception of a variety of speech contrast types including, voicing, vowel quality, and a variety of linguistic boundaries (Kimbrough other and Rebecca, Eilers, 1981).

Pitch is a difficult property of speech for deaf children to learn to control. (Boothroyd, 1970). One possible reason for the difficulty is that deaf children may lack a conceptual appreciation of pitch (Anderson, 1960; Martony, 1968). A lack of the intuitive gray of the concept may help explain when deaf children often attempt to raise their pitch by increasing their vocal intensity (Phillips, Remillard, Bass, and Pro-ovest, 1968).

Most often phonation of a vowel is considered for measuring fundamental frequency.

But the fundamental frequency of phonation may not always represent the fundamental frequency used in speech. Hence a separate evaluation of speaking fundamental frequency is important.

This too has been studied by various investigators as a function of age and sex; both in normals and in cases with various pathological conditions like cerebral palsy (Duffy, 1954); mongoloids (Hollien and Copeland, 1965; Michael and Carney, 1964; McIntire and Dutch, 1964; Strazulla, 1953; Benda, 1949; Weinberg, and Zlatin, 1970; Montague, Brown and Hollien, 1974), aeromegaly (Weinberg, et al 1975); stutterers (Healey, 1982); Schizhophrenies (Burk and Saxman, 1968) and various pathological conditions of larynx (Ship and Huntington, 1965; Murray, 1978; Murry and Doherty 1980; Sawashima, 1968).

Bohme and Hecker (1970) reporting the age dependent variations of mean speaking fundamental frequency in normals indicate that mean speaking fundamental frequency decreases with age upto the end of adolescence. A marked lowering takes place during adolescence in men. In advanced age, it becomes higher in man but is slightly lowered in women.

A study of mean modal fundamental frequency in reading in 200 young black adults between 18-29 years, showed lower mean modal fundamental frequencies (i.e. 110.15Hz in males and 193.10Hz in females) when compared to similar white population studied by Fitch and Holbrook (1970).

Hollien and Shipp (1972) present data on the mean speaking fundamental frequency of 175 male talkers ranging in age from 20 - 89 years mean frequency levels by age decade show a progressive lowering of speaking fundamental frequency from age 20-40 with a rise in level from age 60 through the 80s. In the 20-29 years range the mean frequency is reported to be 120Hz. This value (120Hz) obtained for the 20-29 year olds agrees (1) best with the data reported by Hanley (N=27, median freq. = 128.Hz) for a population of about the same size and age. (2) reasonably well for a larger and younger group studied by Hollien and Jackson (N=157, Mean freq. = 128 Hz, mean age = 21 years), and (3) Poorest (tut still not in conflict) with studies by pronovest (N=6, Mean freq.=132 Hz) and by Philhour (N=24, Mean freq. - 132 Hz).

The results indicated by Michel, Hollien and Moore (1965), studying the speaking fundamental frequency characteristics of 15-, 16- and 17- year old girls, in order to determine the age at which adult female speaking fundamental frequencies are established, show that females attain adult speaking fundamental frequencies by 15 years of age.

Rashmi (1985) in her study reports that there is very little change in the SFF as a function of age in males upto the age or

14 years at which age a sudden decrease in SFF is observed (from around 240 Hz in 13-14 years group to about 170Hz in the 14-15 years group) but there is little change in the SFF in the females with increase in age.

In the hearing impaired speakers, due to lack of proper feedback, an inability to control the SFF is seen. Meckfessel (1964) and Thornton (1964) reported SFF data for 7- and 8- year old hearing impaired speakers that were higher than values for normally hearing speakers. Ermovick (1965) and Gruanewald (1966) reported values that were equal to or lower than values for normally hearing speakers.

Meckfessel(1964) and Thornton (1964) reported SFF values in post-pubescent hearing impaired males that were higher than those obtained for normally hearing post-pubescent males, while values obtained by Green (1956) were similar to those for normal hearing males. For hearing impaired females. Green (1956) reported higher values than for normal hearing females, while Ermovick (1965) and Gruenewald (1966) reported values that were similar.

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

A discrepancy, then, exists as to whether or not there are differences in SFF values between normally hearing and hearing-impaired speakers of the same age.

Another factor that may influence SFF is method of communication. Oralinu versus total communication. Green (1956) studied the effects of these two methods of communication on 8-12 and 16-21 year old speakers and found that the differences between the two schools were not statistically significant. But the study by Gilbert and Campbell (1980) in their population of children between 4-6 years and 8-10 years showed that the hearing impaired children from the oralschool for the deaf had speaking fundamental frequencies which were closer to values exhibited by normal hearing speakers than that in the total communication school as shown below:

	Mean speaking fundamental frequency	
	4-6 years	8-10 years
Normal hearing speakers	280.62	264.83
Hearing impaired (Oral school)	316.30	281.21
Hearing impaired (total communication school)	351.85	362.58

The difference between schools may be explained in part by the work of Pollack (1964). The hearing impaired child trained in total communication expressed himself/herself through signs, finger spelling and speech. Pollack (1964) stated that when conflicting or competing "attention tendencies" are present (attending to correct production of signs and finger spelling, as well as voice production), one "tendency" receives most of the attention at the expense of the other. It may be assumed therefore that the child's concentration on the correct production of signs and finger spelling detracts from his or her ability to self-monitor his or her voice through the aid of residual hearing. At an oral school, there is greater emphasis on speech training then at a total communication school.

As may be seen from the following table (Table 2.1) data reported in the literature for preadolescent hearing-impaired speakers, indicate lower fundamental frequency values for females (Ermovick, 1965; Gruenewald, 1966) and values for males which were either similar to (Meckfessel, 1964) or higher than those attained by Gilbert and Campbell (1980).

In post pubescent hearing impaired male and female speakers, again differences are seen. In post-pubescent males Green (1956) and Gilbert and Campbell (1980) reported higher SFF (about 20Hz) than in normals of that age group as reported by Hollien and Shipp (1972). But Meckfessel (1964) and Thornton (1964) reported still higher SFFs. In post-pubescent females, Ermovick (1965), Gruenewald (1966) and Gilbert and Campbell (1980) reported almost similar values which was about 30Hz higher than that reported for normals. But Green (1956) reported values that were still higher.

Table-2.1, Mean SFF in Hz reported in literature for hearing-impaired speakers.

Researcher	Age	Sex	Mean SFF in Hz.
Gilbert & Campbell(1980)	4 - 6	Male Female	345.88 329.51
Meckfessel (1964)	7 - 8	Male	289
Thornton(1964)	3 - 8	Male	329
Greenewald (1966)	7 -8	Female	246
Ermovick(1965)	7 - 8	Female	252
Gilbert & Campbell(1980)	8 - 10	Male Female	305.53 306.53
Green(1956)	16 - 21	Male	155.87 (Oral) 148.96 (Total commts.
		Female	314.39 (oral 335.57 (total commts.
Meckfessel (1964)	17 - 18	Male	184
Thornton (1964)	17 - 18	Male	193
Greenewald(1966)	17 - 18	Female	225
Ermovick (1965)	17 - 18	Female	256
Gilbert and Campbell (1980)	16 - 25	Male Female	141.73 242.33
Ingrisano et al (1975)	4 - 5	Male Female	272.69 286.23
Weinberg & Zlatin(1973)	5 5 6 6	Male Female Male Female	252.4 247.6 247.3 247.0
Gilbert & Campbell(1980)	4 - 6	Male Female	272.69 288.56
Fairbanks(1949a)	7 8	Male Female	294 297

contd...

Researcher	Age	Sex	Mean SFF in Hz
Fairbanks(1949b)	7	Female	281
	8	Female	188
Meckfessel(1964)	7-8	Male	292
Thornton(1964)	7-8	Bale	302
Greenewald(1966)	7-8	Female	236
Ermovick(1965)	7-8	Female	245
Gilbert & Campbell(1980)	8-10	Male	263.44
		Female	266.22
Curry (1940)	10	Male	269.7(Median)
Duffy(1958)	11	Female	258
Holllen et al(1965)	10	Male	235.4
Michel et al (1966)	15	Female	207.5
	16	Female	207.3
	17	Female	207.8
Hollien & Paul(1969)	15	Female	215.7
	16	Female	213.9
	17	Female	211.9
Hollien 6 Shipp(1972)	20-29	Male	210

Few studies have been carried out to note the changes in fundamental frequency in Indian Population with/reference to age (Samuel, 1973; Usha, 1978; Gopal, 1980; Kushal Raj, 1983; Rashmi, 1985) and no study as yet onthe speaking fundamental frequency in the deaf population.

It becomes all the more important as at present, mean SFF is measured as a clinical test value (Hirano, 1981).

Further such an information would be useful inproviding goal for therapy with deaf. Therefore the study of FF in phonation and SFF will be useful.

Maximum Phonation Time (MPT):

Maximum duration of phonation has been used as a diagnostic tool for some time. A significant reduction below normal levels can be related to inadequate voice production.

Yanagihara and Koike (1967) say that MPT is achieved by three physiological factors:

1. Total air capacity available for voice production
2. The expiratory power
3. The adjustment of larynx for efficient air usage i.e. the glottal resistance.

While Arnold (1955) considers MPT to be a good criterion for general quality of voice which can be determined immediately, Yanagihara (1966) considers it to be a good index of efficiency of the vocal function. It can provide information about an individuals efficiency in using the respiratory system for phonation. Gould (1975) stated that MPT gives an indication of the overall status of lryngeal functioning and of the tension in larynx.

Several authors have suggested "norms" for MPT. But there is a wide variation between the norms suggested by different authors even in a particular age group. While Van Riper (1963) suggests that normal voiced individuals should be able to sustain a front, middle and back vowel for at least 15 seconds without difficulty; Fairbanks(1960) reported a normal duration of 20 to 25 seconds.

This lack of agreement among voice experts has led several investigators to study variables which affect MPT. Variables investigated include vital capacity and airflow rate (Yanagihara et al, 1966; Isshiki, et al 1967; Yanagihara, and Von Laden, 1967; Beckett, 1971); Vocal pitch and intensity(Placek and Sanders, 1963; Yanagihara, 1966; Yanagihara and Koike, 1967), sex (Placek and Sanders, 1963; Yanagihara, 1966; Yanagihara and Koike, 1967; Yanagihara and Von Laden, 1967; Coombs, 1976), age (Lanner, 1971; Coombs, 1976;) and height and weight (Lanner,lS71)

Some of the other variables that are studied are: 1. The amount and kind of training an individual has undergone Lass and Michel (1969) indicated that the athletes do better than non-athletes and trained singers do better than non-singers. However the results obtained by Sheela (1979) were not in agreement with the above findings, in that she found no significant relationship between MPT in trained and untrained singers. The MPT ranged from 15-24 seconds in trained singer and 10-29 seconds in untrained singers.

The position of the individual while phonating has been considered as another variable. Sawashima (1966), however found no significant difference in MPT in standing or sitting positions

The number of trials used to obtain MPT is considered another factor, however most of the studies have been based on three trials (Yanagihara, 1966; Yanagihara and Koike, 1967; Yanagihara and Von Leden, 1967; Lanner, 1971; Coombs, 1976). Sanders (1963) found MPT with 12 trials and found no difference between the 1st and 12th trial.

Stone (1976) indicated that adults demonstrated greater MPT for /a/ when fifteen trials were used. Lewis, Casteel and McMohan (1982) have found that the practice of utilizing three trials to determine MPT is inadequate, for it does not represent a 'true' measure of the MPT. They report that it was not until the fourteenth trial that fifty percent of their subjects produced the maximum phonation and not until the twentieth trial, did all their subjects produce MPT, The authors believe this finding to be not only statistically significant but also more importantly clinically significant.

Shigemori (1977) investigated MPT in school children (Table 2.2). The MPT was found to increase with age. The difference between males and females was not significant except among the seventh grade children.

Lawner (1971) measured MPT for /a/, /u/ and /i/ in children aged 9 through 17 years. There was no statistically significant difference between the three vowels. Phonation time increased with age increase and boys had longer sustained phonation time than girls (Table 2.3).

Grade Level	Sex	Average	Range
1st Grade	M	14.2	9.6 - 22.0
	F	13.1	9.0 - 20.6
	Total	13.6	9.0 - 22.0
2nd Grade	M	16.2	10.0- 21.2
	F	15.2	9.2 - 20.6
	Total	15.7	9.2 - 21.2
3rd Grade	M	19.2	13.0 - 32.8
	F	16.3	9.4 - 26.0
	Total	17.7	9.4 - 32.8
7th Grade	M	23.7	10.8 - 46.5
	F	19.8	13.6 - 34.8
	Total	21.7	10.8 - 46.3

Table 2.2: Normal values of MPT (in seconds) in children (Shigamori, 1977).

Age	Time (Secs)	
	F	M
9	8.8	11.4
10	9.4	10.4
11	11.5	12.8
12	12.2	12.2
13	11.0	12.3
14	13.3	17.6
15	12.4	18.9
16	12.9	17.8
17	13.5	16.9

Table 2.3: Averaged MPT in seconds for /a/, /i/ and /u/ (Launer, 1971).

Clinically MPT values smaller than 10 seconds, should be considered abnormal (Hirano, 1981). Sawashima (1966) reported that phonation lengths below 15 seconds in adult males and 10 seconds in adult females should be regarded as pathological.

The rationale for this measure has been given been (1959) who wrote that this simple test gives information the efficiency of the pneumophonic sound generation in the larynx. He further states that "it also demonstrates the general state of the patient's respiratory coordination". This statement can be modified to say that this measure can demonstrate the general status of patient's respiratory coordination, but more accurately indicates the relative efficiency of the pnenmolaryngeal interaction (Michael and Wendahl, 1971). It is also useful in assessing the phonation quotient and the Mean Airflow rate, which in turn is found to be important diagnostic and therapeutic indicators. The measurement of this parameter is speakers with hearing loss, would provide information regarding their ability to use the respiratory and phonatory system. Thus it may be used a diagnostic as well as therapeutic tool.

Rise and fall time of phonation:

Imaiznmi et al (1980) while investigating the possibility of utilizing a sound spectrography for a multidimensional analysis of pathological voices, measured the rising and falling time of sustained vowels as two of the parameters, among the nine acoustic parameters studied. These two parameters were measured on an amplitude display. The rising time was defined as the time required for the increase in overall amplitude from a value of 10% of the steady level to 90%. The falling time was defined as the time span required for the decrease from 90% to 10% of the steady level.

Howell and Rosen (1983) measured the rise time of voiceless affricates and fricatives, when the test material accured in sentences, in isolated words and in isolated non-sense syllables. The rise time of affricates was significantly shorter than those of fricatives. Rise time varied with the type of test material and for all types of material it was significantly longer than those reported by Gerstman (1957). They also printed out that because rise time varied with the type of test material, no auditory sensitivity at a single rise time value can be responsible for the perceptual distinction between voiceless affricates and fricatives.

Many pathological conditions are more apparent during the transitional phase of phonaton, including the onset and the termination of phonation and hence of speech. In this connection further extensive clinical and basic research is required (Hirano, 1981).

Rashmi (1985) testing rise time and fall time in phonation is 220 children from 4 to 15 years normal children found a gradual decrease in rise-time of phonation of vowels /a/ /i/ and /u/ with increasing age in both males and females, except for a slight increase in rise time seen in9-10 year old group of males and 10-11 year old group of females and finally no difference observed between males and females studied. Unlike rise time, the fall time showed an increasing trend in both males and females and no significant difference between males and females. This may indica the control over the phonatory and respiratory system achieved by the individual.

Inspite of the fact that these measurement are simple and important, no study has been done to note the change in this parameter in pathological cases. So it was taken up in the prese study with hard of hearing.

Harmonics:

The speech spectrum is concerned with the frequency and intensity of each overtone (harmonic) of the speechwave. Even 19th century speech scientists were aware of the important contributions these overtones make to the intelligibility of speech. Over the year therefore, many investigations of the speech spectrum have been made. Results from average speech spectrum analysis reveal that "speech energy is generated roughly from 50 to 10,000Hz. The energy is greatest in the 100 to 600Hz region, which includes both the fundamental component of the speech wave and the first formant" (Denes and Pinson, 1963).

Unlike the tuning fork, most sound sources produce vibrations that are complex. Rather than vibrating in simple harmonic motion, they move in a complex manner, consisting of more than are frequency. If the vibration is complex and repeats itself its called periodic, and aperiodia, if the vibrations are random.

Periodic complex vibrations produce signals in which the component frequencies are integral multiples of the lowest frequency of pattern repetition, or Fo. In physics, the Fo is considered to be the first harmonic. Whereas in music the first multiple (2 time the Fo) is called the first harmonic.

In an aperiodic complex wave, the frequencies are not harmonically related as they are for periodic sounds.

The human voice is a low-frequency sound, compared to most other sounds, including those which the humans, make above the larynx. since it contains many harmonics, the voice is also a complex sound. The lowest frequency in the voice spectrum (Fo) sets up a second harmonic (2Fo), a third harmonic (3Fo) and so forth. It is characteristic of the human voice that the higher harmonics have less intensity than the lower ones, so that although the voice contains many high frequency components, the emphasis is on the low frequencies. The intensity falls at 12dB per octave.

A major difference between the sound of a low frequency and high frequency voice is due to the difference in the spacing of the harmonics. A child with a Fo of 350Hz would have a second harmonic at 700Hz, a third harmonic at 1050 Hz and a fourth at 1400Hz. In contrast, a man with a Fo at 150 Hz would have a second harmonic at 300Hz and the ninth harmonic would correspond closely with the child's fourth harmonic. In the same way, a single person adjusting the frequency of his voice also changes the harmonic spacing. In speech some of these harmonics are emphasized because of the resonant characteristics of the vocal tract. The high energy overtone are called formants. These give the voice a certain quality, which is an important clue in speech perception

The harmonics produced in phonation or speech have been measured using narrow band spectrographs and high resolution signal analyzer.

The richness of high frequency harmonics of sustained vowels was used as one of the acoustic parameter for the multi-dimensional analysis of voice, by Imaizumi et al (1980). They adopted a ratio of the mean level of the frequency range between 3.5 and 4.5 KHz to that below 1KHz, using a section display.

It has also been studied by different authors for understanding and classifying vocal efficiency (schultz-Coulan et al, 1979); hoarseness (Yanagihara, 1967); roughness of voice (Emannel and Whitehead, 1979); nasality (Dickson 1959) and infant cries (Illingworth, 1955; Sedlackona, 1964; Makoi et al, 1972; Tankova-Yampolskaya, 1973).

Frokjaer-Jenson and Prytz (1976) obtained the α-parameter, defined as the distribution of amplitude above 1000Hz relative to amplitude below 1000Hz in a patient with unilateral laryngeal nerve paralysis, before and after therapy.

Rashmi (1985) studying α-parameter in normal male and female children between 4-15 years of age found the following results:

1. The energy level above 1000Hz is less than the energy level below 1000Hz.

2. The α-parameter shows no significant difference till the age of 9 years in both males and females. The females Who have shows some difference fall in the 9-14 years range while males fall in 9-15 years range.
3. There is no significant difference in the NT-parameter between males and females in the age range of 4-15 years.

The results therefore indicate that with the onset of puberty there is change in the voice quality, which again may be attributable to the increase in volume and other changes in the supraglottal resonators, which might lead to an increase in noise components in the higher parts of the speech spectrum, thereby, suppressing the harmonics.

No information is available to the present investigator regarding the harmonic distribution in the voice of the hearing impaired speakers. A study of harmonic distribution in the voice of the hearing impaired speakers would show not only the phonatory behaviour but also contribution of supraglottal resonators to the voice. It is often stated that the hearing impaired speakers tense their phonatory andresonatory muscles. Therefore it was considered that will be interesting and useful to study the harmonic distribution in the voice spectra of speaking with hearing-impairment,

Intensity range in bhonation and speech:

Empirically it is well known that disorders of vocal intensity constitute one of the important components of voice disorder.

However measurement of vocal intensity, as a clinical diagnostic tool has not proved as popular as that of fundamental frequency in voice clinics.

However Watancbe et al (1977) reported of two patients with laryngeal polyps and laryngeal cancer, who showed no abnormalities in routine study of vocal intensity. They, therefore stressed the importance of vocal intensity as a parameter in showing phonetic dysfunction.

Study of intensity changes reveals the speaker's perception of physical and psychological distance. Increasing or decreasing total speech power, as discussed by Mol and Uhlenbach (1956), is one of the means of achieving dominance of syllables, words and phrases. Changes of energy signify degrees of emotional involvement such as shouting when angry.

Damste (1970), Komiyana (1972) and Coleman et al (1977) proposed a graphic representation of the fundamental frequency intensity profile. The graph mas named "phonetogram " by Damste and "phonogram" by Komiyana. Rauhut et al (1979) proposed theterm "Voice area" for the representation of maximal or minimal intensity of voice as a function of pitch.

Coleman (1979) in a study of the Fo sound pressure level profile of adult males and females, noted an increase in SPL with an increase in frequency upto a certain limit, after which decrease is seen with further increase in frequency. Generally, most subjects' Fo - SPL profiles manifested a change in both minimum and maximum SPL curves at 60 to 80% SPL level. According to Coleman et al (1977) the average intensity range of phonation (in SPL re: 0.0002 dynes/cm) at a single Fo is 54.8 dB for male and 57 dB for female subjects.

Coleman and Mott (1978) found lower SPL ranges for female children (10-13 years) than those for adult females. Further, they observed that the musical range, in terms of Fo, and SPL, is more restricted, i.e., it lies within the boundaries of the physiological range. The mean physiological SPL range was found to be 159 dB, while the mean musical SPL range was 58dB.

Rashmi (1985) in her study of intensity range of phonation, in children from 4-15 years of age found the following results:

1. The intensity range in the phonation of vowel decrease s as a function of age in males.
2. The range shows no difference as a function of age in females.
3. A significant difference between males and females is seen in the younger age groups, upto about 10 years, after which the difference is no longer significant.

The difference in the intensity range of speech between males and females at particular age levels is inconsistent.

The intensity range of phonation and speech in the hearing-impaired was studied to find out if this parameter varied from the normals and if so, in what way. This could be helpful in understanding the intensity parameters of speech and increasing the intelligibility by reducing the differences if any.

Vowel duration:

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

Normally children produce especially long words and vowels. Naeser (1970) observed that vowels produced by 2 and 3 years old children were longer than those of their parents. Smith (1976) provided quantitative data based on instrumental analysis of speec production in 2 years old, 4 years old and adults. The results suggested that 2 year old vowels were 20-30% longer than adults and 4 year old' s vowels were 10-20% longer than adults. More-over the differences were consistent across several consonants environments also.

DiSimoni (1974) making oscillographic measurements of vowel and consonant durations in CVC and VCV utterances of children 3- 6- and 9- years concluded that:-

1. Variability of the durations tended to decrease with age, a result which parallels the age related variances in the study of Egnchi and Hirsh (1969).

2. The vowel duration in the voiceless consonant environments remained relatively constant for all ages tested, while in voiced consonant environments it was found to increase with age.

3. Vowel durational values compared for both voiced and voiceless consonant environments were found to be significantly different in six and nine year old subjects, but not in 3 year old subjects. Durational differences already begin to appear by age 3, although the differences do not reach statistical significance until age six. DiSimoni interpreted his data as evidence of a developmental pattern in which the control of duration changes rapidly in the period between 3 and 6 years.

Rashmi (1985) in her study with 220 children, both mats and females, from 4-15 years, studying duration of vowel /i/ in a word /idu/ reports that both males and females dhow a decrease in vowel duration with increase in age. In males it decreases from 154-08 m.sec. at 4 years to 60.66 m.sec. at 14 years, and this decrease is statistically significant upto the age of 11 year; after which it is not significant though it does show a decrease in pitch. In females the mean value decreases from 167.63 at 4 years to 70.40 at 14 years, and the decrease in significant till the age of 9 years. From 10-13 years it is not significant. The 14-15 years group show significantly lower value than groups below 12 years. After the age of 12 years the decrease in vowel duration is not significant.

Kent (1975) concludes from a review of literature (esp. Tingley and Allen, 1975) on the topic of variability in childhood speech timing that by 8-12 years adult like stability is achieved.

Duration of individual segments differ widely from the averages of vowel duration of different vowels in a language due to systematic influence of phonetic and syntactic environ-= ments.

Some of the factors that can influence the durational structure of a sentence are (Klatt, 1976):-

- Extra linguistic:
  Psychological and physical state (Williams and Starens, 1972)
  Speaking rate (Huggins, 1964; Goldman Eisler, 1968).
- Discourse level:
  Position within a paragraph (Lehiste, 1975).
- Semantic:
  Emphasis and semantic novelty (Coker et al, 1973)
- Syntactic;
  Pnrase structure lengthening (Martin, 1970; Klatt, 1975)
- Word level:
  Ward final lengthening (Lehiste, 1972; Oiler, 1973)
- Phonological/phonetic:
  Inherent phonological duration of a segment (Peterson and Lehiste, 1960).

Effect of linguistic stress (Parmenter and Travino, 1936).

Effect of post-vocalic consonant (House and Fairbanks, 1953).

Segmental interactions, for eg. Consonant clusters (Klatt, 1973; Haggard, 1973).

- Physiological:

Incompressibility (Klatt, 1973).

In addition to these factors, Lyberg (1981) reported a strong relationship between duration and the Fo change. However, he further goes on to say that the Fo contour can never be a secondary effect of segment durations and that it seems quite impossible to generate the Fo contour only from the durational values.

Lee (1978) has reported that the difference in duration between the tone classes is primarily determined by the shape of the Fo contour. The intrinsic duration of a vowel in a tone language is conditioned by the tone that the vowel carries.

Nataraja. and Jagadeesh (1984) have shown a relationship between Fo of voice and vowel duration and also it is hypothesized that vowel duration would vary with age.

On the other hand, Nooteforem (1972), Cooper (1976), Lindblom et al (1976) and Lehiste (1976) have observed the duration to be independent of the Fo contour.

Measurements of vowel duration has been made using oscillograms, spectrograms, electrokymographic tracings and computers.

Vowel duration in deaf speakers appear to be overlong by a much greater than seen in normal 2- or 4- year olds. Calvert (1961) found the duration of initial unstressed vowels were nearly five times as great in deaf as in normally hearing speaker: Furthermore stressed vowels were nearly twice as long in deaf as in hearing speakers.

Judging from Calvert's data, deaf speakers may have a peculiarly high instability of vowel and consonant durations. As an indication of the variability, Calvert (1962) presents ranges. For example, duration of unstressed vowels before plosives ranged from less than 180 to 800 m.sec for deaf subjects. Comparable durations on hearing adults ranged from 25-180 m.sec.

It is not clear why the deaf should have particular difficulties with timing of speech events, prolonging them and producing apparently high variability of timing. One possibility is that they depend heavily upon vision and that vision simply does not operate in as rapid a time frame as audition (Carlson,1977; Ganong, 1979). Another possibility is that auditory feedback is necessary for rapid smooth production of complex motoric sequences of speech (Lee, 1950) and that hearing impairments limits the necessary information too severely, requiring a general slowing of the mechanism of production and imposing high instability upon timing. Therefore the present study is also considering the vowel duration in the speech of hearing-impaired.

Frequency range in phonation and speech:

During speech, the fundamental frequency of phonation varies. This range is called the speech range or the speech frequency range (Hirano, 1981). The patterned variations of pitch over linguistic units of differing length (syllables, words, phrases, clauses, paragraphs), yield the critical prosodic feature, namely intonation (Freeman, 1982). Variation in Fo and the extent of range use also relate to the intent of the speaker as discussed by Fairbanks and Pronovost (1939), More specifically, the spread of frequency change use corresponds to the mood of the speaker, that is, as Skinner (1935) reports, cheerful animated speech exhibits greater range use, than serious, thoughtful speech. Changes in duration and Fo during syllable elements of words are basic to the melody and rhythm patterns unique to English. Stressed syllables are perceived as being higher in pitch than unstressed syllables (Freeman, 1982).

In terms of developmental changes in the range or variability of Fo, relatively little is known. Most of the literature on the new bom infants cry appears to have the capability of attending this range appreciably in either direction. Ringel and Kluppel (1964) reported a range of 290-508Hz for ten infants aged 4-10 hours. Fairbanks (1942) observed a range of 153-888Hz for an infant in the first mouth of life and a range of 63-263lHz for the first nine months of life. McGlone's (1966) investigation of children aged between one and two years revealed a total range of 16.2 tones, or about two octaves. Van Cardt and Drost (1963) concluded from a study of 126 children in two age groups (0-5 years and 6-16 years) that ".... even in very young children the physiological range of the voice has a broad, almost"adult" range...." and that, the change in the frequency of the speaking voice parallels that of the lowest reachable physiological tone.., Their data indicate that even young children have a Fo range of two and one half to three octaves. If a conclusion is forced from these rather limited data, it would be that the range of vowel frequency does not change appreciably during maturation (Kent, 1976).

The discovery that Fo variability diminishes with age has important implications for the quantitative investigation of speech development. It is not known at what age this apparent refinement of control begins to occur (Kent, 1976). Sheppard and Lane (1968) in a study of infants during the first 141 days of life, reported a rather small and constant variability in Fo values. However Presscott (1975) discovered small developmental increases in the Fo variability within the first nine months of life. Possibly at the same time that a child gains control over the accuracy of his laryngeal adjustments, he begins to vary Fo to achieve intonation like effects. Of course to some degree, accuracy of adjustment is requisite to controlled variation. Concerning this subject, studies of infant intonation have revealed evidence that definite patterns are established during the first year of life (Kent, 1976).

Rashmi (1985) in her study with 220 children from 4-15 years found the following results with respect to frequency range :-

1. The frequency range in phonation decreases as a function of age in both males and females.
2. A sex difference is seen at some age groups.

The findings on the frequency range in speech as follows:-

1. The males show a decreasing trend in the frequency range of speech with increasing age.
2. The females also exhibited a reduction in range of frequency as a function bf increasing age.
3. The difference in frequency range used by males and females are inconsistent.

One of the most extensive study on variability of Fo is that of Eguchi and Hirsh (1969), who collected data for 84 subjects representing adulthood and the age levels of 3-13 years, at one year intervals, for the vowels /i/,/ae/ /u/, /s/, /a/ and /D/, as produced in the sentence contexts. The variability of Fo progressively decreased with age until a minimum was reached at about 10-12 years. This is taken as an index of the accuracy of the laryngeal adjustment during vowel production, then the control improves continuously over a period of at least 7-9 years.

Hudson and Holbrook (1981) studied the fundamental frequency range in reading, in a group of young black adults, age ranging from 18 to 29 years. Their results indicated a mean range from 81.95 to 158.50Hz in males and from 139.05 to 266.10HZ in females. Compared to a similar white population studied by Pitch and Holbrook (1970), the black population has greater mean frequency ranges. Fitch's white subjects showed a greater range below the mean made than above. This behaviour was reversed for the black subjects. Hudson (1981) pointed out that such patterns of vocal behavior may be important clues which alert the listener to the speaker's racial identity.

McGlone and Hollien (1963) studying the pitch characteristics of aged women, 65 to 79 years, reported that women's speaking pitch variability changes little with advancing age. However Stoicheff (1981) reported an increase in variability of Fo in post menopausal adults, which was interpreted as indicating decreased laryngeal control over Fo adjustments.

General conclusions about the diagnostic value of Fo variability are difficult to make because such measurements are helpful in certain pathological conditions but not in others (Kent, 1976).

Frequency range has also been studied in different pathological conditions like laryngitis (Shipp and Huntington, 1965) vocal fold paralysis (Murry,1978) and laryngeal cancer (Murry and Doherty, 1980) and also in stutterers (Travis, 1927, Bryngelson, 1932; Adams, 1955; Gocler, 1961; Laschinger and

Dubois, 1963; Healey, 1982; Lechner, 1963; Ramig and Adams, 1981).

Thus the review of literature indicates the importance of the acoustic parameters of speech in understanding the phonatory and resonatory aspects of the speech of individuals with normal and abnormal speech.

The review of literature has not shown any study regarding the analysis of various acoustic parameters like:-

- Maximum phonation duration
- Fundamental frequency in phonation
- Frequency range in phonation
- Intensity range in phonation
- Rise and tall time of phonation
- Speaking fundamental frequency
- Frequency range in speech
- Intensity range in speech
- Intensity distribution of harmonics.
- Vowel duration of /i/.

In hearing-impaired individuals. However some attempts have been made to study these parameters in normal population.

These and other studies have indicated that a measurement of these parameters provide very useful information regarding the functioning of respiratory and phonatory and resonatory systems and thus help in diagnosis and treatment of individuals with abnormal speech.

Therefore it was considered that it will be necessary to measure these parameters in hearing impaired individuals and to note the deviations from normals. The information thas collected would be useful in describing the speech of hearing impaired individuals and in providing specific goals for therapy with these individuals.

Therefore the present study was undertaken.

METHODOLOGY

The present study was planned to measure the following parameters in the speech of the hearing-impaired.

1. Maximum duration of phonation of vowels.
2. The fundamental frequency of phonation.
3. Rise and Pall time of phonation.
4. Frequency range in phonation.
5. Intensity range in phonation
6. The speaking fundamental frequency.
7. Frequency range in Speech
8. Intensity range in Speech.
9. Vowel duration.
10. Intensity at different harmonics.

Subjects :

Fifty three subjects, both males and females studying in VII, VIII, IX and X standard of Sheila Kothwala School for the Deaf, a day school in Bangalore, were taken for this study.

Age group in years	No.of males	No.of females
10 - 15	17	13
16 - 20	14	9

Table 3.1: Showing the distribution of the subjects in this study

Their age ranged from 11 to 19 years. The criteria for the selection of these subjects was the absence of mental retardation respiratory problem and any observable deformities of the nasal, oral or pharyngeal cavities.

The audiograms of all the subjects showed a hearing loss of 60dB HL or more in 500, 1000, 2000 and 4000Hz.

Samples:

To measure the sample of phonation of vowels, the 3 vowels /a/, /i/ and /u/ were used.

The following 3 Kannada sentences were used for collecting speech samples.

1. idu pa:pu (This is baby)
2. idu ko:ti (This is monkey)
3. idu kempu banna (This is red colour).

These 3 sentences were chosen as they have used in earlier studies of the acoustic analysis of the speech of children (Kushal Raj, Rashmi, 1985) and so it would be possible to compare the results of the present study and also provide details about the acoutic parameters of the speech of hearing-impaired.

Recording of the samples:

All the recordings were made using a Philips Tape Recorder ( ) with a built in microphone and coney cassettes. For all the subjects the distance between the microphone and the month was kept the same (approximately 12 inches). The responses were recorded in a quiet isolated room in the building, where the noise level was minimum.

The data was collected in 2 steps:

Step-1: In step-1, the sample of phonation of vowels was recorded. The subjects were given written instructions in English as follows:-

"When I switch on the tape recorder take a deep breath and say /a/ as longes you can. Do not stop in the middle. Next say /i/ and /u/ in the seme way".

A demonstration was done to each subject by the investigator to confirm that the instructions were understood by the subject. Only when the investigator was satisfied that the instructions were understood by the subject, the recording was done. To facilitate proper understanding of the task, the next subject on the list was made to watch the recordings of the previous subject.

Three phonations of each vowel was recorded. Thus a total of 9 trials, I recordings of the 3 vowels were recorded.

Step-2: In step-2, the speech samples were recorded.

Three cards, containing each of the 3 sentences, "idu pa:pu", "idu ko:ti", and "idu kempu banna" written on them, were placed in front of the subject, and the subjects were asked to read out loudly the sentence to which the investigator pointed,

The written instructions to the subject were - "Read out loudly the sentence, to which I point out now".

However, the recording was done only after each of the subject had a few trials so that he could produce as soon as the card was pointed to.

Three repetitions of each sentence was recorded. Thus a total of 9 sentences i.e., 3 recordings of each of the 3 sentence were collected.

Thus for each subject, a total of 18 trials (3 trials of each of the 3 vowels and 3 trials of each of the 3 sentences) were recorded for analysis.

Analysis:

1. Measurement of maximum phonation duration of vowels:

The recorded samples of the phonation of vowels were played back. The stop watch was started at the initiation of each phonation, and stopped at the termination of each phonation by the investigator. This provided the phonation duration in second: The phonation duration for all the three trials of each of the vowels /a/, /i/ and /u/ were measured. The longest phonation duration among the three trials was considered as the maximum phonation duration in seconds for each vowel for each of the subjects. Thus the phonation duration for each vowel for each subj act was obtained.

2. Measurement of the fundamental frequency:

The samples containing phonation and speechrecording were transferred from the cassettes to the spool type using tape recorder section of the Voice Identification Incorporated, VII-700 Series Spectrograph. The transfer of signal was done using line recording procedures. The following instruments mere used for the measurement of fundamental frequency.

1. Tape recorder.
2. Pitch analyzer (PM-100) (see fig.3.6)

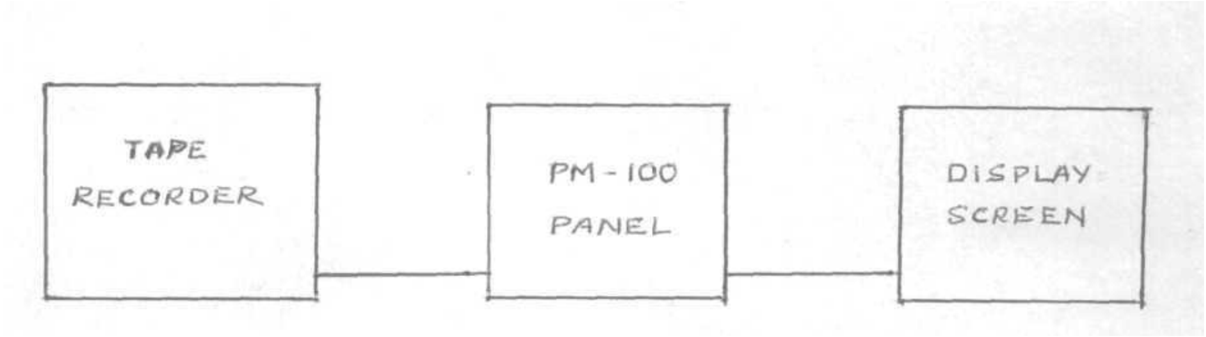


Fig.3.1 Instrumental set up for the measurement of fundamental frequency.

The signal was fed from the tape recorder to the Pitch Analyzer* (PM-100).

This experimental set up who used for the measurement of the fundamental frequency of phonation.

A satisfactory sample for analysis, out of the three trials (for each of the vowels /a/, /i/ and /u/ which had maximum duration) was selected. The selected sample was fed to the Pitch Analyzer as shown in the experimental set up. The mean fundamental frequency was directly read from the digital display on the screen of the pitch analyzer.

3. Measurement of Rise Time and Fall Time of Phonation:

The sample selected for analysis 2 was used for the measurement of the rise and fall time of phonation also. With the experimental set up used in analysis 2, the initial segment of the selected sample was fed to the upper half of the screen, on the display screen of the pitch analyzer, while the final segment of the selected sample of phonation was fed to the lower half of the display screen. The rise-time in centiseconds was measured by moving the cursor from the point where the intensity curve begins (a) to the point to the point where the curve becomes steady (b) The difference between these two points (a and b) provided the rise time in centiseconds.

Similarly the fall time was measured by moving the cursor from the end of the steady portion of the intensity curve (c) to the last point where the curve (d) was visible. The difference between these two (c and d) on the time scale, was noted down as the fall time in centiseconds.

This was done for all the three vowels. The rise and fall time for each subject for each vowel was obtained.

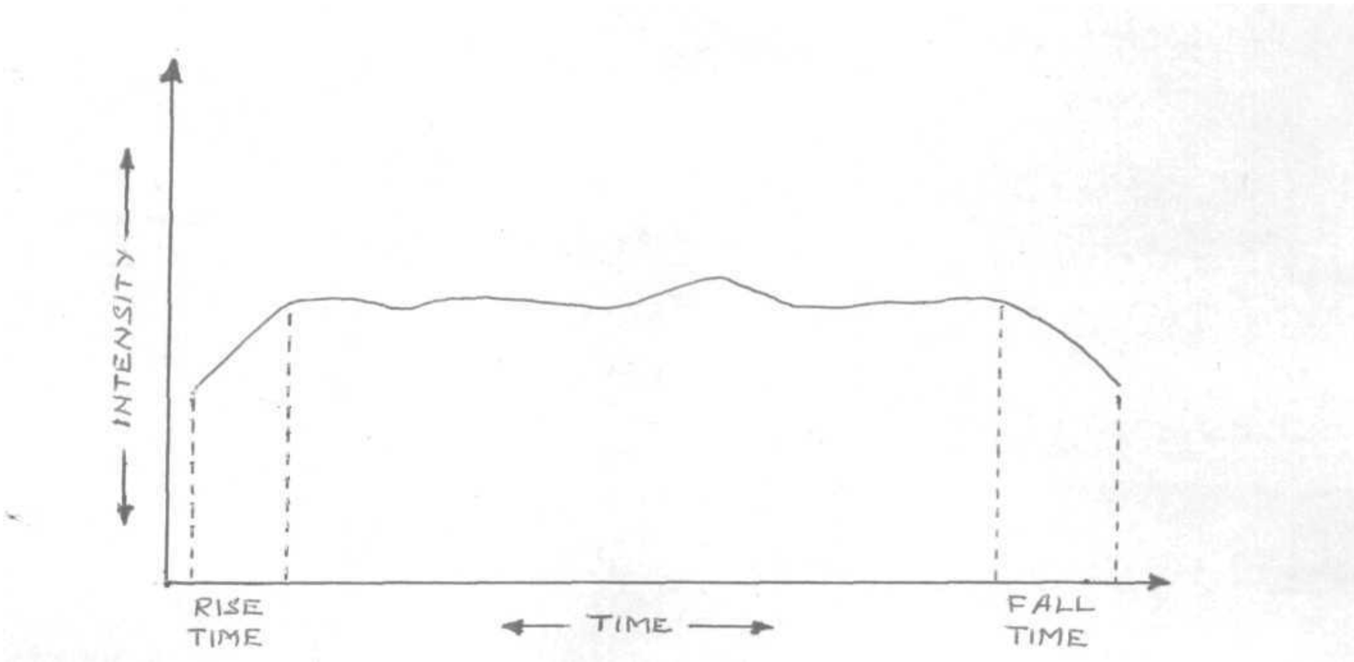


Fig.3.2: The rise time and fall time of Phonation.

4. <u>Measurement of frequency range and intensity range in Phonation</u>

With the experimental set up used in the measurement of fundamental frequency the sample selected in Analysis 2 was fad to the pitch analyzer. The cursor was moved to the highest point on the frequency curve (occuring on the relatively steady portion of the frequency curve) as shown in the Fig, 3.3 . The difference between these two provided a measure of the frequency range used in the phonation of each vowel /a/, /i/ and /u/ for each subject.

Next, with the same sample of the steady portion on the display screen, the cursor was now moved to highest and the lowest points of the intensity curve as shown in Fig. 3.4 The intensity range in decibels in the phonation of each vowel was then determined by finding the difference between the two intensities and noted down. This was done for samples of phonation of the three vowels of each subj act.

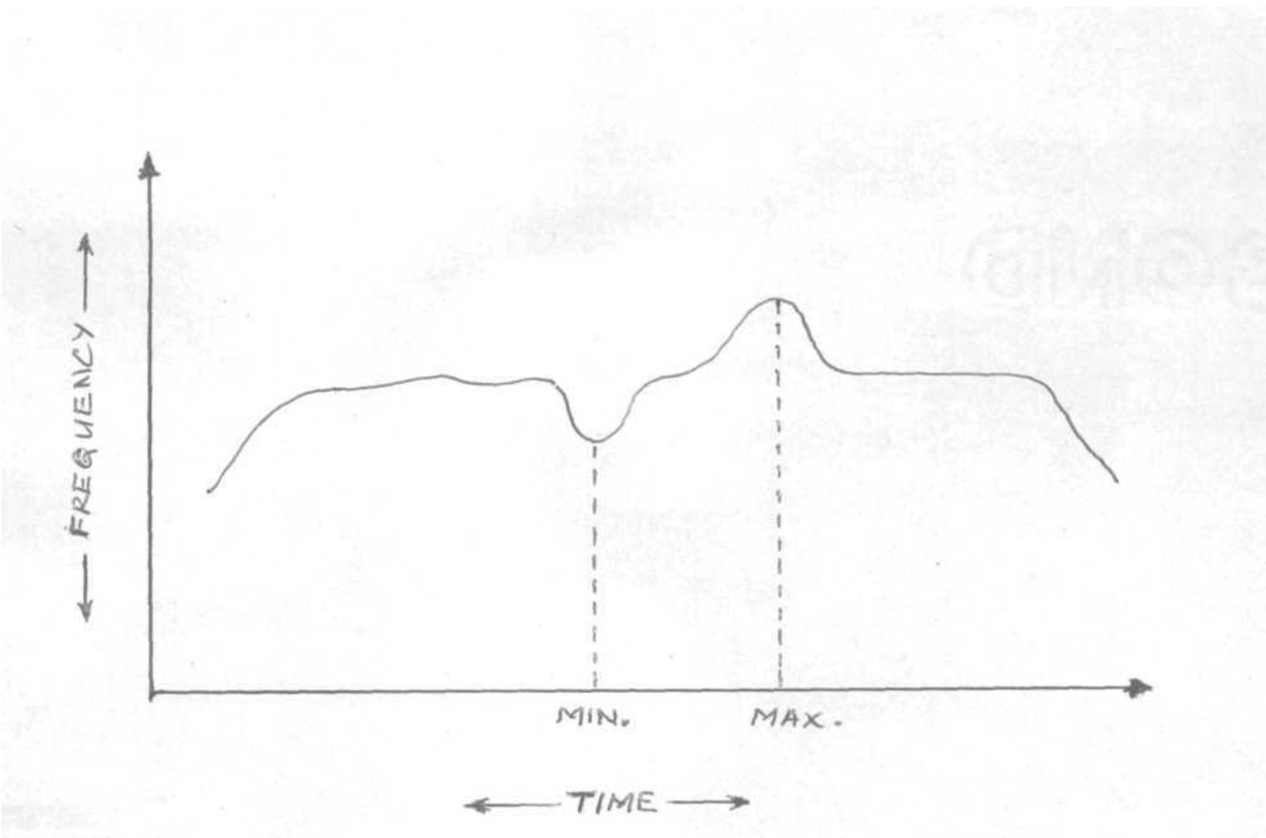


Fig.3.3: The measurement of frequency range in phonation.

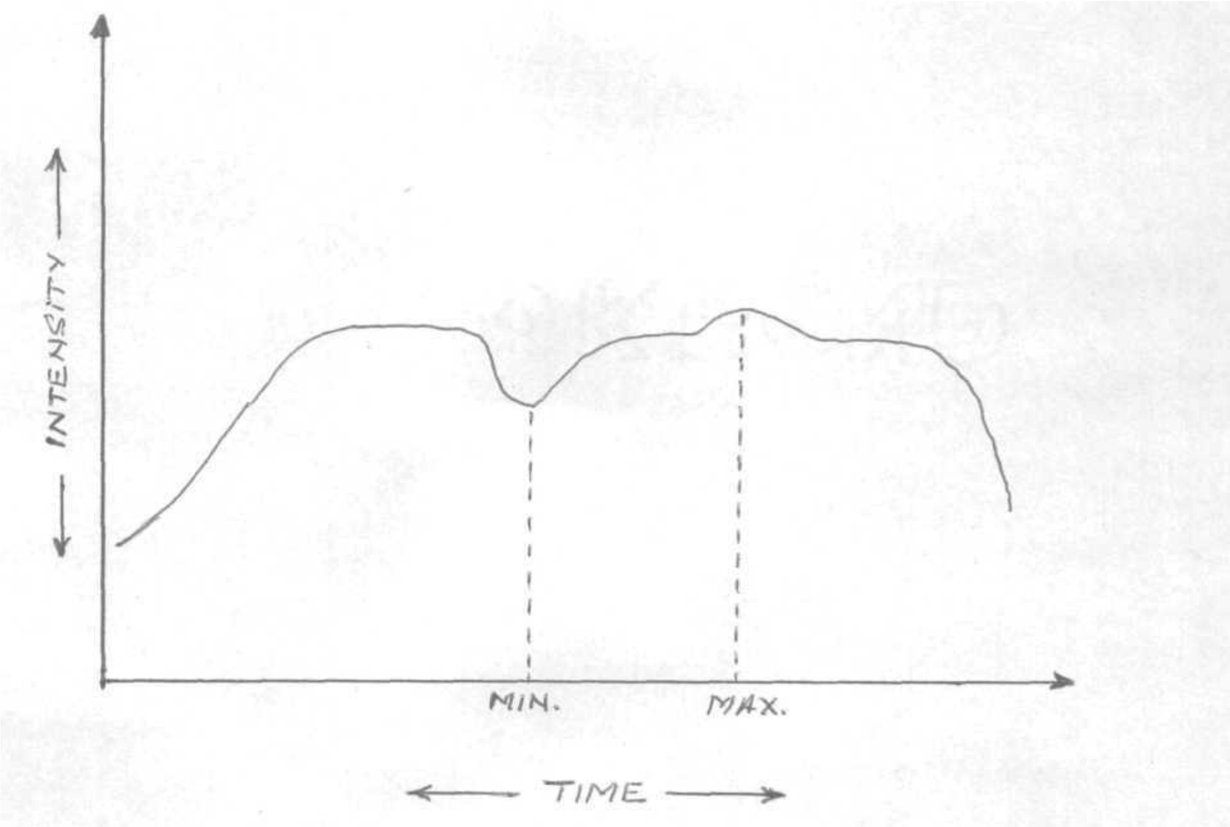


Fig.3.4: Measurement of intensity range in phonation.

5. Measurement of Speaking Fundamental Frequency:

To determine the speaking fundamental frequency. the same experimental set up as in Analysis 2 was used. The display duration was set to 2 seconds so that each stimulus sentence could be displayed more clearly. The stimulus sentences "idu palpu", "idu ko:ti", and "idu kempu banna" was fed to the pitch analyzer one at a time. The mean speaking fundamental frequency for each sentence was directly read using the digital display.

Thus, the mean fundamental frequency used for speaking by each subject was obtained for each of the sentence.

6. Measurement of the Frequency and Intensity range in Speech:

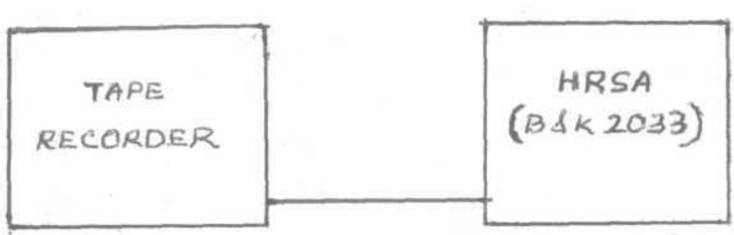
With the same experimental set up and stimulus sentence fed to pitch analyzer as in Analysis 5. The frequency range used by each subject in speech was determined, by moving the cursor to the highest and lowest frequency occuring in the test sentence, and finding the difference between the two. This was found for each of the 3 test sentences, "idu papu", idu ko:ti" and"idu kempu banna".

Also along with the measurement of the frequency range for each sentence, the intensity range for each of the three sentences was also found by moving the cursor from the highest to the lowest intensity points occuring in the sentence. The difference between these two, provided the intensity range in dB, used in each of these sentence, for each subject.

7. Measurement of vowel duration:

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

1. Spectrograph (VII-700 series)
2. High Resolution Signal Analyzer (B&K 2033)



Pig.3.5: Experimental set up for the measurement of vowel duration.

The signal was fed from the output of the tape-recorder section of the Spectrograph to the High Resolution Signal Analyzer.

With this experimental set-up, the word "idu" from one of the stimulus sentences, which was considered as "Good" by the investigator wasted to the HRSA in the time made.

The signal was fed to the HRSA. As soon as the word "idu" appeared on the display screen, the "stop" key was applied. The cursor was moved to the point where the vertical striation began, that is, to the beginning of the envelope and then to the end of the envelope. The difference in milli seconds between these two points was recorded as the duration of the vowel /i/ in "idu". Thus the duration of the vowel /i/ in "idu" as uttered by each subject was obtained.

8. Measurement of Harmonics:

With the above experimental set-up, and the same stimulus word fed into the HRSA (see fig. 3.6) as in Analysis 7, the cursor was moved to the middle of the envelope of the vowel /i/ of "idu", and the input function, showing "Inst.Spectrum" was switched on. This caused the input function to the display selector to be the instantaneous spectrum. The frequency scale selected was 2000Hz.

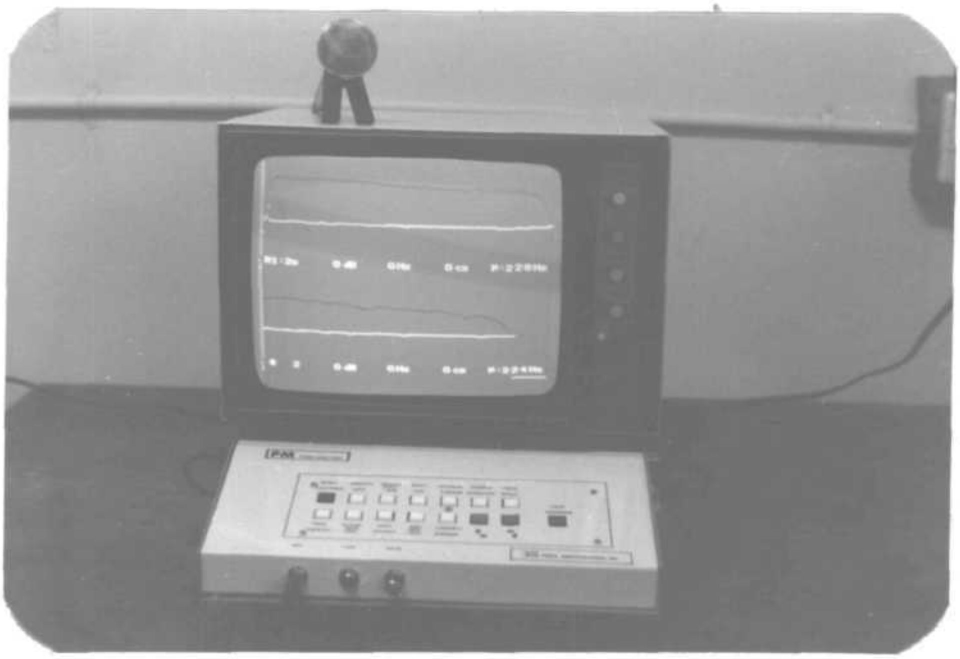


Fig.3.6(a) Pitch Analyzer PM-100

Fig.3.6(b) High Resolution Signal Analyzer
(B&K 2033)

Peaks were seen on the display screen at different frequencies. The cursor was then moved to the peak, in each envelope. The first peak corresponded to the fundamental frequency and the following peaks to the harmonics. The intensity at each peak mas read directly on the digital display. This value was added to the reference intensity level of 60 dB. This provided the intensity of the harmonics upto 2000Hz.

Thus the following parameters were obtained for all the 53 subjects.

Maximum phonation duration of vowels.

Fundamental frequency of phonation

Rise and Fall time of phonation

Intensity range in phonation.

Speaking fundamental frequency

Frequency range in Speech

Intensity range in Speech

Vowel duration and

Harmonics of vowel/i/ and in "idu".

The obtained values were then tabulated and subj acted to statistical analysis.

RESULTS AND DISCUSSION

The present study was carried out to measure the following acoustic parameters in the speech of the hearing-impaired population.

1. Maximum phonation duration of /a/, /i/ and /u/
2. Fundamental frequency of phonation of /a/, /i/ and /u/
3. Frequency range in phonation
4. Intensity range in phonation
5. Rise and fall time of phonation
6. Speaking fundamental frequency
7. Frequency range in speech
8. Intensity range in speech
9. Intensity levels at harmonics and
10. Vowel duration.

These parameters were studied both for males and females in the age range of 10-15 years and 16-20 years. The mean and the standard deviation of all the parameters for both males and females in each of the age groups were calculated. The significance of differences between the age groups in the same sex and between males and females were also determined using Mann-Whitney U-Test.

The results and discussion of each of the parameter given here.

Fundamental frequency in phonation (Fo):

The mean and the standard deviation of Fo of vowels /a/, /i/ and /u/ for both males and females are provided in Table 4.1 and 4.1(A) along with significance of difference between males and females for each age group.

The males, the comparison of Fo in 10-15 years age group (referred to hereafter as "younger group") and 16-20 years age group (referred to hereafter as "older group") indicated a mean of 218.53; 287.65 and 317.06Hz for /a/, /i/ and /u/ respectively for the younger group and a mean of 197.86, 309.79 and 271.14Hz for the older group. Thus the younger group showed a higher mean value for vowel /a/ and /u/, whereas for /i/ the older group showed a higher mean value.

The standard deviation of /i/ was maximum for both younger and older group 108.1 and 102.43 respectively followed by /u/ 92.21 and 78.65 and vowel /a/ showed lesser deviation, 79.56 and 59.61

Also, the older group showed a slightly larger range in Fo varying from 112Hz to 511Hz when compared to younger group which varied from 121-505 Hz.

However, there was a significant difference between the different age groups in males in Fo at 0.05 level. Thus the hypothesis that there is no significant difference between males as a function of age was rejected.

The females showed a mean of 271.69; 301 and 300.54 Hz respectively for vowels /a/, /i/ and /u/ in younger group whereas the older group showed a mean of 249, 295.89 and 333.56Hz respectively. Thus the older group showed a lower mean value for /a/ and /i/, and a higher value for vowel /u/.

The younger group showed a range of Fo from 167Hz to a higher value o± 491.Hz, but the older group showed from a lower value to 130Hz to the highest value of 417 Hz.

The standard deviation in females varied in the younger group from 54.3 for /a/, 69.8 for /i/ and 75.97 for /u/ and in older group from 83.69 for /a/, 59.28 for /i/ and 62.3 for /u/.

Thus there was a significant difference between the females in Fo as a function of age at 0.05 level. Hence the null hypothesis that there is no significant difference between females in Fo as a function of age was rejected.

Further, a significant difference is seen between males and females in the younger group(at 0.05 level for /i/ and /u/ and at 0.01 level for vowel /a/), and also in the older group (at 0.05 level for /a/ and /i/, and at 0.01 level for vowel /u/). So the hypothesis that there is no significant difference between males and females in Fo is rejected for both the age groups.

A comparison of the present data with that of the normative data on Indian population by George Samuel (1973), Usha Abraham (1978), Gopal (1980) and Rashmi (1985) indicated that Fo of Vowel /a/ in 10-15 years age group was closer to the normal range, whereas Fo of vowels /i/ and /u/ were much higher than that reported for normals of that group.

In the higher age group a comparison with results of a study on normals (Vanaja, 1986), who studied the age group 16-25 years, the hearingimpaired showed a significant increase of Fo even at this age group.

This result agrees with that of several investigators (Augelocci, Kopp and Holbrook, 1964; Boone, 1966; Engelberg, 1962; Martony, 1968) who have noted that deaf speakers are apt to have a relatively higher average pitch or to speak in falsetto voice. Also it is more for teenagers than for pre-adolescents and particularly for adolescent boys.

The difference in Fo between vowel to vowel in some deaf speakers, as found in this study, also been reported by Angelocci, Kopp and Holbrook (1964). They attribute this type of abnormal pitch variation to effects by deaf speakers to differentiate vowels by varying Fo and amplitude rather than frequency and amplitude of formants. "In physiological terms, he is achieving vowel differentiation by excessive laryngeal variation with only minimal articulatory variation".

Thus the study of Fo in males and females in the age group of 10-15 years and 16-20 years revealed the following results:-

1. In males, there was a significant difference between the two age groups in Fo.
2. In females also there was a significant difference between the two age groupsin Fo.
3. A significant difference was observed between males and female in Fo for both the age group.
4. The Fo for vowel /a/ was lowest in comparison with /i/ and /u/ which were variable in different age groups for both males and females.

Table-4.1:- Mean and standard deviation of fundamental frequency of phonation in males and females.

Vowels		/a/		/i/		/u/	
Age group		18-25	16-20	10-15	16-20	10-15	16-20
Male	Mean	218.53	197.86	287.65	309.79	317.06	271.14
	S.D.	79.56	59.61	108.1	102.43	92.21	78.65
Female	Mean	751.69	249	301	295.89	300.54	333.56
	S.D.	54.3	83.69	69.8	59.28	75.97	62.3

Table:4.1(A) Significant of difference between different age groups and between males and females on fundamental frequency in phonation

Groups compared	/a/	/i/	/u/
M (10-15)/M(16-20)	p	P	P
F (10-15)/F(16-20)	p	P	P
M (10-15)/F(10-15)	A	P	P
M (16-20)/F(16-20)	P	P	A

*Key provided in Appendix.

Maximum phonation tlme(MPT):

Table 4.2 and 4.2(A) provides the mean and standard deviation of phonation duration for vowels /a/, /i/ and/u/ for both males and females and the significance of the difference between the 2 groups for both sexes.

In males, the younger group showed a mean of 11.59 secs., 11.06 secs and 9.65 secs for vowels /a/, /i/ and /u/ respectively whereas the older group showed a mean of 11.21, 9.93 and 9.71 secs for the same vowels.

The standard deviation of the younger group showed values of 4.77, 3.56 and 3.32 whereas the older group showed a little higher value of 5.79, 4.27 and 4.78 for vowels /a/, /i/ and /u/ respectively.

The older group showed a wider range varying from 4-15 secs, and the younger group also showed similar but slightly lesser range of 5 to 25 secs.

There was a significant difference between the 2 groups of males at 0.05 levels. Thus the hypothesis that there is no significant difference between males for the different age groups were rejected.

In females, the younger group showed close mean values of 7.88, 7.62 and 6.62 secs for /a/, /i/ and /u/ respectively whereas the older group showed slightly higher values of 10.22, 9.33 and 8.56 respectively.

But the younger group showed lesser standard deviation values of 2.22, 2.6 and 2.06 whereas the older group showed a larger variation of 2.73, 2.87 and 2.65.

Compared to males the females showed a smaller range in MPT varying from 3 to 15 secs in young group to 6.15 secs in older group.

In all, the females showed a significant difference between the two age group at 0.01 level. Thus the hypothesis that there is no significant difference between the two groups of females was rejected.

However there was no significant difference between the males and females in the younger age group but the difference was significant for the 16-20 years age group at 0.05 level. Thus the hypothesis that there is no significant difference between males and females was partly accepted and partly rejected.

A review of literature showed that even in normals upto the age of 14415 years (Shigomori,1977; Rashmi, 1985) to even 17 years (Launer, 1971) there was no significant difference in MPT between males and females. It was also seen in hearing-impaired children in this study. So this statement can also be true for the hearing impaired population i.e. no significant difference in MPT between males and females in younger age groups.

Secondly as in normals, with the increase in age there was an increase in MPT and a difference arises between males and females.

However unlike the normal population, some hearing-impaired subjects showed a very low MPT value even at the later age i.e., after puberty and adolescence. This may be due to improper co-ordination between the respiratory and phonatory systems as reported by Yanagihara and Koike (1967) who attribute 3 physiological parameters affecting MPT i.e. a) total air capacity available for voice production (b) the expiratory power and (c) the adjustment of larynx for efficient air usage i.e. the glottal resistance. Michel and Wendahl (1971) also state that MPT can demonstrate the general status of subjects respiratory coordination but more accurately indicates the relative efficiency of the pnenmo-laryngeal interaction.

Based on the results of MPT in males and females in the age group of 10-15 and 16-20 years studied, the following conclusions were drawn:-

1. There was a significant difference between the two age groups studied both in males and females showing an increase in the duration of phonation with increase in age.
2. No significant difference in MPT between males and females was seen in the 10-15 years group; this was also seen in normals, thus indicating that at the early ages not much difference was seen in MPT between males and females.
3. Among the three vowels, the phonation duration of /a/ is found to be greatest, followed by /i/ and finally /u/.

Conclusion (3) was unlike that of normals as studied by Rashmi (1985) who reported that MPT of /i/ was greatest, followed by /u/ and then /a/. A longer phonation on /a/ may be due to the fact that, vowel /a/ was produced at a frequency nearer to the natural or optimum frequency of the subject than vowels /i/ and /u/ which were produced at a more higher frequency (as shown in results showing the fundamental frequency of this population). Thus these results also indicated that the hearing impaired individuals were not using the respiratory and/or phonatory mechanisms

Table:4.2 Mean and standard deviation of the phonation duration of /a/, /i/ and /u/ (in seconds) in males and females.

Vowels				/i/		/u/	
Age group		10-15	16-20	10-15	16-20	10-15	16-20
		11.59	11.21	11.06	9.43	9.65	9.71
		4.77	5.39	3.56	4.27	3.32	4.78
Female	Mean	7.88	10.22	7.62	9.33	6.62	8.56
	S.D.	2.22	2.73	2.6	2.87	2.06	2.65

Table 4.2(A) - Significance of difference between different age groups and between males and females on phonation duration of vowels.

Groups compared	/a/	/i/	/u/
M(10-15) / M(16-20)	P	P	P
F(10-15) / F(16-20)	A	A	A
M(10-15) / F(10-15)	-	-	
M(16-20) / F(16-20)	P	P	p

Appendix

Frequency range in phonation:

It was the difference between the highest and the lowest frequency observed during phonation.

Table 4.3 and 4.3(A) presents the mean and standard deviation of the frequency range in phonation for the different age groups of males and females for the vowels /a/, /i/ and /u/, along with the significance of the difference between means.

Table showed the means of the males in the 10.15 years age group to be 116.71, 136.65 and 145.70Hz for vowels /a/, /i/ and /u, respectively and for the older group to be 155.14, 137.5 and 146.71 respectively.

Along with the large means of frequency range the deviation also showed large values of 103.18, 124.83 and 129.01 for the younger group and 106.42, 102,69 and 84.97 for the older group for vowels /a/, /i/ and /u/ respectively. These large variations may be accounted for by large frequency range shown by each group. While the younger group showed a wide range from a minimum of 7Hz to a maximum of 455Hz, in the older group the range extended from 10-340Hz.

There was a significant difference between the younger and older group of males at 0.05 levels, thus leading to the rejection of the hypothesis that "there is no significant difference between the younger and the older group of males, in frequency range in phonation".

This was also true for females, who showed a significant difference at 0.05 level between the 2 age groups studied, thus rejecting the hypothesis that, there is no significant difference, as a function of age, between the 2 groups of females in the frequency range in phonation.

While the females in the younger group showed a mean of 179.69, 104.69, and 139.77Hz range for vowels /a/, /i/ and /u/ respectively, the older group showed a mean of 220.44, 160.22 and 94.1Hz respectively. But the females showed standard deviation values lesser when compared to males, with the younger group showing 114.07, 95.0 and 93.71 for vowels /a/, /i/ and /u/ and the older group showing 81.20, 109.26, and 80.46 respectively for the three vowels.

Even in the female group, similar to males, the younger group showed a wider range (15-423Hz) than the older group (11-315 Hz).

The males and females showed a significant difference between them for both age groups at 0.05 level. Thus the hypothesis that "there is no significant difference in the frequency range of phonation between males and females" was rejected.

The review of literature en frequency range shows no study in the hearing impaired population. Hence the present study cannot be compared with others. However when compared with studies on normal population (Rashmi, 1985). The hearing-impaired population show a large difference, due to wide variation in frequency in each individuals production. This may be because of 2 reasons, one, even in the stable production of vowels due to large intensity variations in phonation, there are simultaneous variations in the pitch. Secondly, the presence of frequent pitch breaks, sometimes towards lower frequency and sometimes higher, resulted in a wide frequency range. Thus showing the inability of hearing impaired individuals to produce the vowel with steady pitch or intensity.

This also shows that there was lack of laryngeal control in this population, which persists due to lack of auditory feedback, and thus results in inappropriate variation in speech and rendering it unintelligible.

Hence a focus on stabilizing the appropriate pitch would be very useful.

Table 4.3: Mean and standard deviation of the frequency range in phonation in males and females.

Vowels		/a/		/i/		/u/	
Age group		10-15	16-20	10-15	16-20	10-15	16-20
Male	Mean	116.71	155.14	136.65	137.5	145.70	146.71
	S.D.	103.18	106.42	124.83	102.69	129.01	84.97
Female	Mean	179.69	220.44	104.69	160.22	139.77	94.1
	S.D.	114.07	81.20	95.0	109.26	93.71	80.46

Table 4.3(A) Significance of difference between different age groups and between males and females on frequency range in phonation.

Groups compared	/a/	/i/	/u/
M(10-15) / M(16-20)	P	P	P
F(10-15) / F(16-20)	P	p	P
M(10-15) / F(10-15)	P	p	P
M(16-20) / F(16-20)	P	P	P

* Key provided in appendix.

Intensity range in phonation:

The intensity range in phonation was determined by feeding a relatively stable sample of phonation of different vowels to the PM-100 and moving cursor to the maximum and the minimum intensity points. Table 4.4 and 4.4(A) indicates the mean and standar deviation of the intensity range in phonation of vowels /a/, /i/ and /u/ and significance of the difference between the means of each groups.

In males the younger group showed a mean intensity range of 10.65, 10.76 and 12.29 dB respectively for vowels /a/, /!/ and /u/, whereas the older group showed a mean of 8.36, 9.79 and 10.43 dB. Thus both groups showed increasing intensity range for /a/ to /i/ and from /i/ to /u/.

However the range varied in the younger group from 3-24dB and from 3.17 dB in the older group, thus the younger group showed a wider range.

There was also a larger variation in the younger group with the standard deviation values i.e. 4.99, 4.73 and 5.02 respective for vowels /a/, /i/ and /u/ and for older group it was 3.32, 3.3: and 4.29.

Significant difference was seen between the two groups of males in intensity range of vowels /a/ and /u/ at 0.05 level but no difference was seen for vowel /i/. Thus the hypothesis that "there is a significant difference between the males as a function of age, for intensity range in phonation" was partly accepted and partly rejected.

In females, the younger group showed a mean of 8.62, 9.85 and 10.85 dB for vowels /a/ and /i/ and /u/ with a wide range varying from 4-24 dB, while in older group showed a mean of 10.56, 7.56 and 9.56 dB respectively with a range of 5-16dB. Thus the younger group showed a wider range.

While the younger group of females showed a standard deviation of 3.93, 5.1 and 2.67, the older group showed values of 2.96, 2.55 and 2.79 respectively for vowels /a/, /i/ and /u/.

Significant difference between females was seen at 0.05 level for vowel /i/ and /u/ whereas at 0.01 level for vowel /a/. Thus the hypothesis that "there is no significant difference between females in intensity range in phonation" was rejected.

There was also significant difference at 0.05 level between males and females for the lower age group and the higher age group (except vowel /a/ which showed difference at 0.01 level), thus rejecting the hypothesis that "there is no significant difference between males and females in intensity range of phonation".

Rashmi (1985) in her study of normals 4-15 years of age, has shown that the intensity range in the 110-11 years is around 11dB and in the 13-14 years around 8dB. As compared to that the present study shows a slight increase in the average mean (ll.5dB) This is also true for females. And in general, as in normals, even the hearing impaired males show wider intensity range than hearing impaired females of particular age-group.

However the individual variations were wider (4-24 dB) as compared with normals, probably indicating the lack of control in monitoring the intensity of phonation. Thus the younger age group had greater variation in intensity. In case of normals was attributed to anatomical and physiological this variation/changes at or around puberty and at later age it was expected to stabilize. In case of hearing impaired individuals, apart from the anatomical and physiological changes, the variations in intensity were, probably influenced by lack of control over the laryngeal system due to disturbance in auditory feedback. This factor i.e., monitoring of intensity during phonation and thus in speech, must also be considered during therapy with hearing impaired individuals.

Table 4.4: Mean and standard deviation of intensity range in phonation in males and females.

Vowels		/a/		/i/		/u/	
Age group		10-15	16-20	10-15	16-20	10-15	16-20
Male	Mean	10.65	8.36	10.76	9.79	12.29	10.43
	S.D.	4.99	3.32	4.75	3.31	5.02	4.29
Female	Mean	8.62	10.56	9.85	7.56	10.85	9.56
	S.D.	3.93	2.96	5.1	2.55	2.67	2.79

Table 4.4(A): Significance of difference between different age groups and between males and females, on intensity range in phonation.

Groups compared	/a/	/i/	/u/
M(10-15) / M(16-20)	p		P
F(10-15) / F(16-20)	A	P	P
M(10-15) / F(10-15)	P	P	P
M(16-20) / F(16-20)	A	P	P

<u>Rise-time of phonation:</u>

The rise-time of phonation was found by subtracting the point at which phonation-is initiated from the point at which phonation became steady in terms of intensity on the time scale, in centiseconds. The rise-time of phonation was found for the three vowels /a/, /i/ and /u/. The mean and the standard deviation for each group for both males and females, is presented in table. 4.5 and 4.5(A) along with significance of difference between means.

In males, the mean of rise-time in younger group showed values of 6.65, 5.29 and 6.18 centiseconds respectively for vowels /a/ /i/ and /u/ whereas in the older group it showed 6.29, 5.14 and 6.36 centiseconds.

The range varied in younger group from 1-12 centiseconds and for older groups from 2-12 centiseconds time showing a wider range in younger group.

The standard deviation for the younger group of males was 2.55, 2.23 and 2.96 centiseconds whereas for the older group it was 2.73, 2.66 and 2.84 centiseconds. respectively for the three vowels.

There was a significant difference between the 2 age groups at 0.05 level thus the hypothesis that there is no significant difference between the2 age group in males" was rejected.

It was also true for females who showed a significant difference as a function of age at 0.05 level. Thus the hypothesis that "no significant difference exists between the 2 groups of females" was rejected.

In females, the younger group showed the mean rise time of 5.92, 4.77 and 5.92 centiseconds respectively for the 3 vowels, with a range of 2-13 centiseconds while the older group showed mean of 5.44, 4.67 and 6.33 centiseconds with a range varying from 2-11 centiseconds.

Further, males and females showed significant difference between them at 0.05 level for both the younger and older age groups. So the hypothesis that "no significant difference exists between males and females in rise time in phonation" was rejected.

Comparing the results of the present study with that of normals studied by Rashmi (1985) it can be seen that for normals the rise-time shows a higher value in the 10-15 year range in males. At 10-11 years for normals mean value is 9.8, 10,2 and 9.4 centiseconds for /a/, /i/ and /u/ and at 14-15 years and is 8.1, 6.7 and 8.2 centiseconds respectively. This reduced rise-time may be possibly due to the abrupt initiation of phonation which was typical of many of the subjects especially some who showed a minimum of just 1-2 centiseconds. A similar result was seen in case of females also in the 10-15 years age group.

The large individual variation and wide range in rise-time indicated the lack of laryngeal control as well as coordination between respiratory and phonatory system.

It would be interesting to train the hearing impaired individuals, through visual feedback, to initiate phonation smoothly, thus increasing the rise-time and observing its effect on the intelligibility of speech.

It becomes all the more important around and after the onset of puberty, where there are more changes in the laryngeal system.

Table 4.5: Mean and standard deviation of rise-time in phonation (in centiseconds) in males and females.

Vowels		/a/		/i/		/u/	
Age groups		10-15	16-20	10-15	16-20	10-15	16-20
Male	Mean	6.65	6.29	5.29	5.14	6.18	6.36
	S.D.	2.55	2.73	2.23	2.66	1.96	2.84
Female	Mean	5.92	5.44	4.77	4.67	5.92	6.33
	S.D.	2.72	3.05	2.52	1.58	2.5	2.55

Table 4.5(A) significance of difference between different groups and between males and females on rise-time in phonation.

Groups compared	/a/	/i/	/u/
M(10-15) / M(16-20)	P	P	P
F(10-15) / F(16-20)	P	P	P
M(10-15) / F(10-15)	P	P	P
M(16-20) / F(16-20)	P	P	P

*Key provided in Appendix.

Fall-time of phonation:

Fall time of phonation has been defined as the time in centiseconds between the drop in intensity of the steady state to the termination of phonation. The mean and the standard deviation for the fall time of phonation for vowels /a/, /i/ and /u/ for males and females in different age groups are given in Table 4.6 and 4.6(A) along with the significance of the difference between means

A scrutiny of thetable showed the mean values for the younger group of males for the three vowels /a/, /i/ and /u/ to be 7.76, 6.53 and 6 centiseconds, and for older group it showed 7.71, 7.71, and 9.07 centiseconds.

However the range for the younger group varied from 3-12 centiseconds with standard deviation of 3.01, 2.07 and 2.35 and for the older group from 4,16 centiseconds with standard deviations of 2.73, 2.16 and 3.2 centiseconds for the vowels /a/, /i/ and /u/.

Significant difference at 0.05 level for vowel /a/ and /i/ and 0.01 level for vowel /u/ were seen between the 2 groups of males thus rejecting the hypothesis that "no difference exists between the 2 groups in fall time".

The females, in the younger group showed mean rise-time values of 7.77, 6.77 and 6.62 with a range varying from 3-13 eent seconds while the older group showed mean values of 8.33, 8.44 and 7.44 centiseconds for the three vowels /a/, /i/ and /u/ with a range of 5-12 centiseconds.

The females also showed a significance difference in the fall time between the 2 groups as a function of age, thus reading to the rejection of the hypothesis that "no significant difference exists between the 2 group of feameles".

The difference was also significant at 0.05 level between males and females for the 2 groups thus the hypothesis that "there is no significant difference between the two sexes in the fall-time of phonation" was rejected.

Comparing with the results in normals (Rashmi, 1985) the present study also showed the fall time to increase with increasing age for the vowels /a/, /i/ and /u/ in both males and females.

But comparing with the normal data, which showed the rise time to vary from a minimum of 10.7 centiseconds in 10-11 years group to a maximum mean value of 19.9 centiseconds for 14-15 years group, the hearing-impaired showed a sharper and shorter fall time which again indicates abrupt termination of phonation.

Thus the hearing impaired population showed abrupt initiation and termination of phonation.

This could be one of the factors in making the speech of the hearing impaired unintelligible. So, further studies to increase the rise and fall time. In hearing impaired and noting its effect on the intelligibility of speech, would be useful in therapy and better understanding of the speech of the hearing impaired.

Table 4.6: Mean and standard deviation of All-time in phonation (in centiseconds) in males and females.

Vowels		/a/		/i/		/u/	
Age group		10-15	16-20	10-15	16-20	10-15	16-20
Male	Mean	7.76	7.71	6.53	7.71	6.0	9.07
	S.D.	3.01	2.73	2.07	2.16	2.35	3.2
Female	Mean	7.77	8.33	6.77	7.44	6.62	7.44
	S.D.	2.77	2.78	2.13	1.88	1.71	2.65

Table 4.6(A) Significance of difference between different age groups and between mats and females on fall time in phonation.

Groups compared	/a/	/i/	/u/
M(10-15) / M(16-20)	P	P	A
F(10-15) / F(16-20)	P	P	P
M(10-15) / F10-15)	P	P	P
M(16-20) / F(16-20)	P	P	P

*Key provided in Appendix

Speaking fundamental frequency(SFF):

The SFP for the sentences "idu papu", "idu koti", and "idu kempu banna" were found by the method described in chapter-3. The mean and standard deviation along with the significance of the difference; between the means are shown in the Table-4.7 and 4.7(A).

For the three sentences, the mean values in the younger group of males showed 284.71, 298 and 295.23Hz respectively with the range varying from 205-419Hz, and for the older group it showed the mean values of 286, 275.14 and 291.5Hz respectively with the range varying from 203-437 Hz.

The standard deviation for the younger group showed 33.86, 45.99 and 42.2 for the three sentences "idu papu", "idu koti", and "idu kempubanna" respectively whereas the older group showed values of 57.29, 58.25 and 51.34 respectively showed more variation than the younger group.

There was a significant difference between the two groups of males, at 0.05 level, thus rejecting the hypothesis that "no difference existed between the two groups of males in the SFF".

In females, however the younger age group showed mean value of 269.92, 285.08, and 271.77 respectively for the three sentenc with a range from 206-408Hz, while the older group showed slight higher mean values of 273.33, 308.44, and 310.67Hz respectively with a range varying from 209-358 Hz.

But in younger females the standard deviation showed higher values of 55.03, 58.90 when compared with the older group which showed 44.4, 47.94 and 29.66 respectively. Thus the older female showed higher mean values with lesser variation than the younger population.

A significant difference at 0.05 level was noted for the 1st and 2nd sentence "idu papu" and "idu koti" and at 0.01 level for the 3rd sentence "idu kempu banna",thus the hypothesis that "no significant difference exists between the2 groups of females."

There was also a significant difference at 0.05 level between males and females for both the age groups, thus leading to the rejection of the hypothesis that "no difference between the two sexes existed for the SFFV

A review of literature indicates that, when compared With the normal population of a similar age group (Michel et al, 1966; Hollien and Paul, 1969; Hollien and Shipp, 1972; Rashmi, 1965; Shukla, 1985 and others) the hearing impaired show a higher SFF.

This was in agreement with many other studies in literature (Meckfessel, 1944; Thornton, 1964; Green, 1956; Gilbert and Campbell, 1980.

This may indicate lack of laryngeal control due to absence of auditory feedback. And also the fact that these children were from a school where total communication is encouraged (Gilbert and Campbell, 1980; Polack, 1964). Thus the hearing impaired must also get therapy for modification of lowering of fundamental frequency.

Table 4.7: Mean and standard deviation of the speaking fundamental frequency in males and females.

Sentences		Idu papu		Idu koti		Idu kempu banna	
Age group		10-15	16-20	10-15	16-20	10-15	16-20
Male	Mean	284.71	286	298	275.14	295.23	291.5
	S.D.	33.86	57.29	45.99	58.25	42.2	57.34
Female	Mean	269.92	273.33	285.08	308.44	271.77	310.67
	S.D.	55.03	44.4	58.90	47.94	57.59	29.66

Table4.7(A) significance of difference between different age groups and between males and females on speaking fundamental frequency.

Groups compared	Idu papu	Idu koti	Idu kempu banna
M(10-15) / M(16-20)	P	P	P
F(10-15) /F(16-20)	P	P	A
M(10-15) / F(10-15)	P	P	P
M(16-20) / F(16-20)	P	P	P

*Key provided in Appendix.

Frequency range in Speech:

The frequency range utilized in each of the three sentences "idu papu", "idu koti"& "idu kempu banna" was determined and the maximum range, i.e. the difference between the highest and the lowest values of the three sentences were also calculated. The mean and standard deviation for each age group for both males and females along with significance of the difference between means is given in Table 4.8 and 4.8(A).

The mean value of the younger group of males showed 376.06Hz, with standard deviation of 67.96 and range varying from 268, 534Hz, The mean value of the older group showed 359.86Hz with a standard deviation of 38.83 and range varying from 302-410Hz.

There was a significant difference between the males at 0.05 level thus rejecting the hypothesis that no significant difference exist between males as' a function of age.

In females, the younger group showed a mean of 343.38Hz (SD 47.78) with a range varying from 252-403Hz, while the older group of females showed a mean of 373.89Hz (SD 30.10) with a range varying from 313-414Hz.

The females also showed a significant difference as a function of age,at 0.01 level of significance, thus rejecting the hypothesis that "no difference exists between the 2 groups". So the males showed more difference as a function of age than the females.

Males and females showed significant difference for both age groups at 0.05 level of significance thus the hypothesis that "no difference exists of between males and females" was rejected.

A review of literature showed that as in normals the males showed a significant decrease in the frequency range with increas in age but it was not so in the case of females who showed an increase in the frequency range with increasing in age.

However, in comparison with the normals the hearing-impairs showed a larger variations. While the normals showed a maximum of 74Hz to around 54Hz the hearing-impaired showed variations around or above 300Hz. This may be due to the pitch breaks which were common in them or due to large variations in fundamental frequency. This again indicates the lack of control over the laryngeal system in hearing impaired individuals.

Table-4.8: Mean and standard deviation of frequency range in speech in males and females.

Age group		10-15	16-20
Male	Male	176.06	359.86
	S.D	67.96	38.83
Female	Mean	343.38	373.89
	S.D.	47.78	30.10

Table 4.8(A) Significance of difference between different age groups and between males and females on Frequency range in Speech.

Groups compared	Significance
M(l0-15) / M(16-20)	P
F(10-15) / F(16-20)	A
M(10-15) / F(10-15)	P
M(16-20) / F(16-20)	P

*Key provided in Appendix.

Intensity range in speech:

The intensity range in speech was calculated by feeding and 3 sentences "idu papu", "idu koti", "and "idu kempu banna" to the pitch analyzer and noting the highest and lowest intensity points The maximum and the minimum points of the 3 sentences were noted to find out the intensity range in speech. Table 4.9 and 4.9(A) provides the mean, the standard deviation and the significance of difference between means.

As can be seen from the table, the younger males showed a mean of 24.65dB(SD = 3.99) with a range varying from 19-32 dB, while the older group showed a mean of 23.29 dB(SD=4.97) with a range varying from ll-33dB,

A significant difference was seen between the 2 groups of males at 0.05 level, thus the hypothesis that "there is no significant difference between the males as a function age"was rejected

In females,the mean for the younger group showed 22.31dB (3D 4.33) with a range varying from 14-28dB, while the older group showed a mean of 23.78 dB(SD=3.70) with a range varying from 18-30dB.

Females also showed a significant difference at 0.05 level, this the hypothesis that "there is no significant difference between the 2 groups of females" was rejected.

A significant difference between males and females was also seen at 0.05 level for both the groups, thus the hypothesis that "no difference exists between males and females" got rejected.

Comparison of the results of the present study with a similar study on normals (Gopal, 1986) showed that the intensity range in speech of males (16-20 years) in normals and hearing impaired to similar but the hearing-impaired showed a large individual variations. This could be due to the lack of feedback in this population.

In contrast to males, the hearing impaired females showed a larger mean value than normals and also a wide individual variations.

So the hearing-impaired can either use very narrower or a very wide range. This can be partly due to lack of auditory feedback and/or due to use of a higher Fo than normal.

Thus a focus on correcting the intensity range in speech and phonation could be useful in increasing the intelligibility of speech.

Table 4.9: Mean and standard deviation of intensity range in Speech in males and females.

Age group		10-15	16-20
Male	Mean	24.65	23.29
	SD	3.99	4.97
Female	Mean	22.31	23.78
	SD	4.33	3.70

Table 4.9(A) Significance of difference between different group and between males and females on Intensity range in speech.

Groups compared	Significance
M(10-15) / M(16-20)	P
F(10-15) / F(16-20)	P
M(10-15) / F(10-15)	P
M(16-20) / f (16-20)	P

* Key provided in Appendix.

Harmonics:

α ratio,showing the ratio between intensity of harmonics below and above 1K.

The ratio of vowel /i/ and "idu" was found by the method described in Chapter-3. Table 4.10 and 4.10(A) shows the mean and standard deviation and also the significance of difference between the means.

The younger group of males showed a mean of 0.72(SD=0.09) with a range of 0.50 - 0.86, while the older group showed a mean of 0.76(SD =.06) with a range of 0.65 - 0.84 on this measure.

A significant difference at 0.05 level was seen between the 2 groups of males, thus rejecting the hypothesis that "no difference exists between them as a function of age".

Similarly a significant difference at 0.05 level was also found for the females as a function of age thus the hypothesis that "no difference exists between them" was rejected.

The younger female group with a mean value of 0.75(SD 0.05) with a range varying from 0.66 - 0.81 and for the older group with mean of 0.71 (SD 0.09) with a range of 0.61 - 0.85.

Both males and females also showed a significant difference at 0.05 level for different age levels thus rejecting the hypothesis that "no difference exists between males and females".

The α -parameter was recommended by Frokjaer-Jenson and Prytz(1976) as an indicate of voice quality. So the results of this study indicates that there was a change in voice quality, both as a function of age in males and females, and also between males and females. This was unlike that in normals (Rashmi,1985) who showed that from 4-15 years no difference was seen between males and females.

But the energy level above 1000Hz is less than the energy level below 1OOOHz which was also true for normals (Rashmi, 1985)

The change in voice quality may be due to the onset of puberty in males, and changes in any one of the other parameters like the fundamental frequency of phonation, increase in volume change in the supraglottal resonators, or even mode of initiation of phonation and the shape and size of the resonators. As the hearing impaired individuals had shown a change in α ratio than in normals it is to be interesting to investigate further in this aspect and to find out the effect of this an intelligibility.

Table 4.10: Mean and stanard deviation of theratio of the intensity level of harmonics above 1000Hz to that below 1000Hz in males and females.

Age group		10-15	16-20
Male	Mean	0-72	0.76
	S.D.	0.09	0.06
Female	Mean	0.75	0.71
	S.D.	0.05	0.09

Table 4.10(A) Significance of difference between different age groups and between males and females in the parameter

Groups compared	Significance
M(10-15) / M(16-20)	P
F(10-15) / F(16-20)	P
M(10-15) / F(10-15)	P
M(16-20) / F(16-20)	P

Vowel duration:

The duration of the vowel /i/ occuring in the word "idu" in milliseconds was found using the High Resolution Signal Anazer (B&K 2033).

As can be seen from Table 4.11 and 4.11(A), the younger males showed a mean value of 147.76 m.sec. with a wide range from 76-281 milliseconds and a standard deviation of 59, while the older group showed a lower mean of 127 m.sec. with a wider range from 45-328 m.sec. and hence a standard deviation of 75.99.

The males showed a significant difference at 0.05 level between the 2 age groups, thus rejecting the hypothesis that "no significant difference exists between mats as a function of age".

But no significant difference showed up in the females as a function of age, thus accepting the hypothesis that "no difference exists between the 2 age group in females".

However the younger girls showed a mean of 112.15 m.secs as against 188.11 m.sec in older group. The range was 76-175m.sec. for the younger group with a standard deviation of 24.47 while in older group range varied from 107-305 m.sec. with a standard deviation of 76.67.

Significant difference at 0.01 level was seen between males and females at both age groups, thus rejecting the hypothesis that "no difference exists between the 2 sexes for vowel duration".

When compared with normals (Rashmi, 1965; Shukla, 1985) the hearing impaired showed a longer vowel duration. This agrees with the study by Shukla (1985) who states that duration of vowels /i/ and /u/ in hearing impaired speakers were longer than those in normal.

Also the vowel duration in hearing impaired showed a wide variation or wide range. This also agrees with other similar studies on the hearing impaired (Shukla, 1985).

The longer vowel duration in 10-15 year old males may be due to the higher fundamental frequency in them than the older group. It is also seen in normals when they had used in higher pitch (Rashmi, 1985; Nataraja and Jagadeesh, 1983, 1984).

The absence of significance of difference between the two females groups in terms of vowel duration can be attributed to the absence of significant difference in the speaking fundament frequency between the two groups of females. Thus variation or changes made in P.P. during therapy with hearing impaired may a being about changes in vowel duration, which warrants further studies.

Table 4.11 : Mean and standard deviation of vowel duration (in milliseconds) in males and females.

Age group		10-15	16-20
Male	Mean	147.76	127.0
	S.D	59.0	75.99
Female	Mean	112.15	188.11
	S.D	24.47	76.67

Table 4.ll(A) Significance of difference between different groups and between males and females on vowel duration of /i/ in "idu".

Groups compared		Significance
M(10-15) / M(16-20)		P
F(10-15) /F(16-20)	-	
M(10-15) / F(10-15)		A
M(16-20) / F(16-20)		A

* Key provided in Appendix.

The results of this study was tabulated in Table 4.12. It can be seen that most of the parameters studied have shown a significant difference between mats and females. Also in the same sex, there was significant difference between the two age groups i.e. 10-15 years and 16-20 years, which could be due to the pubertal changes, especially in the males.

However no significant difference in maximum phonation duration in the 10-15 years was seen between males and females. This was also true in case of normals (Rashmi, 1985) where upto 14 years no significant difference was seen between males and females. But as can be expected the olders age groups had showed significant difference, as was also true for normals (Vanaja, 1986). Thus it can be accounted for by the pubertal changes in males around 13-15 years.

Secondly, the vowel duration in females, as a function of age, showed no significant difference.

This may be due to the continuation of using of high frequency in case of females even at the later age, which resulted in increase of vowel duration (Rashmi, 1985; Nataraja and Jagadeesh, 1983; 1984).

A comparison of the results of present study with that of normals of a similar age group (Rashmi, 1985; showed that in general the hearing impaired population showed a clear cut difference away from that of the normals. It has been either increased (eg. fundamental frequency. Speaking fundamental frequency, frequency range in phonation and speech) or decreased, (eg. Rise and Fall time of phonation of vowels). In normals all the above parameters controlled by a proper coordination between the respiratory, phonatory and resonatory system and also by the finer control of laryngeal movement. Thus it can be seen that the hearing-impaired lack these controls in monitoring their voice and speech.

The measurement of these parameters would help the clinician in better understanding of the processes of speech in hearing impaired and in thus describe their speech in better terms.

So by concentrating on these parameters in therapy and by a proper feedback of these parameters by the different modes in

Table-4.12 Summary of the parameters with respect to age & sex.

Sl. No.	Parameter	Trend with increasing age		Sex difference with in the same age gro
1.	Maximum phonation duration.	Males	Significant difference.	No difference at 10.15 years group between significant difference at 16.20 years.
		Females	Significant difference.	
2.	Fundamental frequency of phonation.	Males	Significant difference.	Significant differe
		Females	Significant difference.	
3.	Frequency range in phonation.	Males	Significant difference.	Significant difference
		Females	Significant difterence	
4.	Intensity range in phonation	Males	Not significant difterence for vowel/i/ but significant difference for /a/ and/u/-	Significant difference.
		Females	Significant, difference.	
5.	Rise-time in phonation	Males	Significant difference	Significant difference
		Females	Significant difference.	
6.	Fall-time in phonation	Males	Significant difference	Significant difference
		Females	Significant difference	
7.	Speaking fundamental frequency.	Males	Significant difference	Significant difference
		Females	Significant difference.	
8.	Frequency range in speech	Males	Significant difference	Significant difference
		Females	Significant difference.	

contd....

Contd.

Sl. NO.	Parameter	Trend with increasing age		Sex difference with in the same age group
9.	Intensity range in speech.	Males	Significant difference.	Significant difference
		Females	Significant difference.	
10.	α ratio	Males	Significant difference	Significant difference
		Females	Significant difference.	
11.	Vowel duration	Males	Significant difference.	Significant difference
		Females	Significant difference.	

hearing impaired can be helped in achieving voice and speech closer to the normals and thus probably, at the same time, increas the intelligibility of their speech to the'person on the street'.

The results of the present investigation have shown the possibilities of describing the speech and voice of speech disorders, including speech and voice of hearing impaired. It is hoped that this would stimulate further investigation on similar lines.

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SUMMARY AND CONCLUSIONS

The speech of the deaf differs from that of normals in all regards (slack, 1971).

In all the studies of the speech of the hearing-impaired, attention is drawn to the fact that, to a greater or lesser degree, the hearing-impaired, individuals do not produce speech as well as those who hear (Monsen, 1974).

To bring the speech of the hearing impaired closer to the normals, a clear understanding of their speech is a must, which should be done by objective measurements. This would help in describing objectively the speech of the hearing-impaired and also in deciding the selection of the parameters for therapy.

But a review of literature shows studies based on subjective evaluations (Hudgins and Numbers, 1942; Mangan, 1961; Markides, 1970, Nober, 1967; Smith, 1975 and others) and very few studies on the objective measurements of the speech of hearing-impaired.

Hence the present investigation was undertaken in order to study certain acoustic parameters, recommended by Hirano (1981) and the norms of which have been given for the Indian population, (Rashmi, 1985; Gopal, 1986; and Vanaja, 1986) namely:-

1. Maximum phonation duration of vowels.
2. Fundamental frequency of phonation.
3. frequency and intensity range in phonation.

4. Speaking fundamental frequency
5. Frequency and intensity range in speech
6. Rise and fall time of phonation
7. Intensities at harmonics and
8. Vowel duration.

These parameters were studied in a sample of 53 school-going hearing impaired children, 31 males and 22 females, ranging in age from 10-20 years. All these subjects had hearing-loss, with a minimum of 60dB or above, in the better ear. They had no respiratory problem, no observable deformities of nasal, oral or pharyngeal cavities and no mental retardation.

The collection of sample consisted of recording the maximum duration of phonation for three vowels /a/, /i/ and /u/ and the repetition of three Kannada sentences namely "idu papu", "idu koti" and "idu kempu banna. Each subject was given 3 trials. One of these samples from each of the three trials was used for analysis.

The duration of vowels was measured using a stop watch, the longest was considered as the maximum duration of phonation.

This sample was then fed. to the PitchAnalyzer (PM-100) to obtain the fundamental frequency of phonation, frequency and intensity range in phonation and the rise and fall time of phonation.

The three stimulus sentences were then fed to the Pitch Analyzer and the speaking fundamental frequency, frequency range in speech and intensity range in speech, were obtained, for each subj act.

To measure the vowel duration and the intensities at harmonics below and above 1K (α -ratio) the word "idu" was fed to the High Resolution Signal Analyzer. The duration of the vowel /i/ and the α -ratio was measured for all the subjects.

The data thus obtained was subjected to statistical analysis, in order to determine the mean, standard deviation and the significance of difference.

After th e statistical treatment, the following conclusion were drawn:-

I. Maximum Phonation duration:

1. A significant difference between the age groups studied, both in males and females showing an increase in MPD with increase in age was noted.
2. No significant difference was observed in MPD between males and females in 10-15 years group. This parameters showed a similar frequency as in normals.
3. Of the three vowels studied MPD of /a/ was found to be greatest followed by /i/ and finally /u/. This was unlike in normals had showed maximum MPD for /i/ followed by /u/ and then /a/.

II. Fundamental frequency of phonation:

1. A significant difference in Fo for the two groups was seen between males and females.
2. A significant difference between the two sexes was also seen.
3. The Fo for vowel /a/ was lowest when compared with /i/ and /u/, which varied in different age groups for both males and females

III. Frequency range in phonation:

1. A significant difference was seen between males and females and also between the two age groups as a function of age.
2. Both males and females at different age groups showed greater frequency range when compared with normals, also showed a wide individual variation.

IV. Intensity range in phonation:

1. A significant difference was seen between males and females and also between the two age groups as a function of age, except for vowel /i/ where the males showed no difference between the two age groups.
2. A large individual variation was seen in intensity range as compared with the normals,

V. Rise and Fall time in phonation:

1. A significant difference was seen between males and females and also between the two age groups as a function of age.
2. Compared with normals the hearing impaired population showed a lower rise and tall time,indicating an abrupt initiation and termination of phonation.

VI. <u>Speaking fundamental frequency:</u>

1. A significant difference was seen between males and females and also between the two age groups as a function of age.
2. Compared with the normals, the hearing impaired in general showed a higher SFF.

VII. <u>Frequency range in speech:</u>

1. A significant difference was seen between males and females and also between the two age groups as a function of age.
2. The hearing impaired showed almost double the frequency range as compared with normals, again with large individual variations.

VIII. <u>Intensity range in speech:</u>

1. A significant difference was seen between males and females and also between the two age groups as a function of age.
2. The hearing impaired females showed a higher intensity range than normals but in males it was similar to normals. But both showed a large variation when compared with normals.

IX. <u>α-parameter:</u>

1. A significant difference was seen between males and females and also between the two age groups as a function of age.
2. In comparison with normals the of-ratio value in hearing impaired indicated a slightly lower value, which may be indicative of a change in the quality.

X. <u>Vowel duration:</u>

1. A significant difference between the males and females in the two age groups was seen.

2. No significant difference was seen in females as a function of age in vowel duration, which could be due to continuation, in later age of using a higher Fo.
3. A significant difference was seen between males as a function of age.
4. The hearing impaired showed a significantly higher vowel duration, as compared with normals.

It is clear from the present study that the speech of the hearing impaired differed from that of the normals in the acoustic characteristics mentioned above.

In addition to the deviations from normals, there were large individual variations among the hearing impaired individuals.

To improve the speech of the hearing-impaired, these parameters may be worked upon through the use of different feedbacks, thus improving their intelligibility of speech.

Recommendations:

1. The study may be carried out with a larger sample and also for other age groups.
2. The analysis could be extended to other vowels and larger speech samples.
3. A study to observe the effect of modifying these deviant features on the overall speech intelligibility of the hearing-impaired would be interesting.

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APPENDIX-I

Key to the Significance Tables:

- No significant difference at 0.05 level of significance.

P - Significant difference between the two groups at 0.05 level of significance.

A - Significant difference between the two groups at 0.01 level of significance.

APPENDIX-II

Definitions of Terms:

Maximum phonation time:

The longest duration, out of three trials, for which an individual can sustain phonation, after taking a deep inhalation.

Fundamental frequency of phonation:

The mean frequency of the steady portion of phonation as displayed on the Pitch Analyzer.

Speaking Fundamental frequency:

The mean frequency of the speech stimulus displayed.

Frequency range in phonation:

The difference between the highest and the lowest frequency occurring in the steady portion of phonation.

Frequency range in speech:

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

Intensity range in phonation:

The difference between the highest and the lowest intensity in the steady portion of phonation.

Intensity range in speech:

The difference between the highest and the lowest intensities in the speech stimuli.

α -parameter:

The ratio of the intensity levels of the harmonics between 1-2KHz to the intensity levels below 1000Hz, as shown by the High Resolution Signal Analyzer.

Rise Time of Phonation:

The difference in centiseconds between the initiation of phonation and the time at which phonation becomes steady, in terms of the intensity.

Fall-time of phonation:

The difference in centiseconds between the time at which the intensity curve began to decrease and the termination of phonation.

Vowel Duration:

The duration from the beginning of the vowel to the beginning of the following stop as shown by the High Resolution Signal Analyzer.