ACOUSTIC ANALYSIS OF SPEECH OF MALAYALAM SPEAKING HEARING IMPAIRED CHILDREN

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DEDICATED TO

DADDY, MUMMY AND PREMI

CERTIFICATE

This is to certify that the dissertation entitled "ACOUSTIC ANALYSIS **OF SPEECH OF MALAYALAM SPEAKING HEARING-IMPAIRED CHILDREN"** *is the bonafide work in part fulfillment for the degree of Master of Science (Speech of Hearing), of the student with Register No. M 9612.*

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CERTIFICATE

This is to certify that this dissertation entitled "ACOUSTIC **ANALYSIS OF SPEECH OF MALAYALAM SPEAKING HEARING-** IMPAIRED CHILDREN", *has been prepared under my supervision and guidance.*

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DECLARATION

This dissertation entitled "ACOUSTIC ANALYSIS OF SPEECH OF MALAYALAM SPEAKING HEARING-IMPAIRED **CHILDREN",** *is the result of my own study under the guidance of* **Dr. N.P.Nataraja,** *Professor and Head of the Department of Speech Sciences, All India Institute of Speech of Hearing, Mysore, and has not been submitted earlier at any University for any other Diploma or Degree.*

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INTRODUCTION

Speech is a form of communication in which the transmission of information takes place by means of speech waves which are in the form of acoustic energy. The speech wave forms are the result of interaction of one or more sources with the vocal tract filter system (Fant, 1960).

"Man's need for communication with his fellowmen is possibly the greatest need and the fulfillment of his other needs and desires is largely dependent upon, or at the least greatly facilitated by, his ability to satisfy this basic one".

Louise Tracy (1970)

The need for communication is achieved through spoken language. And it is hearing, the main channel through which all learn to speak. A serious impairment in hearing hinders the normal development of speech. Hearing impairment either at birth or soon after birth and during early childhood results in a concomitant deficiency in comprehension and usage of speech. To understand the speech sounds of a language it is necessary to learn about the articulatory and acoustic nature of the speech sounds. The speech sounds are perceived by the human being as an acoustic event. These acoustic events are the consequence of articulatory movements. The study of acoustic characteristics of speech sounds will give information about the articulatory nature of the sound and also how these sounds are perceived (Picket, 1980).

Acoustic analysis of speech sounds provides information about the source characteristics like fundamental frequency, intensity etc., filter characteristics like formant frequencies, formant bandwidths.... etc., and the temporal characteristics like vowel duration, consonant duration,... etc apart from spectral characteristics.

The speech sounds of a language are classified into vowels and consonants. Vowels are the result of interaction of minimally obstructed vocal tract and vocal fold vibration. The laryngeal acoustic energy is modulated by various configurations of the vocal tract producing different vowels.

The present study was taken up for an extensive acoustic analysis of the speech of Malayalam speaking hearing impaired children. Malayalam is the official language of Kerala state, on the south-west coast of India. Malayalam is an important member of Dravidian family of languages with respect to the three hundred dialectal maps of Kerala, the regional dialects are divided into twelve major divisions and thirty two subdivisions.

Acoustic analysis of the temporal parameters of the vowels of the Malayalam language can be used in evaluating the speech deviations of hearing impaired Malayalam speaking children, spastics and other patients with speech disorders.

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

Studies of Hudgins and Numbers (1942), Mangan (1961), Nober (1967), Markides (1970), Smith (1975), Mc. Garr (1978) and Geffner (1980), have described the speech of the hearing impaired individuals by using a normal listener as an analytical tool. Descriptions of the speech of the hearing impaired individuals have, for the most part, been based on subjective evaluations. However according to Monsen (1976b), the usefulness of the normal listener as an analytical tool has limitations. They are:

1. Some sounds that are produced by hearing impaired individuals may not simply be classifiable as a variant of any phoneme.

2. Since each phoneme is signalled by a variety of cues, confusion matrices do not tell the exact cause of the confusion.

These observations underline the importance of objective measurements of different parameters of speech. Several studies have employed objective measurements to describe the speech of the hearing impaired.

Holbrook and Crawfred (1970) and Boone (1966) found that hearing impaired individuals exhibited higher than normal fundamental frequency values, while Thornton (1964) reported essentially normal speaking frequencies for hearing impaired speakers. Acoustic analysis of hearing impaired speech permits a finer grained consideration of some aspects of both correct and incorrect productions than would be possible using methods applied in the subjective procedures (Osberger and Mc Garr/1982). Angelocii, Kopp and Holbrook (1964) and Monsen (1976c) showed that the vowel formants of deaf individuals tend to be more centralized than those of normal speakers. Monsen (1974) from his study of durational aspects of sound production of deaf individuals concluded that the vowel production characteristics of the deaf subjects account in part for the low intelligibility of consonants in the speech of the deaf individuals. Monsen (1976 d) showed that in the speech of the hearing impaired subjects the second formant transitions may be reduced both in time and frequency. At the transition onset, the second formant was found to be nearer to its eventual target frequency than in the speech of the normal subjects.

The results of many studies have suggested that the speech of the hearing impaired children is not a viable instrument for verbal communication and can cause break down, of daily communication a frustrating and unrewarding experience for the children and their listeners alike. (Smith, 1975). Many factors like residual hearing, segmental errors, supra segmental errors have been correlated with the poor speech intelligibility of the hearing impaired individual's speech. -

The present study was planned to determine the relationship between some of the segmental errors and intelligibility of the hearing impaired children's speech.

Aim of the study:

This study aims to determine the relationship between some of the segmental errors and intelligibility of the speech of Malayalam speaking hearing impaired children.

Hypothesis 1:

There is no significant difference in the utterance of normal hearing and hearing impaired in terms of -

a) Vowel duration

b) Intersyllabic pauses

c) Total duration of words

d) Average Fo

e) Formant frequencies

f) Bandwidths

Hypothesis 2:

2(a) There is no significant difference in the utterance of normal males and normal females on all the parameters measured.

2(b) There is no significant difference in the utterance of hearing impaired males and hearing impaired females on all the parameters measured.

Twenty congenitally hearing impaired children in the age group of 7-10 years were selected for the study. All the children had bilateral severe to profound sensorineural hearing loss. They had no other problem than that directly related to the hearing impairment. All read simple bisyllabic words in Malayalam.

Ten simple meaningful bisyllabic Malayalam words were selected. The speech samples of all the hearing impaired children were recorded as they read the words. Each subject read them for three times each. Recordings were also obtained of a matched group (for age and sex) of twenty normal hearing children reading the same set of words.

Experiment:

The samples were analysed using computer programmes of VSS, Bangalore. And the following parameters were obtained from each sample.

1) Vowel duration
2) Duration of pauses
3) Total duration of words
4) Average Fo
5) Formant frequencies (F_1, F_2 and F_3)
6) Bandwidth (BW_1, BW_2 and BW_3)

The obtained data was subjected to statistical analysis to determine the mean, SD and significance of differences between the two groups

Implications of the study:

1. The results of this study would help in understanding the speech of the hearing impaired children.

2. The results would help to know the role of segmental errors in the intelligibility of the speech of the hearing impaired.

3. This study would also help or to plan and develop therapy programmes for the hearing impaired children.

Limitations of the study:

1. The speech samples studied were limited to words with VCV combinations only.
2. All the hearing impaired subjects differed in terms of
   - Hearing aid usage
   - Therapy duration
   - Parental participation in therapy
   - Motivation in therapy and other factors.

REVIEW OF LITERATURE

Communication, as it is in today's world, makes the human race different from animals. Speech may be viewed as the unique method of communication evolved by man to suit the uniqueness of his mind (Eiseason, Amer and Irwin 1963). The ability to communicate through speech is of enormous value. It provides a range of opportunities and options in personal, educational and social life, as well as in employment, that cannot exist through any other form of interaction. (Ling, 1976).

Speech is an integrated function involving the reception of words by the ear or the eye, their interpretation and synthesis as language within the brain and the expression of this language response as further spoken or written words. It includes the whole of this receptive, formative and expressive activity words are composed of sequences of sounds. They are symbolic and have a consistent range of meaning (Morley, 1972).

"It is through the auditory mode that speech and language are normally and usually effortlessly developed". (Ross and Giolas, 1978). The auditory pathway is the natural and most effective way to learn speech and language, in addition to providing all the other auditory information from our environment such as, music, door bell, bird song and so on" (Pollack, 1987).

The normal hearing child is continuously exposed to sounds from birth or even before birth. By continuous auditory stimulation by the constant feeding of speech into his ear3, by increasing encouragement from his mother, by hours and hours of practice, a normal child attains speech. The task is however very difficult for a child born deaf. Thus hearing controls speech, and without hearing speech fails to develop hearing impairment has a marked effect on the child's ability to acquire speech (Whetnall and Fry, 1964).

Normal child controls his speech movements with the help of auditory and kinesthetic feedback (Whernall & Fry, 1964). The exact role normally played by auditory feedback in the normal acquisition of speech is not known. Observations indicate that it is particularly important in the early stages, in that it allows the. child to develop the same speech characteristics as those around him (Van Riper and Irwin, 1958).

Several have reported the effect of hearing less on acquisition and maintenance of speech. The orderly and seemingly natural development of speech, language and communication is interfered with by the presence of hearing loss. (Stark, 1979; Chermaks, 1981). The deaf child is faced with a denbly severe communication handicap. Normal speech is unintelligible to him and as a result of lack of auditory feedback of his own speech production, he has considerable difficulty in learning to speak correctly (Hevitt etal 1974; Cavic and Couric, 1983).

The oral communication skills of the hearing - impaired children have long been of concern to educators of the hearing impaired, speech pathologists and audiologists, because the adequacy of 3uch skills can influence the social, educational and career opportunities available to these individuals. (Osberger and Mc. Garr, 1982).

The ultimate goal in aural rehabilitation for the hearing impaired individual, is to attain, as far as possible, the same communication skills as those of the normal hearing individuals. The poor oral communication skills of the hearing impaired are evident to any body who have heard their speech. However those can be overcome. But a very few deaf individuals achieve good speech quality. Many more deaf children could be trained to speak proficiently if we had greater in right into the essential problems. (Levitt, 1974).

A congenital hearing loss tends to produce speech problems, the more severe the hearing loss, the more deviant and less intelligible is the speech produced by the child (Boothroyd, 1978). There appears to be a fairly good consensus in the literature regarding the nature of the speech errors made by hard of hearing children. Omissions of consonants, particularly in the word-final position, constitute about half the errors made. (Gold and Levitt, 1975). Accompanying the omission of the final consonant one can find the prolongation and nasalizatiion of the preceding vowel.

Other speech problems manifested by some hard of hearing children include voice/voiceless confusions and errors on compound and abutting consonants. (DiCarlo 1968). When vowel errors are made, they are usually confused with vowels in close proximity in the vowel quadrilateral that is, the vowel substitutions are usually correct in terms of frontness of the tongue but wrong in terms of tongue height or tensions.

In their langauge abilities, the children appear to be delayed rather than deviant in their performance, giving results not unlike younger normally hearing children.

Several methods have been employed to study speech production in hearing impaired. These include physiological (Metz etal, 1985), Acoustic (Momen, 1976a, 1976b, 1974, 1978; Angelocic, etal. 1964; Cilbut, 1975; Mcclumphe, 1966; Calvert, 1962; Shukla, 1985; Rajnikanth, 1986; Sheela, 1988; Jadgish, 1989; Rasitha, 1994) and perceptual methods (Levitt, etal 1976; Stenens, etal 1983; Hudgins & Numbers 1992; Marbides, 1970; Gettner, 1980 etc.)

Use of acoustic analysis of speech for studying the speech production skills, offers several advantages as it is non invasive, needs relatively simple instrumentation, may be used routinely to depict changes in the physical characteristics of frequency, intensity and the duration of speech segments (Leeper, et al 1987). Acoustic analysis of speech of hearing impaired permits of finer grained consideration of some aspects of both correct and incorrect production than would be possible using methods applied in the subjective procedures (Osberger and Mc. Garr, 1982). It provides objective description of speech of the hearing impaired. More information about the characteristics of the speech of the hearing impaired would help in making use of the advances in the technology with maximal effectiveness is facilitating the oral production skills of the hearing impaired.

In order to develop more effective speech training procedures for deaf children, it is necessary to know the deviation in their speech from that of normally hearing children and the effect of various errors and abnormal speech patterns on the intelligibility (Levitt, 1978). Thus, analysis of speech of hearing - impaired becomes important.

INTELLIGIBILITY OF SPEECH OF THE HEARING IMPAIRED

The speech produced by many deaf persons is frequently unintelligible to even experienced listeners. Moreover it is frequently difficult to determine the exact nature of speech errors that reduce the speech intelligibility without a clear understanding of the underlying nature of the unintelligible speech of the deaf, the development of effective clinical statement is limited (Metz, 1982).

"Speech intelligibility refers to how much of what a child says can be understood by a listener" (Osberger and Mc. Garr, 1982). Speech intelligibility of the hearing impaired as a measure of their speech potential, has been studied by a number of investigators.

In a study of intelligibility of 192 hearing impaired subjects ranging 8-19 years of age, a group of experienced listeners were asked to listen to the speech samples of the hearing impaired and write down whatever was understood by them. The mean score for the group was found to be only 29% (Hudgins and Numbers, 1942). Brarson (1964) found that only 20-25% of the words in the speech of hearing impaired subjects were intelligible to listeners unfamiliar intelligible than words and sentences which are spoken directly to listeners in a face to face situation are more intelligible than sentences that are tape recorded (Hudgius, 1949; Thomas, 1964). This suggests that contextual cues also affect the intelligibility of speech.

Poor speech intelligibility achievement in the hearing impaired has been correlated to several variables related to reception and production of speech. Among the perceptual variables - residual hearing (Monlgomeny, 1967; Clliot, 1969; Boothroyd, 1969; Markides, 1970; Smith 1975; Stroker's lake, 1980;; Ravishankar, 1985;; Vasantha, 1995) and lip reading (Stroker and Lake, 1980; Vasantha, 1995) abilities have been studied. The results have indicated that both residual hearing as well as one's lip reading ability affect intelligibility, children with lesser degree of hearing loss were found to have better speech intelligibility. Also, hearing impaired children tend to have a better speech intelligibility when their lip reading abilities were better.

From the production side speech intelligibility has been studied in relation to segmental and suprasegmental errors. Errors involving individual speech phonemes i.e. segmental errors have been studied by (Hudgins and Numbers, 1942; Wober, 1963; Smith 1973;; Meclen, 1980; Markides, 1970; Raisskanda 1985, etc.) These studies suggest a negative correlation between frequency of segmental error and intelligibility, is the higher the incidence of segmental error the poorer the intelligibility of speech (Parkburst and Levith, 1980) .

Both consonant and vowel errors have long been recognized in the speech of the hearing impairment. Consonant errors include, voicing errors, substitution and omission, while vowel and diphthong errors include, substitution, neutralization of vowels, diphthongization of vowels etc. Mensen (1978) examined the relationship between intelligibility and

a) Four acoustically measured variables of consonant production.
b) The acoustic variables of vowel production, and
c) Two measures of prosody,

to find the variables which were highly correlated with intelligibility. He found VOT and the second formant frequency to be significant.

Other segmental errors that have been observed to have a significant negative correlation with intelligibility axe omission of phonemes in the word initial and medial positions, consonant substitution and unidentifiable or gross distortions of the intended phonemes (Levitt, etal, 1980).

TIMING

1. **RATE**

Physical measure of speaking rate have shown that profoundly hearing impaired speaker on average take 1.5 to 2.0 times longer to produce the same utterance as do normal hearing speaker (Boone, 1966; Hood, 1966; Voclker, 1935).

Voelkar (1938) compared 98 deaf and 13 normal hearing children in grade 1-3 on reading rate. He found that the -fastest deaf reader was slightly slower than the average normal reader. The average reading rates for the two groups were 69.6 and 164.4 words/minute for the deaf and normal hearing child, respectively.

Nickenson et al (1974) studied on 3lightly older children on reading rate and still found large difference between the groups. Although the mean rate for the deaf group was as high as 108 word3/min. This supports Bcore's (1966) finding that the rate of the speech of deaf increases with age but still remains considerably slower than that of normal speaker.

The problem of reduced rate of speaking in the deaf speaker seems to be related to two separate problems, i.e.,

1) increased duration of phonemes
2) improper and often prolonged pause within utterances (Gold, 1980).

INCREASED DURATION OF PHONEMES

The duration of phoneme because important function in the perception of a speech message. Duration changes in vowels serve to differentiate not only between vowel themselves but also between similar consonant adjacent to those vowels (Raphel, 1972; Gold, 1980). There is a general tendency towards lengthening of vowels and consonant in deaf (Argclici, 1962; Boone, 1966; Leish et al. 1974; Sheela, 1988; Rasitha, 1994).

Calvert (1961) was among the first to obtain objective measurements of phonemic duration in the speech of hearing impaired by spectrographic analysis of bisyllabic words. The result of this study showed that hearing impaired speaker increased the duration of vowel, fricative and closure period plossive upto 5 times the average duration for normal speaker.

Monsen (1976) studied 12 deaf and 6 normal hearing adolescent as they read 56 CVC's word containing the vowel /i/ or /I/. He found that the deaf subjects tend to create mutually exclusive devotional classes for 2 vowels, such that, the duration of one vowel could not approximate that the other, even when they occurred in the presence of different consonants. For the normal subjects, the duration of /i/ was always longer than /I/ for a particular consonantal environment, but the absolute duration of the two vowel could overlap if the accompanying consonant differed. Thus, although vowels produced by deaf subjects were distinct in terms of duration, they were still less intelligible since the listener could not rely on normal recording strategies to interpret the speech that was heard. The vowel duration also varies with reference to the voice - voiceless distinction of the following consonant. The hearing impaired fail to produce the approximate modification in the vowel duration as a function of voicing characteristic of the following consonant. Hence, the frequent voiceless-voiced confusion observed in their speech may actually be due to vowel duration error (Calvert 1961).

Shukla (1987) compared vowel duration and consonant duration in 30 normal and hearing impaired matched for age and sex. The results indicated the following.

a) On the average the duration of vowel /a:/ was longer when followed by a voiced consonant than when followed by a voiceless consonant in both groups of subject. However, in both the groups the difference was less than JND for duration.

b) In both the groups vowel /a/ was longest in duration when followed by a nasal sound within the voiced sound category and when followed by fricative /s/ within the voiceless sound category.

c) The duration of the vowel /a:/ in the medial position was longer in the speech of hearing impaired than in speech of normal hearing speaker.

d) In normal hearing subjects the mean duration of the vowels /a/, /i/, and /u/ in the final position preceded by different consonant were around 200 msec. 195 msec and 185 msec respectively. In the hearing impaired /i/ and /u/ tended to be longer than in normal speaker and the vowel /a/ tended to be either longer or shorter when compared to the length of the vowel /a/ in normal speaker.

e) Hearing impaired speaker show a greater variation in vowel duration than normal hearing speaker.

f) In the normal hearing speakers vowel /a/ in the final position was longer than vowel /i/ and /u/ whereas in the hearing impaired speakers vowel /a/ was shorter than vowel /i/ and /u/.

g) A vowel lengthening phenomenon was observed in Kannada Language "Vowel lengthening phenomenon" is the increasement in duration of the final syllable vowel of 100 msec or more. It was first described in English Language for phrase final and utterance final positions. (Keath, 1975a, 1976).

h) Both the groups of subjects did not show any consistent changes in the duration of the vowels depending on the preceding consonants.

i) In both the groups the durations of consonants were longer in vowels /i/ and /u/ environments, than in the /a/ environment.

j) In both the groups velar sounds tended to be longer than bilabial consonants in both voiced and voiceless categories.

k) In normal hearing subjects, the voiceless consonants were significantly longer than the voiced consonants, whereas, in the hearing impaired the duration difference between voiced and voiceless consonants were considerably reduced.

1) In normal hearing the affricates /ch/ and / j / were the longest, whereas in the speech of the hearing impaired /t/ and /d/ were the longest in voiceless and voiced categories of sounds respectively.

m) Durations of all the consonants were longer in the speech of the hearing impaired than in the normal hearing speakers.

n) Hearing impaired speakers showed a greater variation in controlling the length of all the consonants than the normal learning speakers.

The factors leading to or related to particular difficulties with timing of speech events, prolonging them and producing apparently high variability of timing in the speech of the hearing impaired are not known. One possibility is that auditory feedback is necessary for rapid smooth production of complex motoric sequences of speech (Lee, 1950) and that hearing impairment limits the necessary information too severely, requiring a general slowing of the mechanism of production and imposing high instability upon timings.

In English, changes in contrastive stress have been found to produce systematic changes in vowel duration. When vowels are stressed, they are longer in duration than when the same vowels are unstressed. (Parmeuter & Trevino, 1936). Several investigations have shown that while hearing impaired speakers make the duration of unstressed syllables shorter than that of the stressed syllables, the proportional shortening is smaller, in the speech of the hearing impaired than in the speech of normal hearing subjects (Levitt, 1979; Stevans, et al 1978).

Osberger and Levitt (1979) found the mean ratio for the duration of stressed and unstressed vowels to be 1.49 and 1.28 for normal hearing children and deaf children respectively. The reduced ratio for the deaf children indicated that while the average duration of unstressed vowels is shorter than the duration of stressed vowels in the speech of the deaf children, the proportional shortening of unstressed vowels is smaller, in the deaf child's speech. These studies have shown that the hearing impaired produce mostly stressed syllables and that there is an overall tendency for increasing the duration of all phonemes in the speech of the hearing impaired. The lack of differentiation between the length of stressed and unstressed syllables may contribute to the perception of improper accent in the speech of the hearing impaired. (Gold, 1980).

Learning velar control is difficult for the hearing impaired children because:

1. Raising and lowering movements of the velum are not detectable via lip reading.

2. The activity of the velum produces very little proprioceptive feedback.

Improper velar control is difficult to judge subjectively, in part because the distinctive perceptual features of nasalization have not been clearly defined and in part because the perception of nasality may be affected by factors in addition to the activity of the velum. Some researchers have suggested that such factors as misraticulation, pitch variation and speech tempo affect the proper judgement. (Colton, and Cooper, 1968). For these reasons, objective measures that correlate with the velar activity are put forward. Acoustic properties of nasal sounds that have been investigated include shifted and split first formant (Frijimuna, 1960; Houze, 1961) and enhanced amplitude of the lower harmonics (Delattre, 1955). Attempts to detect nasalization directly have included the measurements of acoustic energy radiated from the nostrils (Fletchen 1970; Shelton, Know, Arudt and Elbert, 1967) and measurement of the vibration on the surface of the nose (Holbwook and Crawford, 1970; Stevens, Kalikow and Willemain, 1974).-

Ravishankar (1985) found that the intonation errors were most frequent followed by errors in pitch, rate of speech, nasality and voice quality.

Pauses:

Pause may be inserted at syntactically inappropriate boundaries such as between two syllables in a bisyllabic word or within phrases by the hearing impaired (Osberger and McGarh, 1982) Stork and Hevitt (1974) reported that the deaf subjects tended to pause after every word and stress almost every word. It has been reported that profoundly hearing-impaired speakers typically insert more pauses, and pauses of longer duration than do speakers with normal hearing (Boone, 1966; Boothroyd et al. 1974; Stevens et al, 1978).

Boothroyd, et al (1974) Considered that with phrase pauses were more serious problems pauses in deaf speakers. Hudgians (1934, 1937, 1946) suggested that the frequent pauses observed in the speech of the hearing impaired may be the result of poor respiratory control. The results showed that deaf children used short, irregular breath group often with only one or two words and breath pauses that interrupts the flow of speech at inappropriate places. Also there was excessive expenditure of breath on single syllables, false grouping of syllables and misplacement of syllables. Inspite of these deviances, there is evidence suggesting that hearing impaired talkers manipulate some aspect of duration such as those involving relative duration in a manner similar to that of a speaker with normal hearing.

VOICE QUALITY

There seems to be a general agreement that the deaf speakers have a distinctive voice quality (Calvert, 1962; Boone, 1966) Hearing impaired is reported to have a breathy voice quality (Hudgins, 1937; Peterson,1946) a characteristic that were attributed in large to inappropriate positioning of the vocal cords and poor control of breathing during speech.

Calvert (1962) also attempted to determine empirically whether in fact the speech of deaf persons is distinguishable on the basis of quality from that of people with normal hearing. He had teachers of the deaf attempt to determine by listening whether recorded speech sounds (vowels, diphthongs in isolation, non-sense syllable, words and sentences) had been produced by profoundly deaf speakers, speakers imitating, deaf speakers, speakers simulating harsh and breathy voice or normal hearing speakers. Isolated vowels from which onset and termination characteristics had been clipped could not be distinguished as to source but the sources of the sentence were identified with 70% accuracy. Calvert (1971) concluded that deaf voice quality is identified not only on the basis of relative intensity and fundamental and the harmonics but also by the dynamic factors of speech such as transition gestures that change one articulatory position into another.

FUNDAMENTAL FREQUENCY

The fundamental frequency varies considerably in the speech of given speakers and the average or characteristic fundamental frequency varies over speakers. The Fo is often loosely called the intech hand of hearing speakers often tend to vary the pitch much seen than do hearing speakers and the remoting speech has been described ass flat or motone (Calvert, 1962; Hood, 1966; Martony, 1968).

The poor phonatory controls in the hearing impaired individuals may be divided into two major parts.

1. Inappropriate average Fo
2. Improper intonation
 a) Little variation in Fo resulting in flat and monotonous speech.
 b) Examine a erratic pitch variation.

AVERAGE FUNDAMENTAL FREQUENCY

Several investigators have reported that the hard of hearing speakers have a relatively high average pitch than that of normals of comparable ages (Angeloci, 1962; Calvert, 1962). Angeloeci et al (1964) noted that the Fo of he.aring impaired individuals were higher than those of normal hearing individuals, also that the average Fo for different individuals sparred a wider range.

Whitehead (1977) reported that while the speaking Fo was higher for deaf adult than for normally hearing adults, on the average, a majority of the deaf adults had speaking Fo values which fell within the normal range.

Some differences in average Fo have been found as a function of age or sex of the hearing impaired speaker. The results of several studies have shown that there were no significant differences in average Fo between young normal hearing and hearing impaired children in the 6-12 years age range. (Boone, 1966; Green, 1956; Monsen, 1979). Differences have been reported between groups of older children. Boone (1966) found higher average Fo for 7-18 years old males than females. Osberger (1987) found that the difference in Fo between hearing impaired speakers in the 13-15 years age range was greater for females than for males. The Fo for female hearing impaired speakers ranged between 250-300. This value is about 75 Hz higher than that observed for the normal hearing females.

Meckfessel (1964) and Thorution (1964) reported in speaking (FFs) values in post - pubertal hearing impaired males were higher than those obtained for normally hearing post pubertal males, while values obtained by Greene (1956) were similar to those for normal hearing males. Gilbert and Campbell (1980) studied FFS in three groups. (4-6 years, 8-10 years, 16-25 years) of h earing 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. The average Fo value of the utterances of the male hearing impaired speakers was slightly lower than that of the hearing males for the first part of the utterance. The Fo. values for the hearing and hearing impaired male speakers overlapped for the last half of the utterance. (Osberger, 1981).

Rajanikanth (1986) reported that when compared to normals, the hearing impaired, in general, showed a higher FFS. He also noted that there was a significant difference between males and females and also between the two age groups studied in 10-15 years and 16-20 years. Sheela (1988) reported that on the whole, the hearing impaired children exhibited higher average Fo than that of the normal hearing group. Shukla (1987) reported that in majority of the hearing impaired speakers the Fo fell within the normal range.

The auditory feed back system is the main channel for appropriate establishment and production of pitch (Fo). Fo or pitch, has been a particularly difficult property of speech for deaf children to learn to control (Boothroyd, 1970). There have been explanations offered to the pitch deviation noted in the hearing impaired. One possible reason for the difficulty is that deaf children may lack a conceptual appreciation of what pitch is (Anderson, 1960; Martony, 1968).

Martony (1968) proposed that laryngeal tension noted in the hearing impaired is side effect of the extra effort put into the articulators. He opined that 3ince the tongue muscles are attached to the hyoid bone, cricoid and thyroid cartilages, extra effort in their use would result in tension, and change of position in the laryngeal structure. This would ultimately cause a change in pitch.

Willeman and Lee (1971) hypothesized that the deaf speakers use extra vocal effort to give them an awareness of the onset and program of voicing and this becomes the cause for the high pitch observed in their speech..

Segmental influence on Fo control

It is seen that some hearing impaired children produce the vowels /i/ /I/ /u/ on a higher Fo that the other vowels of English. It has been shown that there is a systematic relationship between vowels and Fo in normal speech. High vowels are produced with a higher Fo than lower vowels; resulting in an inverse relationship between Fo and frequency location of the first formant of the vowel (House and Fairbanks, 1953; Peterson and Barney, 1952).

Angelocci et al (1964) first examined some of the vowel, changes in Fo in the speech of the hearing impaired, their results showed that the average Fo and amplitude for all vowels were considerably higher for the hearing impaired than for normal subjects. In contrast, the range of frequency and amplitude values for the vowel formants were greater for the normal hearing than for the hearing impaired speakers. So they suggested that the hearing impaired subjects attempted to differentiate vowels by excessive laryngeal variation rather, than with articulatory maneuvers as do normal hearing speakers.

Bush (1981)' found that vowel to vowel variations produced by the hearing impaired speakers were in some way, a consequence of the same articulatory maneuver used by normal speakers in vowel production. He has postulated that because of the non linear nature of the stress strain relationship for vocal fold tissue, increase in vocal fold tension may be greater in magnitude when the tension on the vocal fold is already relatively high (as in the case with hearing impaired) resulting in some what larger increases in Fo during the articulation of high vowels. According to Honda (1981) moving the tongue root forward for the production of high vowels causes the hyoid bone to move forward tilting the cartilage anteriorly. As a result of this, there is increased tension on the vocal folds resulting in an increased Fo.

From the above studies it is clear that pitch deviation is present in the speech of the hearing impaired. There are also evidences which suggest that the hearing impaired individuals know and use some of the rules as used by the normal speakers.

Velar control

Velum functions as a gate between the oral and nasal cavities. It lowers to open the passage to the nasopharynx for the production of nasal consonants and it raises to seal off the passage for the production of non-nasal sounds. If the velum is raised when it is to be lowered, the resulting speech will be hyponasal, if it is lowered when it should be raised the speech would be hypernasal. .

Improper control of velum has long been recognized as a source of difficulty in the speech of the deaf (Hudgins, 1934) Miller (1968) has suggested that hyponasality may be more prevalent among people with conductive loss than those with sensori neural loss because nasal sounds may appear excessively loud to the former due to the transmittability of nasal resonances via bone conduction. Individual with sensori neural loss on the other hand may welcome, the additional cues provided by the nasal resonances and therefore tend to nasalize sounds that showed not be nasalized.

Learning velar control is difficult for a hearing impaired child for two reasons:

1) Raising and lowering the velum is not a visible gesture and is therefore not detectable by lip reading.

2) The activity of the velum produces very little proprioceptive feedback.

Improper velar control is difficult to judge subjectively in part because the distinctive perceptual features of nasalization have not been clearly defined and in part because the perception of nasality may be affected by factors in addition to the activity of the velum.

Vowel formants

Angelocci et al (1962) reported the vowel formants of the deaf and normal hearing eleven to fourteen year old boys. They concluded that there are a number of differences between the two groups for the fundamental and formants one, two and three in both frequency and amplitude. The means of fundamental frequency and amplitude for the deaf covered a wider range than the same measures for the normal hearing. In contrast, the range of the mean frequencies and amplitudes of the three formants was greater for the normal hearing than for the deaf. This would suggest that for the statistically average subject at least, the deaf child attempts to achieve vowel differentiation by varying fundamental frequency and amplitude of the voice relatively more than the frequency and amplitude of the formants. In physiological terms, he is achieving vowel differentiation by excessive laryngeal variations with only minimal articulatory variations. It was concluded that the deaf did not have clearly defined articulatory vowel target areas. In effect, vowels were seldom accurately spoken by the deaf. .

FORMANT BANDWIDTH AND AMPLITUDE:

Each formant of the vocal tract during vowel production has a bandwidth. Formant bandwidth increases with fcrmant number, so that higher formants have larger bandwidths than does F1.

Experiments have shown that changing the bandwidth of formants has very little effects on vowel perception. Even when the effect of bandwidth reduction is perceprually obvious, as when the bandwidth approaches zero, listeners can still identify vowel sounds.

The primary perceptual effect of formant bandwidth is on the naturalness of the vowel sound. Vowels that have unusually narrow bandwidths sound artificial even though listeners usually can identify these vowels. At the other extreme, increasing formant increasing formant bandwidth eventually can reduce the distinctiveness of vowels, because the energy of the different formants begins to overlap. In such as instance, the vowel spectrum loses the sharpness of its peaks and valleys.

Formant amplitude is related to formant bandwidth in so far as increases in bandwidth often lead to reductions in overall amplitude. The relative amplitudes of the formants in a vowel are determined by the formant frequencies of the formants, the bandwidths of formants, and the energy available from the source.

Nataraja, Savithri and Venkatesh (1993) studied formant frequencies, duration of vowels and the average fundemantal frequency in the speech of the hearing impaired. Fifteen congenitally hearing impaired subjects, served as subjects. Results indicated that:

1) There is signficiant difference between normal hearing and the hearing impaired in terms of first three formant frequencies. Hearing impaired frequently misarticulates the vowels and thus Fl and F2 fall into areas normally associated with other vowels resulting in more extnesive scattering of F1/F2 ratio.

2) On the average the hearing impaired had significantly longer duration for vowels than that of normal hearing.

3) On the whole, hearing impaired exhibited higher average FO than that of normal hearing subjects.

To summarize the review in general, many temporal and frequency characteristics of speech have been identified and measured in different languages, in order to understand the normal process of speech production and speech perception. In the process, researchers found that speech parameters are dependent on many factors either linguistic or non linguistic. This resulted in measurement of different temporal and frequency characteristics of speech in different languages of the world. Similarly temporal and frequency characteristics have been measured in disordered speech like hearing impaired, stuttering, misarticulation etc.

Simultaneously, research in similar lines using accustic aerodynamic and physiological procedures also - have been carried out in the speech of the hearing impaired subjects, with the aim of contributing to the teaching methodologies, and in turn to achieve better results. Until then an attempt at understanding the speech of the hearing impaired subjects were based only on subjective judgements.

Most of the work in the area of speech of the hearing impaired, is done in U.S.A. using American English Speakers. Since the speech parameters are languages specific, there is a need to carry out research to measure and describe different parameters of speech in the hearing impaired speakers of Malayalam language. Rasitha (1994) studies speech pattern in Malayalam speaking hearing impaired children in the age range of 5-9 years. She found that

1. The hearing impaired group had significantly longer vowel duration than that of normal hearing group.

2. Normal hearing children did not show any inter syllabic pauses (intra word) whereas 4 out of 5 children in the hearing impaired group inserted intersyllabic pauses at least once in each word.

3. The total durations of the words uttered by the hearing impaired children were significantly longer than that of the normal hearing group.

4. Higher average Fo than that of the normal hearing group was exhibited by the hearing impaired children.

5. The hearing impaired children had higher first formant (Fi) and second formant frequency F_2 smaller than the normal hearing group.

Rahul (1997) studied the spech pattern of Kannada speaking hearing impaired childrenin the age range of five to eight years. Resuts of his study revealed that

1 . The vowel duration is greater in the speech of the hearing impaired, as compared to the normal hearing speakers, for

vowels /a/, /a:/, /e/, /e:/, /i/, /i:/, /o/, /o:/, /u/ and /u:/ in the word initial and word medial positions.

2. The vowel formant frequencies, in the speech of the hearing impaired, vary from that of the normal hearing speakers, such that:

   a) The first formant frequency may be either higher, lesser or similar to the normal hearing speakers.

   b) The second formant frequency is lesser than normals for the front vowels, and higher than normals for the back vowels.

   c) The third formant frequency tends to the higher than the normal hearing speakers.

The present study is undertaken to study the speech patterns in hearing impaired Malayalam speaking children in the age range of 5-14 years with the hope that it will contribute to the present knowledge of teaching speech to the deaf.

METHODOLOGY

The study was aimed at finding out the difference in the acoustic characteristics of speech of Malayalam speaking normal and hearing impaired children who are using hearing aid and undergoing therapy.

1. SUBJECTS AND TEXT MATERIAL:-

Twenty normal and twenty hearing impaired children between 7-10 years were selected for the study. Each group consisted of 10 males and 10 females. The hearing impaired children selected for the 3tudy were from a special school at Thrissur and these children satisfied the following conditions:

1. Had congenital bilateral hearing loss (PTA of greater than 70dB - ANSI, 1969, in the better ear).

2. Had no other problems/derivations other than that are directly related to the hearing impairment.

3. Were able to read simple bisyllabic words in Malayalam.

4. All the children were attending speech therapy and were regular users of hearing aid.

Twenty children with normal hearing were selected to match each hearing impaired subject in terms of age and sex.

The text material consisted of ten bisyllabic Malayalam words. Words were simple so that both normal and hearing impaired children could read them (Given in Appendix - I) words were taken from "Articulation Test Battery in Malayalam" (Maya 1990). (Note on Malayalam Language given in Appendix - I)

2. DATA COLLECTION:

The speech samples if all the subjects were recorded in a quiet room of the school building, using a National tape recorder with a built in microphone. All subjects were comfortably seated at a distance of 15 cms from the microphone.

3. INSTRUCTION

They were instructed to read out the word written on the. card presented to them, at a comfortable loudness level. One card at a time was presented to the children. Thus all the words read by all the subjects were recorded.

Best out of three trials (which was considered to be most intelligible) was selected for analysis purpose for all subjects of both the groups. Subject was made to repeat after the experimenter, whenever the subject had difficulty in finding the target word.

4. INSTRUMENTATION: (Block diagram)

SIU————> A/D - D/A Converter————>Computer————>Amplifier & Speaker

PHOTOGRAPH SHOWING THE INSTRUMENTATION FOR ACOUSTIC ANALYSIS OF SPEECH

Analysis principally involved the folowing instruments:

1) Antialiasing filter (low pass filter having cut off frequency set at 7.5 KHz) with speech interfacing unit

2) A-D/D-A converter (sampling frequency rate of 16 KHz, 12 bit).

3. Personal computer with Intel Pentium 200 MHz processor

4. Software for analysis of speech, (Developed by voice speech systems, Bangalore

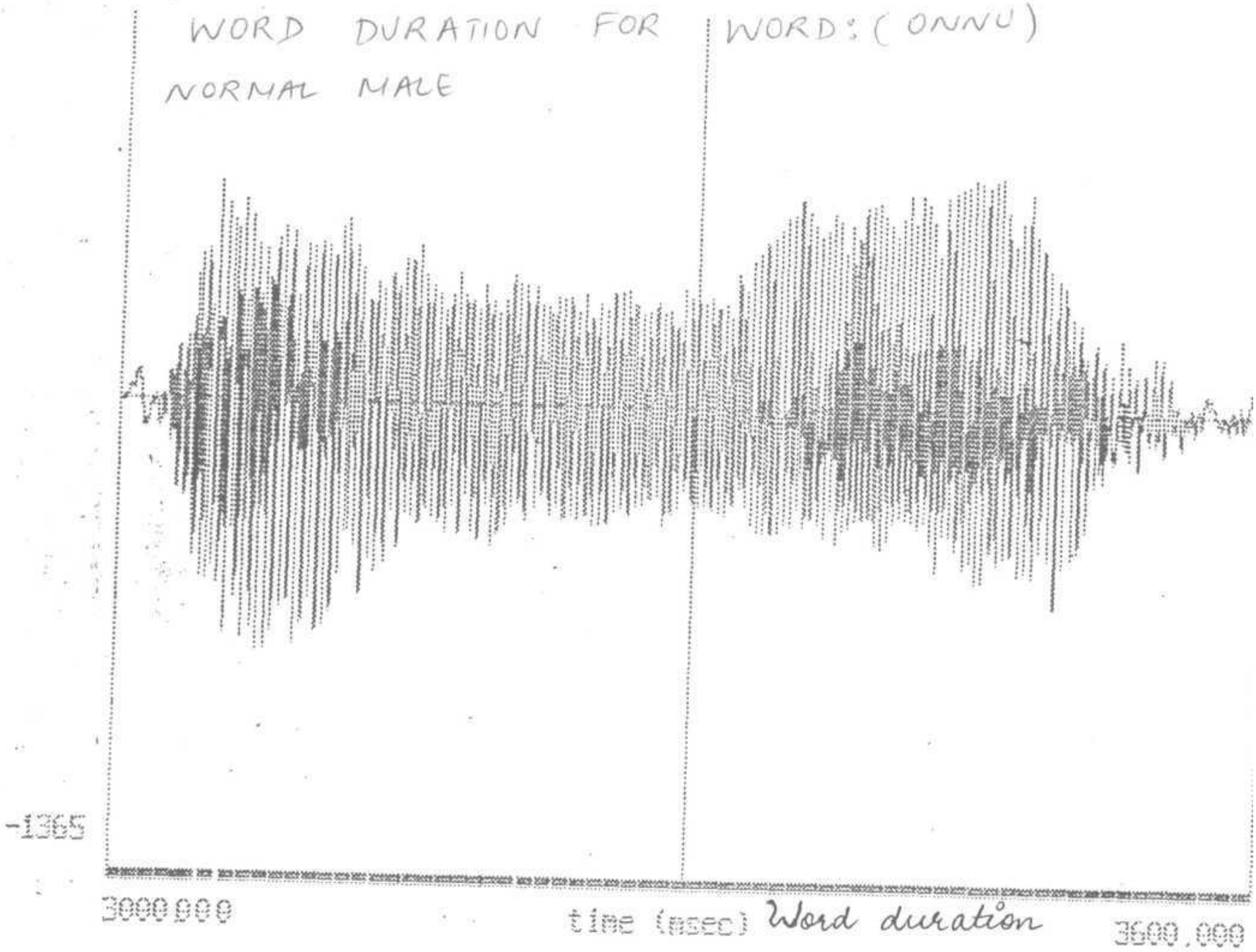
5. Amplifier and speaker (2011 SOIS ampli speakers)

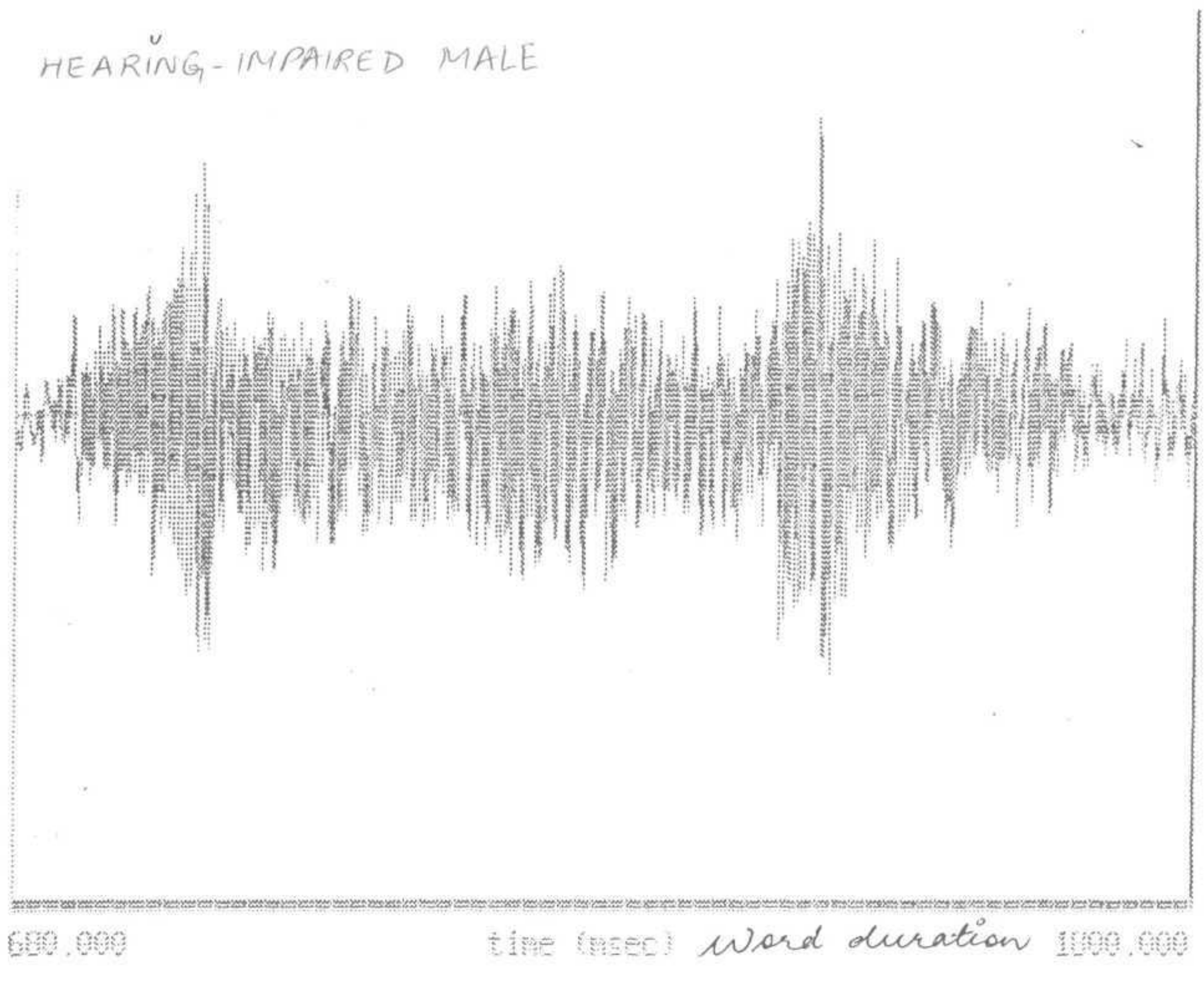
5. ANALYSIS OF THE DATA:

The recorded speech samples were digitized at a sampling frequency of 16,000Hz and block duration and resolution wers 50 msec and 10 msec respectively. Using a 12 bit A/D converter and stored on the hard disc of computer using the programme by voice and speech system, Bangalore.

1. Word Duration:

Word duration is the time taken between initiation and termination of a word. It was measured directly from the speech waveform. The waveform was displayed on the computer monitor using the "DISPLAY" programme of SSL. The words were identified based upon the continuity of the waveform. The word duration was considered to extend from the beginning of the periodic signal to the end of the periodic signals. This


WORD DURATION FOR WORD: (ONNU)
NORMAL MALE
-1365
3000.000
time (msec) Word duration
3600.000


HEARING-IMPAIRED MALE
600.000
time (msec) Word duration
1000.000

duration was high lighted through the use of cursors. The highlighted portion was played back through headphones, to confirm that it contained the word under study. Once this was confirmed, the duration of the highlighted portion was read from the display and considered as the duration of that particular word.

2. Vowel Duration:

The vowel duration was measured directly from the speech waveform and spectrogram. The waveform and spectrogram were displayed on the computer monitor using the "SPGM" programme of SSL. The vowels were identified based upon the regularity of the wave from and verticle striation and formants. The vowel duration was considered to extend from the end of one periodic portion to the beginning of the next aperiodic portion (for vowels in the word medial portion). This duration was highlighted using the cursors. The highlighted portion was played back through headphones, to confirm that it contained the vowel under study. Once this was confirmed, the duration of the highlighted portion was read from the display.

3. DETERMINING THE FUNDAMENTAL FREQUENCY:

For measurement of fundamental frequency the "INTON off-line" programme, in the voice diagnosis module of the software "Vaghmi" was used. The utterance was first analysed and then displayed to obtain the FO contour. Then the speech statistics were displayed to obtain the mean fundamental frequency.

4. EXTRACTION OF FORMANT OF FREQUENCIES:

To extract the vowel formant frequencies (Fl, F2, F3) a spectrogram of each utterance using the "SPGM" programme of the software "Speech Science Lab", was obtained. After identifying the target vowel, the cursor was placed in the middle of the vowel portion so as to avoid the formant transitions, and the formant frequencies were determined by using the sectioning method through the use of linear predictive coding (LPC). This was done with 18 LPC coefficients. The frequencies at the peaks representing the formants were noted using the cursor.

5. **BAND WIDTH**:

To extract the vowel formant band widths (Bl, B2, B3) a spectrogram of each utterance using the "SPGM" programme of the software speech science lab", was obtained. After identifying the target vowel, the cursor was placed in the middle of the vowel portion so as to avoid the formant transitions, and the bandwidths were obtained by using the "PAT PLAY" of the software speech science lab".

6. PAUSE DURATION:

The time between the initiation and termination of a silence. Thi3 pause duration was measured directly from the speech wave from and spectrogram using the "SPGM" programme of SSL as explained earlier. The speech waveforms and spectrograms were visually inspected for 3ilent intervals and the duration of silence was then calculated for silent intervals and the duration of silence was then calculated by placing the cursors at the points of pause onset and termination. Pause onset was defined as the point where the waveform next crossed the zero axis. This portion was highlighted and listened through head-phones for confirmation. When pauses were identified, their location (Intraword) and duration were noted.

Thu3 the following parameters were measured for ten words uttered by each normal and hearing impaired subject.

6. PROBLEMS FACED WHILE ANALYSING:

1. Since the speech samples were not recorded in a sound treated room, there was some amount of extraneous noise which interfered the analysis of the speech signal.

2. Some of the hearing-impaired subjects tended to distort most of the vowels which in turn affected the measurement of the formant frequencies.

7. STATISTICAL ANALYSIS:

Descriptive statistics consisting of mean, standard deviation, minimum and maximum value were obtained for all the five parameters.

To check whether there were any significant differences between the values of the normal hearing group and hearing impaired group, Mann Whitney statistical test was applied.

RESULTS AND DISCUSSION

The objective of the present study was to find out if there was a significant difference between the speech of Malayalam speaking hearing impaired children and children with normal hearing.

ACOUSTIC ANALYSIS:

Ten bisyllabic words uttered by twenty severely hearing impaired and twenty normal hearing children were analyzed to obtain the following acoustic parameters.

1. Vowel duration
2. Total duration of the words
3. Formate frequency F1,F2 and F3
4. Bandwidth, BW1, BW2 and BW3
5. Fundamental frequency

The descriptive statistics was obtained for all the measures. The mean and the standard deviation, the minimum and the maximum values were calculated for all these parameters.

1. VOWEL DURATION

On an average, the hearing impaired subjects had longer vowel duration when compared to the normal hearing group.

Out of all the ten vowels measured all the ten vowels [a, a:, i, i:, u, u: e, e:, o and o:] had longer vowel duration than the normal subjects.

Table 1: [a] and Graph (a) depict the mean values for vowel duration in normal normal and hearing impaired males.

Table 1(a):

Vowels	Normal Males Mean (Msec)	Normal Males Standard deviation	Hard of hearing males Mean (Msec)	Hard of hearing males Standard deviation	Mean difference HI & Normals (msec)
a	210.16	25.46	438.50	140.02	228.34
a:	251.30	36.24	513.75	155.39	262.45
i	254.85	58.23	454.50	135.04	199.65
i:	289.20	63.76	499.37	111.12	210.17
u	195.45	43.92	433.12	85.29	237.67
u:	264.55	24.95	432.50	114.29	167.95
e	204.47	34.72	445.00	147.69	240.53
e:	249.85	36.35	421.87	212.03	172.02
b	191.20	32.13	367.50	153.79	176.3
o:	222.37	37.49	535.62	198.74	313.25

In the normal male group among the ten vowels studied the vowel /i:/ and the longest duration (289.20 msec) followed by /u:/ (264.55 msec), /i/ (254.85 msec), /a:/ (251.30 msec), /e:/ (249.85 msec), /o:/ (222.37 msec), /a/ (210.16 msec), /e/ (204.47 msec), /u/ (195.45 msec), /o/ 191.20 msec).

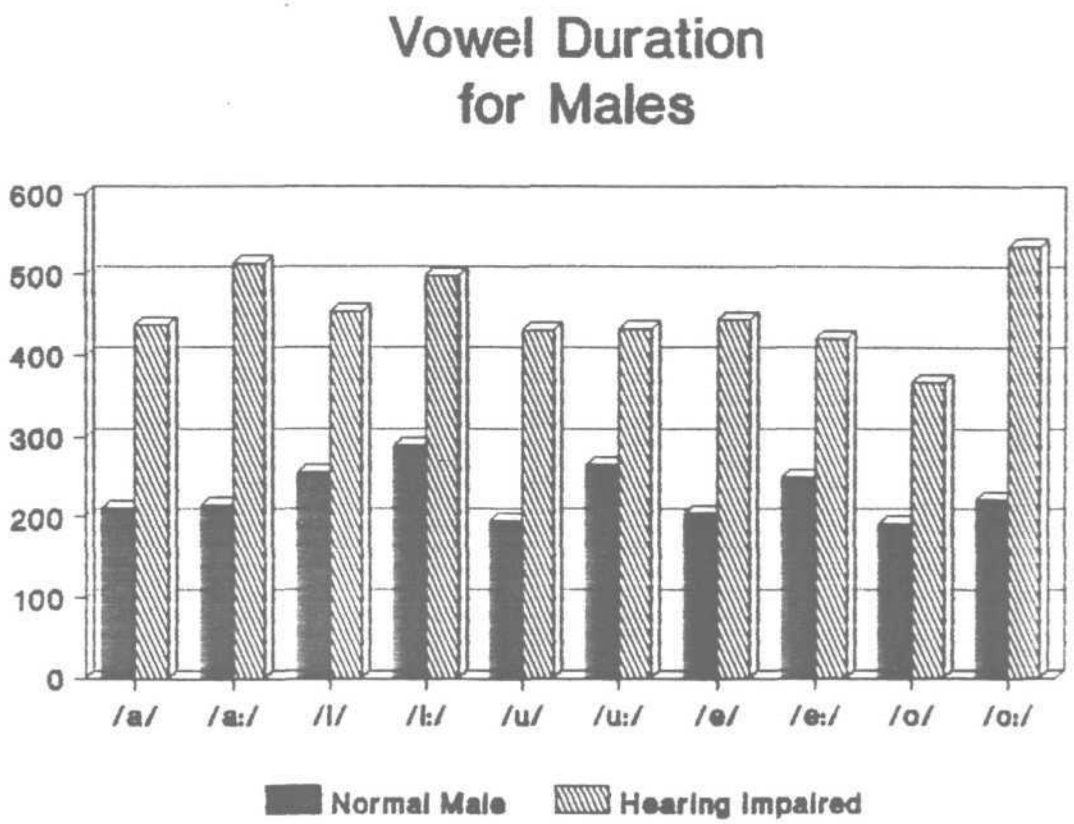
In the case of hearing impaired males the vowel /o:/ had the longest duration (535.62 msec) followed by /a:/ (513.75 msec), /i:/ (499.37 msec), /i/ (454.50 msec), /e/ (445 msec), /a/ (438.50 msec), /u/ (433.12 msec), /u:/ (432.50 msec), /e:/ (421.87 msec), /o/ 367.50 msec).

In both normal and hearing impaired group, vowel /o/ had the shortest duration.

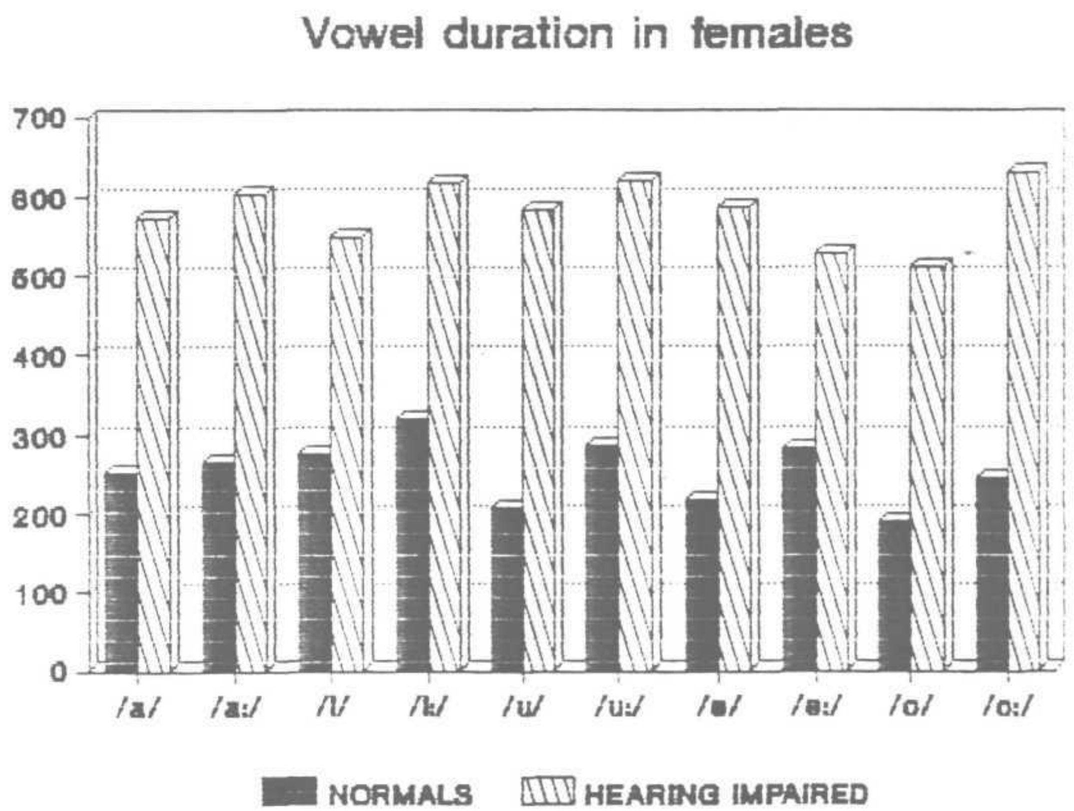
Table l(b): Showing the mean and S.D. in both normal females and hearing impaired females

Vowels	Normal Females		Hard of hearing Females		Mean difference HI & Normals (msec)
	Mean (Msec)	Standard deviation	Mean (Msec)	Standard deviation	
a	250.50	31.61	571.30	178.09	320.8
a:	263.14	52.14	602.50	171.37	339.36
i	276.14	45.36	546.75	165.17	270.61
i:	318.17	56.61	616.25	242.82	298.08
u	207.17	34.59	581.25	163.64	374.08
u:	284.56	49.36	618.75	312.82	334.19
e	216.47	26.42	587.50	146.72	371.03
e:	280.77	59.42	528.75	141.18	247.98
o	191.12	43.96	510.00	223.43	318.88
o:	245.22	34.36	630.00	213.29	384.78

Similarly in the normal female group, the vowel /i:/ had the longest duration (318.17 msec). It was followed by /u:/ (284.56 msec) /e:/ (280.77 msec) /i/ (276.14msec), /a:/



GRAPH 1a : Mean values for vowel duration in normal and hearing impaired males



GRAPH 1b : Mean values for vowel duration in normal and hearing impaired females

(263.35msec), /a/ (250.50msec) /o:/(245.22msec), /e/ (216.47msec), /u/ 207.17 msec), /o/ (191.12 msec).

In case of hearing impaired female vowel /o: / had the longest duration (630msec), and others as follows /u:/ 618.75msec), /i:/ (616.25 msec) /a:/ (602.50msec), /e/ (587.50msec), /u/ (581.25m3ec), /a/ (571.30msec), /i/(546.75msec) /e:/ (528.75msec), /o/(510 msec)

For the normal male group minimum and maximum mean values ranged from 191.20 - 289.20 msec and for the hearing impaired male group the mean values ranged from 367.50 -535.62 msec. For the normal female group ninimum and maximum mean values ranged from 191.12 -318.17 msec and for hearing impaired female group 510 - 630 msec.

The mean vowel duration produced by the hearing impaired males were found to be higher than that of normals by 167.95msec - 313.25msec. The mean difference between hearing impaired males and normals for the vowels /a/, /a:/ /i/ /i:/ /u/ /u:/ /e/ /e:/ /o/ /o:/ were 228.34msec, 262.44msec 199.65msec, 210.17msec, 237.67msec, 176.95msec, 240.53msec, 172.02msec, 176.30msec and 313.25msec. respectively.

Normal male group had vowel duration in the decreasing order as follows /i:/ > u: > i:> a: > e: > o: > a > e > u > o. Hearing impaired group did not follow the same pattern as that of normals.

The mean vowel duration produced by hearing impaired females were found to be higher than that of normals by 247.98 msec-384.78 msec. The mean difference between hearing impaired females and normals for the vowels a, a:, i, i:, u, u:, e, e: o, o: were 320.8msec, 539.36msec, 270.61msec, 298.08msec, 374.08msec, 334.19msec, 371.03msec, 247.98msec, 318.88msec and 384.78msec respectively.

Normal female group had vowel duration in the decreasing order as follows: i:>u:>e:>i>a:>a>o:>e>u>o.

Hearing impaired female group did not follow the same pattern as that of normals.

Mann whitney U test performed showed a significant difference between the

1) Hearing impaired males and normal males.
2) Hearing impaired females and normal females at 0.05 level of significance in terms of vowel duration.

Mann whitney U test performed also showed no significant difference between

1) hearing impaired males and hearing impaired females.
2) normal males and normal females at 0.05 level of significance in terms of vowel duration.

Thus the hypothesis (1) stating that there is no significant difference between normal and hearing impaired subjects in terms of vowel duration is rejected.

Hypothesis (2) stating that there is no significant difference between hearing impaired males and hearing impaired females and normal males and normal females in terms of vowel duration is accepted.

2. TOTAL DURATION OF WORDS

The words uttered by the hearing impaired subjects had longer duration in general when compared to the normal hearing group, which is depicted in Table II (a and b).

Table 2: [a] and Graph 2(a) depict the mean values for total word duration in normal and hearing impaired males.

Table 2(a):

	Normal Males		Hard of hearing males		Mean difference HI a Normals
Vowels	Mean (Msec)	Standard deviation	Mean (Msec)	Standard deviation	(msec)
/anan/	528.76	50.186	1228.72	382.74	699.96
/a:na/	589.27	96.43	1102.50	294.03	513.23
/ila/	546.22	76.44	1017.25	286.97	471.03
/i:cha/	630.27	86.25	1140.00	290.24	509.73
/uri/	503.05	90.13	1055.00	279.52	551.95
/u:nal/	613.05	64.03	1207.50	338.66	594.45
/eli/	506.15	93.82	941.25	294.22	435.1
/e:ni/	565.77	115.83	1066.25	358.96	500.48
/onnu/	579.95	106.37	1081.81	311.11	501.86
/o:la/	518.62	101.47	1228.75	393.48	710.13

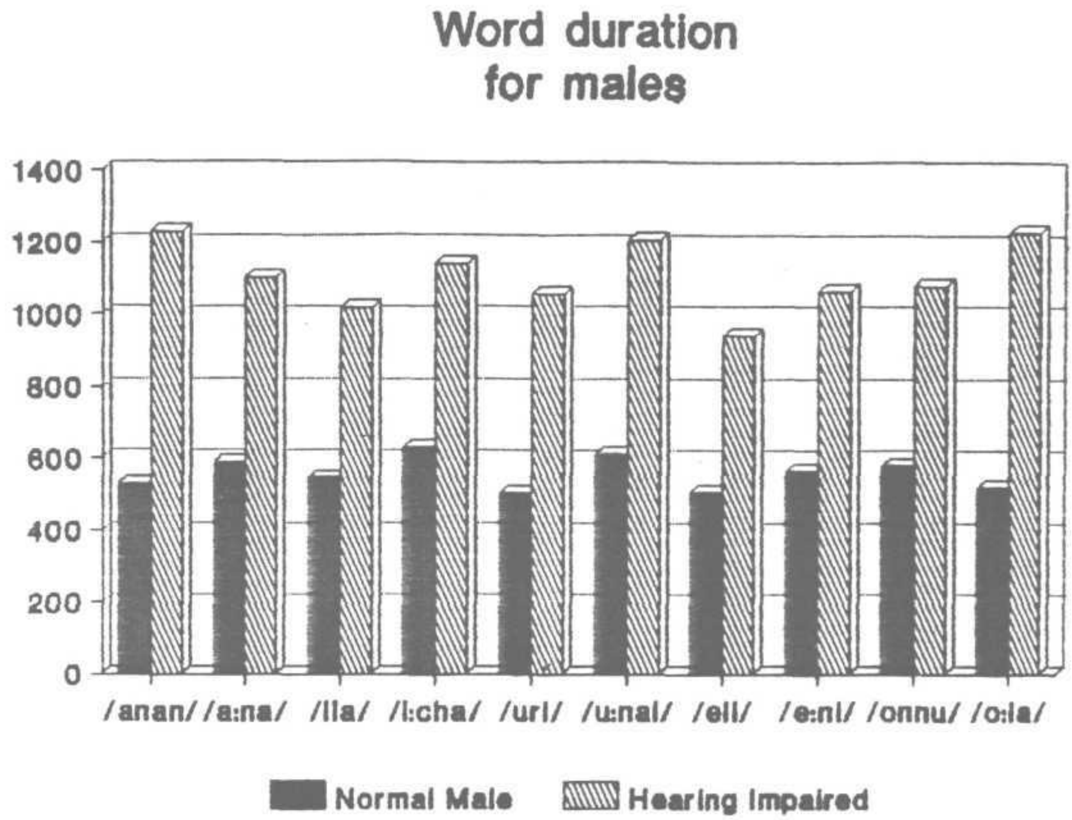
In the normal male group, the word /i:cha/ had the largest duration (630.27msec) followed by /u:nal/ (613.05 msec), /a:na/ (589.27msec) /onnu/ (579.95msec). e:ni/ (565.77 msec), /ila/ (546.22msec) /anan/ (528.76msec) /o:la/ (518.62 msec), /eli/ 506.15msec), /uri/ (503.05msec).

Whereas in the hearing impaired male group, the word /o:la/ had the longest word duration (1228.75msec) followed by /anan/ (1222.72 msec), /u:nal/ (1207.50 msec), /i:cha/ (1140msec) /a:na/ (1102.50 msec) /onnu/ (1081.81msec), /e:ni/ 1066.25 msec), /uri/ (1055msec), /ila/ (1017.25msec), /e;li/ (941.25 msec).

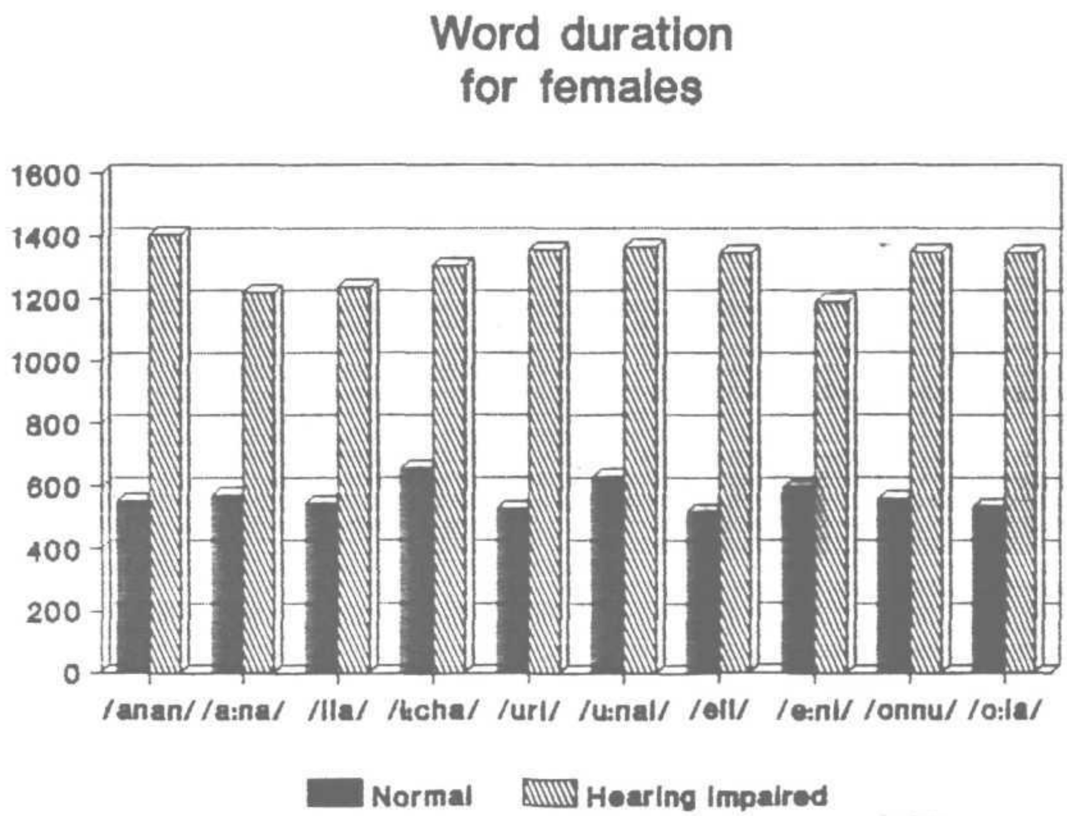
Table 2: [a] and Graph 2(a) depicts the mean values for total word duration in normal and hearing impaired females.

Table 2: (b)

Vowels	Normal Females Mean (Msec)	Normal Females Standard deviation	Hard of hearing females Mean (Msec)	Hard of hearing females Standard deviation	Mean difference HI & Normals (msec)
/anan/	551.67	64.58	1403.35	463.85	851.68
/a:na/	567.65	116.84	1216.25	235.56	648.6
/ila/	545.35	76.44	1236.18	224.48	690.83
/i:cha/	655.30	123.10	1303.75	237.90	648.45
/uri/	528.10	89.21	1352.50	293.14	824.4
/u:nal/	625.20	70.31	1361.25	336.26	736.05
/eli/	519.17	90.11	1341.15	464.96	821.98
/e:ni	592.20	90.95	1186.87	336.84	594.67
/onnu/	555.47	106.37	1347.50	374.62	792.03
/o:la/	534.17	97.75	1342.45	414.57	808.28



GRAPH 2a : Mean values for word duration in normal and hearing impaired males



GRAPH 2b : Mean values for word duration in normal and hearing impaired females

In the normal female group the word /i:cha/ had the longest word duration (655.30 msec), followed by /u:nal/ (625.20) /eni/ (592.20msec), /a:na/ (567.65msec), /onnu/ (555.47 msec) /anan/, (551.67 msec). /ila/ (545.35 msec), /o:la/ (534.17 msec) /uri/ (528.10msec), /eli/ (519.17 msec).

In the hearing impaired female group the word /anan/had the longest word duration (1403.35 mssec) followed by /u:nal/ (1361.25 msec) /uri/ (1352.50 msec), /onnu/ (1347.50 msec), /o:la/ (1342.45 msec), /eli/ 1341.15 msec /i:cha/ 1303.75 msec /ila/ 1236.18 msec /a:na/ (1216.25 msec), /e:ni/ (1186.87msec).

In both the normal male and female group the word /i:cha/ had the longest duration.

The mean difference between hearing impaired males and normals for the words anan, a:na, ila, i:cha, uri, u:nal, eli, e:ni, onnu and o:la were 699.96, 513.23, 471.03, 509, .73, 551.95, 594.45, 435.1, 500.48, 501.86 and 710.13 msec respectively. The mean word duration produced by hearing impaired males were found to be higher than that of normals by 435.1 to 710.13 msec. The hearing impaired group had larger variations than that of the normal hearing group.

The mean difference between hearing impaired females and normals for the words anan, a:na, ila, i:cha, uri, u:nal, eli, e:n i; onnu and o:la were 851.68, 648.6, 690.83, 824.4, 736.05, 821.98, 594.67, 792.03 and 808.28 msec respectively.

The maximum mean difference between hearing impaired females and normals in terms of word duration was for the word /anan/.

The mean word duration produced by hearing impaired females were found to be higher than that of normals hearing by 594.67 to 851.68 msec. The mean whitney U test performed showed significant difference between:

1) Normal hearing males and hearing impaired males and
2) normal hearing females and hearing impaired females at < 0.05 level of significance in terms of word duration.

Where as Mann whitney U test showed also no significant difference between

1) Normal hearing males and normal hearing females
2) Hearing impaired males and hearing impaired females in terms of word duration.

Thus the hypothesis (1) stating that there is no significant difference between normal and hearing impaired subjects in terms of word duration is rejected.

Hypothesis (2) stating that there is no significant difference between hearing impaired males and heaxing impaired females and normal males and normal females in terms of word duration is accepted.

3. AVERAGE FUNDAMENTAL FREQUENCY :

Table 3: [a] and Graph 3(a) depict the mean values for fundamental frequency in normal and hearing impaired males.

The hearing impaired children had higher Fo than that of normal hearing children.

Table 3(a)

Vowels	Normal Males		Hard of hearing males		Mean difference HI & Normals (Hz)
	Mean (Hz)	Standard deviation	Mean (Hz)	Standard deviation	
a	228.90	21.56	347.70	36.32	118.8
a:	221.90	26.52	343.29	38.76	121.39
i	252.71	20.91	451.49	43.73	198.78
i:	253.40	25.04	443.41	38.05	190.01
u	248.03	24.35	420.91	55.93	172.88
u:	204.73	24.64	349.42	40.57	144.69
e	229.67	23.84	348.48	43.62	118.51
e:	212.80	22.20	431.82	46.89	219.02
o	236.46	20.85	353.76	52.42	117.3
o:	224.93	20.59	436.95	47.76	212.02

In the normal hearing male group, the high Fo was for the vowel /i:/ (253.40 Hz) followed by /i/ (252.71 Hz), /u/ (248.03 Hz), /o/ (236.46 Hz), /e/ (229.67 Hz),/a/ (228.90 Hz) /o:/ (224.93 Hz), /a:/ (221.90Hz) /e:/ (212.80 Hz), /u:/ (204.73 Hz).

In the hearing impaired male group the highest Fo was for the vowel /i/ (451.49 Hz) followed by /i:/ (443.41 Hz) /o:/ (436.95 Hz), /e:/ (431.82 Hz), /u/ (420.91 Hz), /o/ (353.76 Hz),/u:/ (349.42 Hz), /e/ (348.48 Hz), /a/ (347.70 Hz), /a:/ (343.29 Hz).

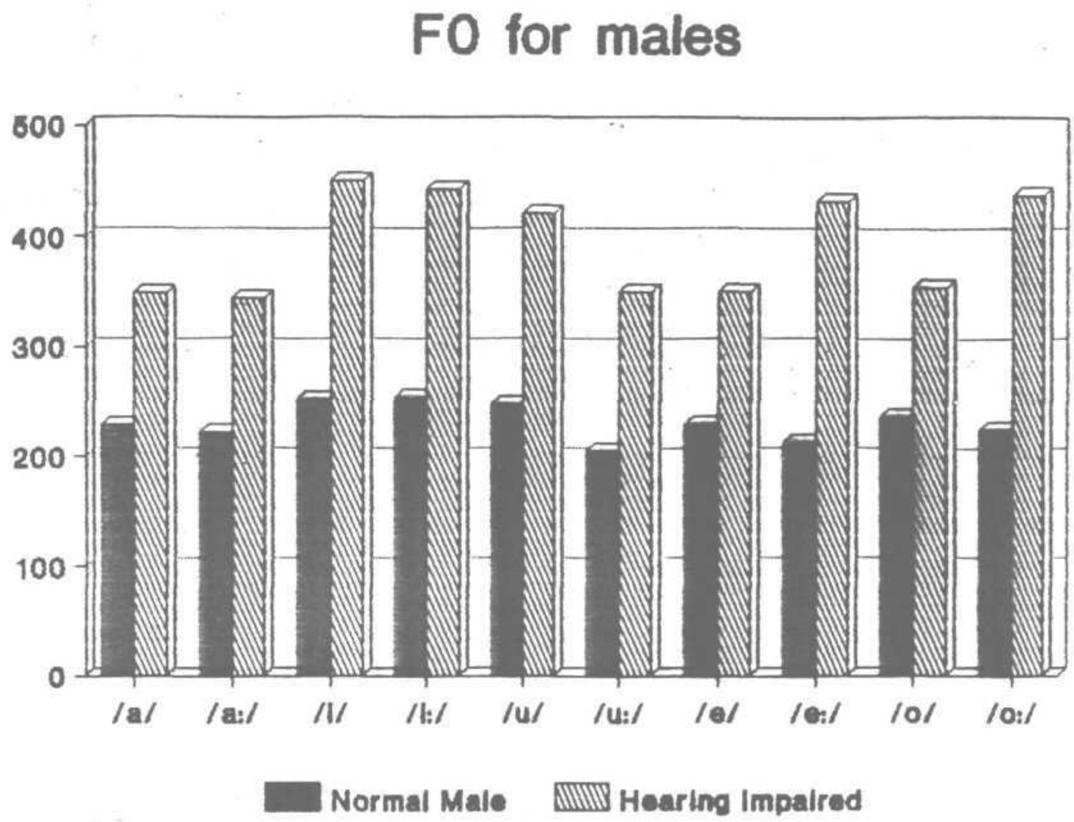
Both in the normal and heairng gearing impaired male groups the highest Fo was for the vowel /i/.

Table 3: [b] and Graph 3(b) depict the mean values for fundamental frequency in normal and hearing impaired females.

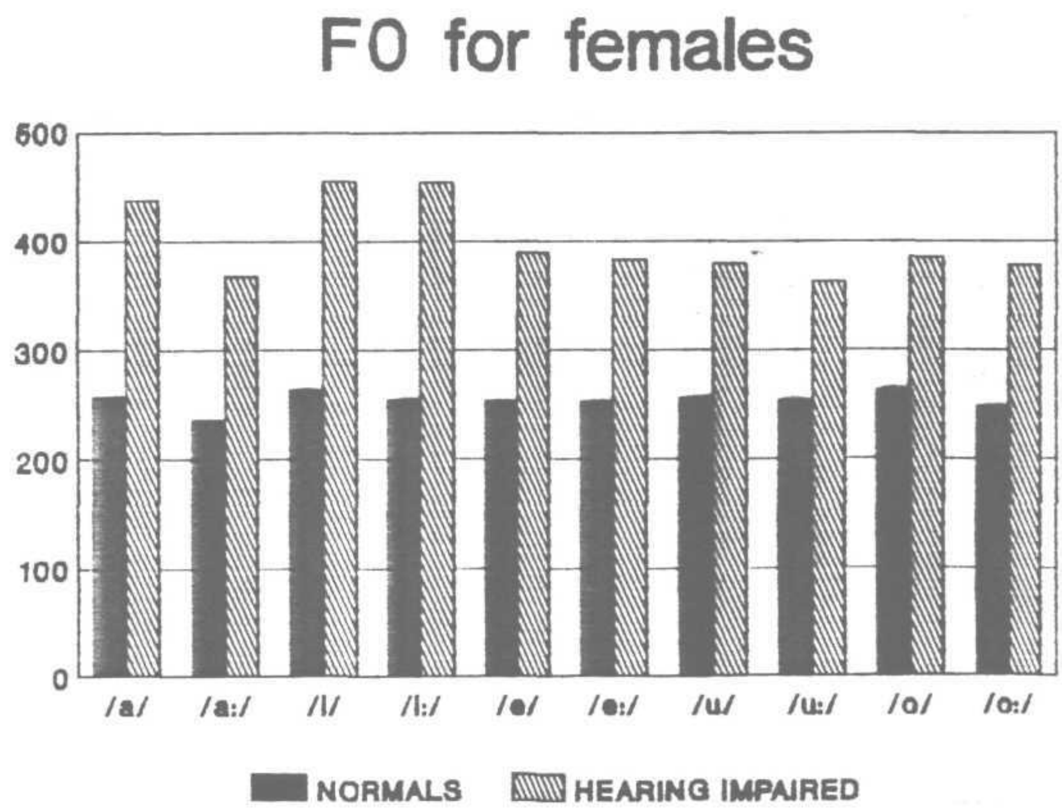
Table 3(b)

Vowels	Normal Females Mean (Hz)	Normal Females Standard deviation	Hard of hearing females Mean (Hz)	Hard of hearing females Standard deviation	Mean difference HI & Normals (Hz)
a	257.58	24.96	437.00	77.15	179.42
a:	235.51	34.99	368.48	19.22	132.97
i	263.88	21.58	455.14	18.91	191.26
i:	254.60	16.93	453.77	41.03	199.17
u	252.93	11.85	388.58	17.03	135.65
u:	252.25	16.98	383.40	19.11	131.15
e	256.59	21.29	378.99	16.81	122.4
e:	254.35	23.86	362.64	34.91	108.29
o	262.98	27.65	385.32	13.58	122.34
o:	248.28	29.44	378.27	16.59	129.99

In normal hearing female group, highest Fo was for the vowel /i/ (263.88 Hz) followed by /o/ (262.98 Hz) /a/ (257.58



GRAPH 3a : Mean values for F0 in normal and hearing impaired males



GRAPH 3b : Mean values for F0 in normal and hearing impaired females

Hz), */e/* (256.59 Hz), /i:/ (254.60 Hz), /e/ (254.35 Hz), /u/ (252.93 Hz), /u:/ (252.25 Hz), /o:/ (248.28 Hz), /a:/ (235.51 Hz).

In the hearing impaired female group highest Fo was for vowel /i/ (455,14 Hz) followed by /i:/ (453.77 Hz), /a/ (437 Hz), /u/ (388.58 Hz), /o/ (385.32 Hz),/u:/ (383.40 Hz), /e/ (378.99 Hz), /o:/ (378.27 Hz), /a:/ (368.48 Hz), /a:/ 362.64Hz).

Similarly in both normal and hearing impaired female group the highest Fo was for vowel /i/.

In the normal groups, minimum and maximum mean values ranged from 204.73 Hz - 263.88 Hz, whereas in the hearing impaired group values ranged from 343.29 Hz - 455.14Hz.

Variation in range was seen to be more in the hearing impaired male group compared to that of the normals, whereas in the female hearing impaired group, the variations in range were more for all the vowels except for /a:/, /i/, /e/, /o/, /o:/.

The Mann whitney U test indicated significant difference between the two groups at 0.05 level of significance in terms of Fo.

Thus the hypothesis stating that there is no significant difference in the utterance of children in terms of average fundamental frequency of the vowels is rejected.

Hypothesis (2) stating that there is no significant difference between hearing impaired males and hearing impaired females and normal males and normal females in terms of average fundamental frequency is accepted.

FORMANT FREQUENCY CHARACTERISTICS OF VOWELS:

One of the purpose of this study was to analyze and compare the vowel formants of the hearing impaired speakers and normal hearing Malayali speakers.

Previous researchers (Potter et al., 1947, Angelocci et al., 1964) have indicated that the first three formants contribute the greatest part of vowel information.

Three formant values namely Fl, F2 and F3 for each vowel were obtained.

First formant frequency:

Table 4: [a] and Graph 4(a) depict mean values for first formant frequency in normal and hearing impaired males.

Table 4(a)

Vowels	Normal males Mean (Hz)	Normal males Standard deviation	Hard of hearing males Mean (Hz)	Hard of hearing males Standard deviation	Mean difference HI & Normals (Hz)
a	853.30	48.39	898.50	155.54	45.2
a:	754.20	176.99	902.00	109.74	147.8
i	428.90	62.42	606.30	190.94	177.4
*i:	398.40	79.93	553.00	155.70	154.6
*u	483.20	71.35	663.70	271.36	180.5
*u:	492.50	72.20	617.80	127.74	125.3
*e	502.00	73.52	702.70	193.17	200.7
e:	538.00	45.62	666.20	197.21	128.2
o	592.30	112.28	665.10	108.63	72.8
o:	697.60	79.54	740.70	89.32	43.1

* Significant at 0.05 level of significance.

In general the hearing impaired children had higher Fl than those of the normal hearing group. The means of first formant frequency (Fl) for the hearing impaired male subjects were higher than for the normal hearing subjects for all the vowels. The mean difference Fl values for these vowels varied from 43.1 to 200.7 Hz. The mean difference of Fl values between hearing impaired males and normals for the vowels, /a/, /a:/, i, i:, u, u:, e, e:, o, o: were 45.2 Hz, 147.8 Hz, 177.4 Hz, 154.6 Hz, 180.5 Hz, 125.3 Hz, 200.7 Hz, 128.2 Hz, 72.8 Hz and 43.1 Hz respectively.

A significant mean difference between hearing impaired males and normals was found only for vowels /i:/, /u:/ and /e/.

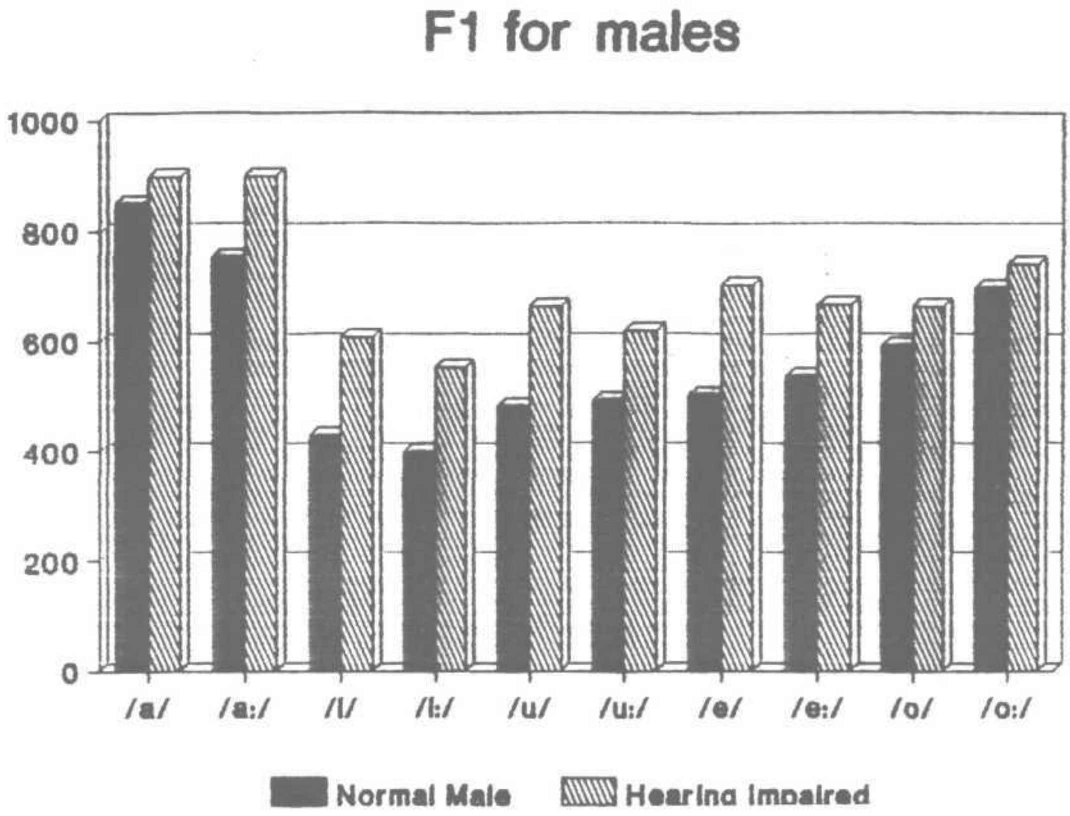
Table 4: [b] and Graph 4(b) depict mean values for first formant frequency in normal and hearing impaired females.

Table 4(b)

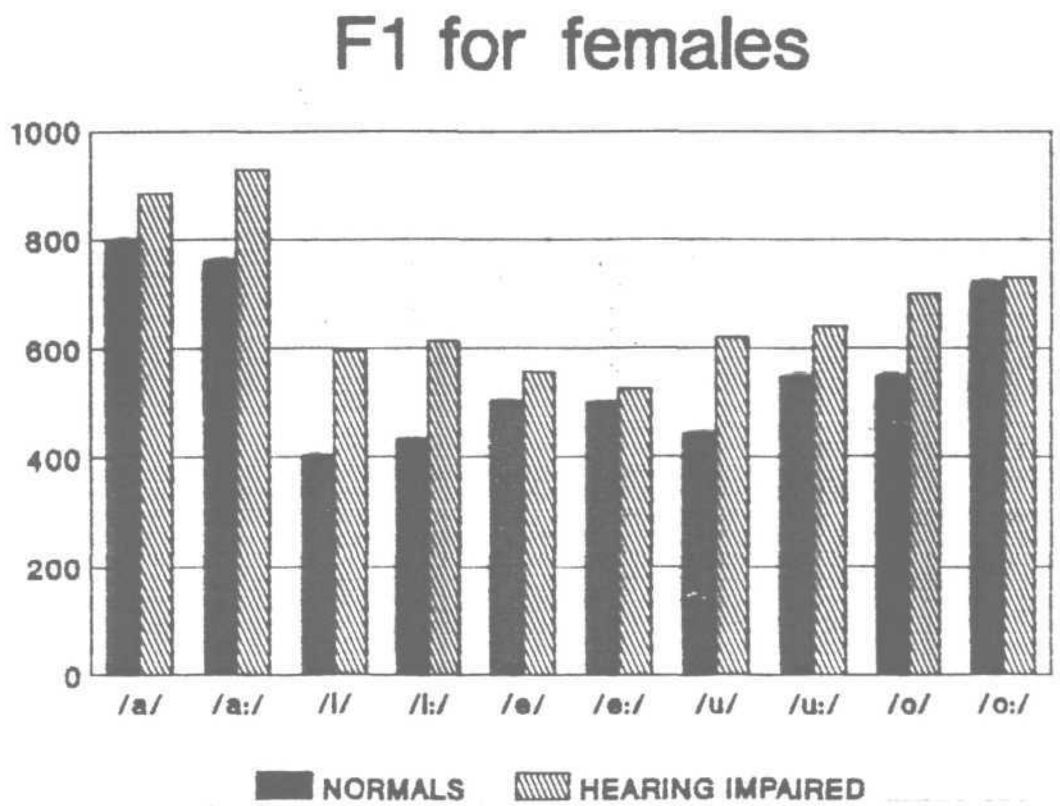
Vowels	Normal Females Mean (Hz)	Normal Females Standard deviation	Hard of hearing females Mean (Hz)	Hard of hearing females Standard deviation	Mean difference HI & Normals (Hz)
a	799.10	111.71	885.30	179.23	86.2
a:	759.40	147.47	928.30	186.83	168.9
i	404.20	42.71	597.70	102.65	193.5
*i:	433.30	56.67	613.90	141.85	180.6
*u	500.90	45.64	558.10	102.26	57.2
u:	499.60	61.13	524.30	109.00	24.7
*e	444.00	98.11	622.60	102.40	178.6
e:	547.50	74.22	642.20	144.02	94.7
*o	548.50	111.86	702.00	142.43	153.6
o:	722.00	94.22	731.10	161.05	9.1

* Significant at 0.05 level of significance.

It was found that hearing impaired females had higher Fl values than that of normals for all the vowels. The



GRAPH 4a : Mean values for F1 in normal and hearing impaired males



GRAPH 4b : Mean values for F1 in normal and hearing impaired females

difference between means of hearing impaired females to that of normals females for the vowels. /a/, /a:/, /i/, /i:/, /u/, /u:/, /e/, /e:/, /o/, /o:/. Were 86.2 Hz, 168.9 Hz, 193.5 Hz, 180.6 Hz, 57.2 Hz, 24.7 Hz, 178.6 Hz, 94.7 hz, 153.6 Hz and 9.1 Hz respectively. A significant mean difference between hearing impaired females and normal females was found only for vowels /i:/, /u/, */&/* and /o/.

Comparison of Males and Females:

It was found that vowels /i:/, /u/ and /e/ in both the groups showed significant mean difference between hearing impaired and normal hearing groups.

The hypothesis stating that there is no significant difference between the means of Fl values of vowels of the hearing impaired males and normal hearing males was rejected for /i:/, /u/, /u:/ and /e/ and accepted for /a/, /a:/, /i/, /e:/, /o/ and /o:/.

The hypothesis that there is no significant difference between the means of Fl values of vowels of the hearing females and normal hearing females was rejected for /i:/, /u/, /e/ and /o/ and accepted for /a/, /a:/, /i/, /u:/, /e:/ and /o:/.

SECOND FORMANT FREQUENCY:

Table 5: [a] and Graph 5(a) depict mean values for second formant frequency in normal and hearing impaired males.

Table 5 (a)

Vowels	Normal males Mean (Hz)	Normal males Standard deviation	Hard of hearing males Mean (Hz)	Hard of hearing males Standard deviation	Mean difference HI & Normals (Hz)
a	1427.70	77.77	1651.80	332.32	224.1
a:	1492.60	376.19	1669.70	283.58	177.1
i	1673.70	353.70	1441.00	481.83	-232.7
i:	1605.20	418.25	1738.00	311.19	132.8
u	1264.60	123.50	1388.70	431.47	124.1
u:	1189.20	154.34	1247.80	252.02	58.6
*e	1441.00	353.70	1673.70	481.83	232.7
e:	1450.90	349.82	1571.00	366.21	120.1
q	1263.70	127.21	1324.40	264.88	60 .7
o:	1247.80	130.26	1303.80	294.61	56.0

* Significant at 0.05 level

The mean F2 values of vowels a, a:, i:, u, u:, e, e:, o and o: were found to be higher for the hearing impaired males compared to normals. The mean difference between normals and hearing impaired were 224.lHz, 177.1 Hz, -232.7 Hz, 132.8Hz, 124.lHz, 58.6 Hz, 232.7 Hz, 120.1 Hz, 60.7 Hz and 56 Hz respectively for /a/, /a:/ /i/ /i:/, /u/ /u:/, /e/ /e:/, /o/ and /o:/ mean difference for these vowels ranged from-232.7Hz to 232.7Hz. The mean F2 value of vowel /i/ was found to be lower for hearing impaired male than that of normal hearing male group.

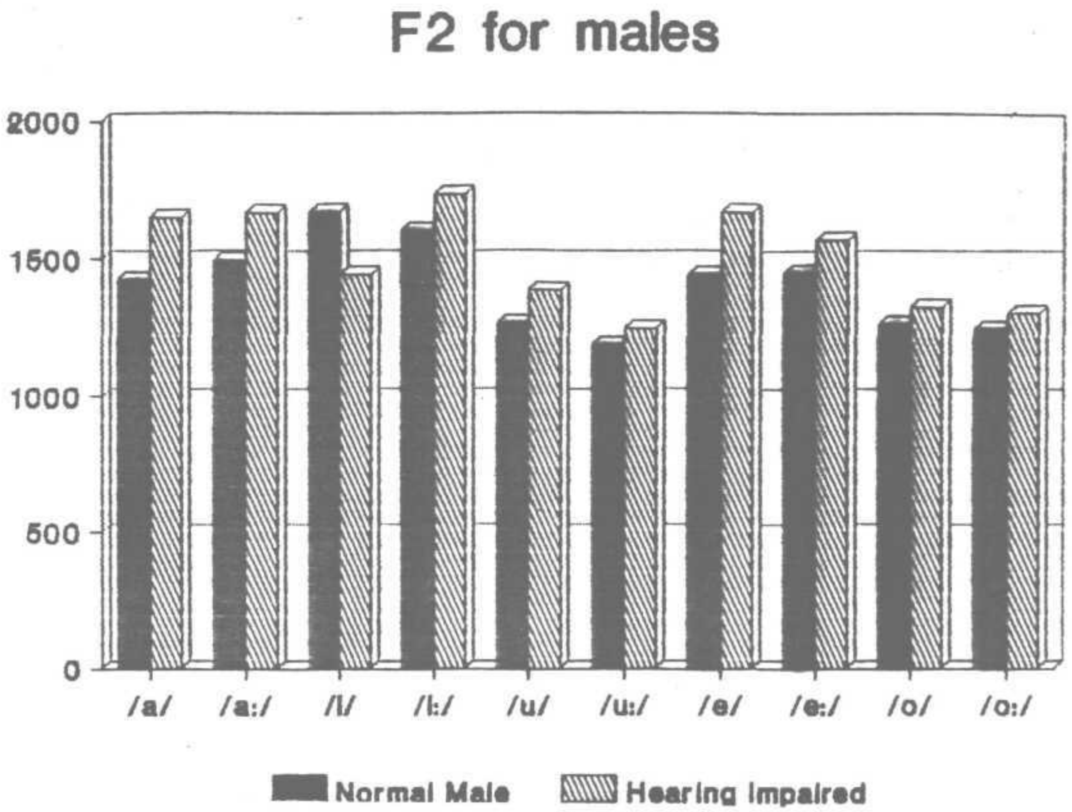
However, significant difference between means for hearing impaired and normal hearing males were found for only vowel /e/ and not for others.

Table 5: [b] and Graph 5(b) depict mean values for second formant frequency in normal and hearing impaired females.

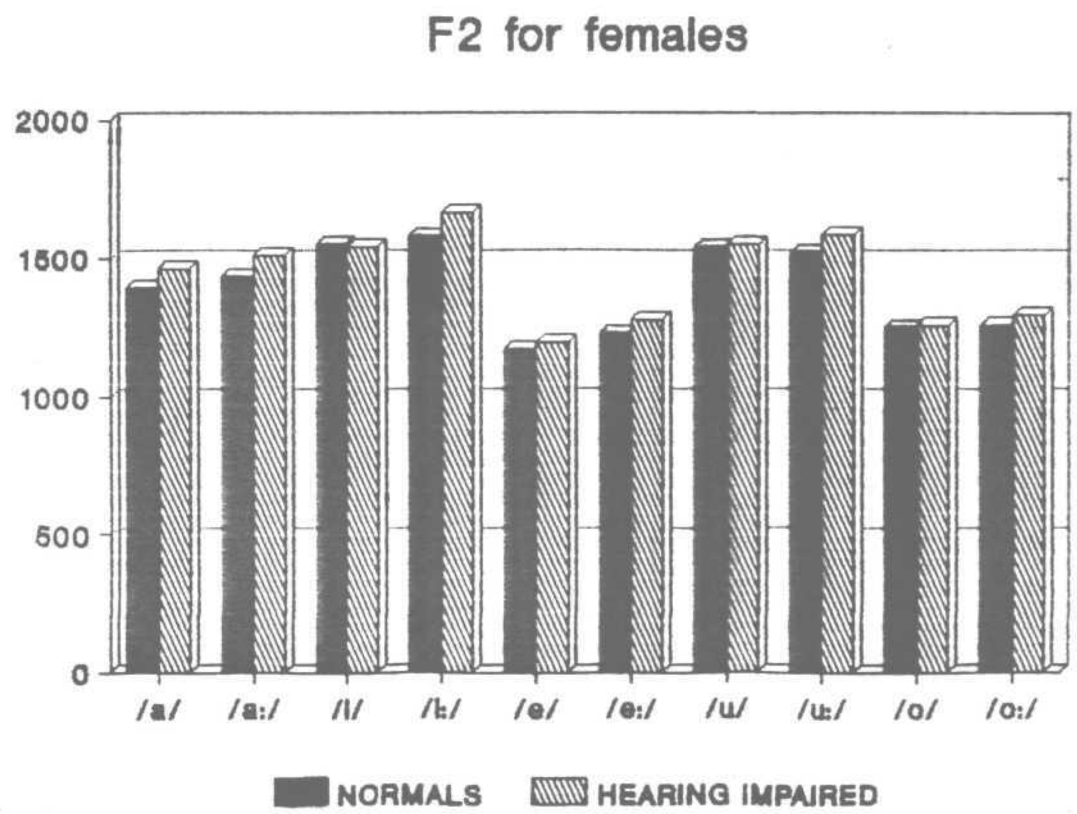
Table 5(b)

	Normal females		Hard of hearing females		Mean difference HI & Normals (Hz)
Vowe1s	Mean (Hz)	Standard deviation	Mean (Hz)	Standard deviation	
a	1395.00	226.72	1462.80	77.66	67.8
a:	1432.80	178.56	1512.10	266.66	79.3
i	1551.50	205.68	1540.10	466.73	-11.4
i:	1581.20	308.08	1664.60	466.27	83.4
u	1171.10	169.24	1192.60	289.87	21.5 .
u:	1230.00	318.25	1279.00	315.45	49.0
e	1540.00	205.68	1551.50	466.73	11.5
e:	1520.20	435.47	1582.70	468.25	62.5
o	1250.50	171.25	1256.20	164.45	05.7
o:	1256.90	237.73	1290.80	274.08	33.9

* Significant at 0.05 level



GRAPH 5a : Mean values for F2 in normal and hearing impaired males



GRAPH 5b : Mean values for F2 in normal and hearing impaired females

The mean F2 values for vowels /a/, /a:/, i:, u, u:, e, e: , o and o: were higher for hearing impaired female group than that of normal hearing females.

The mean differences for both female groups for the vowels a, a: /i/, /i:/, /u/ /u:/, /e/ */e:/,* /o/ and /o:/ were 67.8 hz, 79.3 Hz, -11.4 Hz, 83.4 Hz, 21.5 Hz, 49.0 hz, 11.5 hz, 62.5 Hz, 5.7 Hz and 33.9 Hz respectively. The mean difference values ranged from -11.4 hz to 83.4 Hz.

The mean F2 value for vowel /i/ was found to be lower for hearing impaired female group than that of normal hearing female group.

However no significant difference between means for hearing impaired and normal hearing females was found for any of the vowels.

Comparison of Males and Females:

Over all similar pattern for mean F2 was seen among males and females of hearing impaired groups.

Both hearing impaired males and females showed higher mean F2 for all vowels except for the front vowel /i/.

It was found that generally among hearing impaired males and females none of the vowels showed significant difference in mean F2 when compared to normal hearing males and females except for vowel /e/ being higher in the hearing impaired male group.

Thus the hypothesis that there is no significant difference between the means of F2 values of the hearing impaired males and normal hearing males was accepted except for vowel /e/ and rejected for all the other vowels a, a:, i, i:, u, u:, e:, o and o:.

The hypothesis that there is no significant difference between the means of F2 values of the hearing impaired females and normal hearing females was accepted for all the vowels a, a:, i, i:, u, u:, e, e:, o and o:.

Thus it can be concluded that the mean F2 is not significantly different in the vowels produced by hearing impaired to that of normal group.

Hypothesis (2) stating that there is no significant difference between hearing impaired males and hearing impaired females and normal males and normal females in terms of second formant frequency is accepted.

THIRD FORMANT FREQUENCY:

Table 6: [a] and Graph 6(a) depict mean values for third formant frequency in normal and hearing impaired males.

Table 6(a)

Vowels	Normal males Mean (Hz)	Normal males Standard deviation	Hard of hearing males Mean (Hz)	Hard of hearing males Standard deviation	Mean difference HI & Normals (Hz)
*a	1924.00	116.25	2564.30	289.05	640.3
a:	2231.80	475.61	2388.70	443.18	156.9
i	2648.00	375.46	2494.40	352.03	-154.0
i:	2553.10	462.62	2612.50	328.15	59.4
u	2476.30	314.17	2598.40	384.64	122.1
u:	2423.20	312.82	2273.40	266.35	-149.8
e	2534.40	212.37	2621.40	405.49	87.0
e:	2688.00	320.35	2551.80	326.88	-136.2
o	2319.40	261.84	2460.70	385.60	141.3
o:	2430.60	242.44	2344.90	319.18	-85.7

* Significant at 0.05 level.

It was found that F3 values for the hearing impaired males was higher than that of normal males except for vowels /i/, /u:/, /e:/ and /o:/. The mean difference of F3 values for vowels varied from -154 to 640.3 hz.

By far the greatest group difference in the mean of F3 values was for the vowel /a/ in which the normal-hearing males had F3 of 1924 Hz and the hearing impaired male 2564.30 hz.

The normal hearing males had a high F3 than hearing impaired males for vowels /i/, /u:/, */e:/* and /o:/. The mean difference between both groups for these values were -154 Hz, -149.8 Hz, -136.2 Hz and -85.7 Hz respectively.

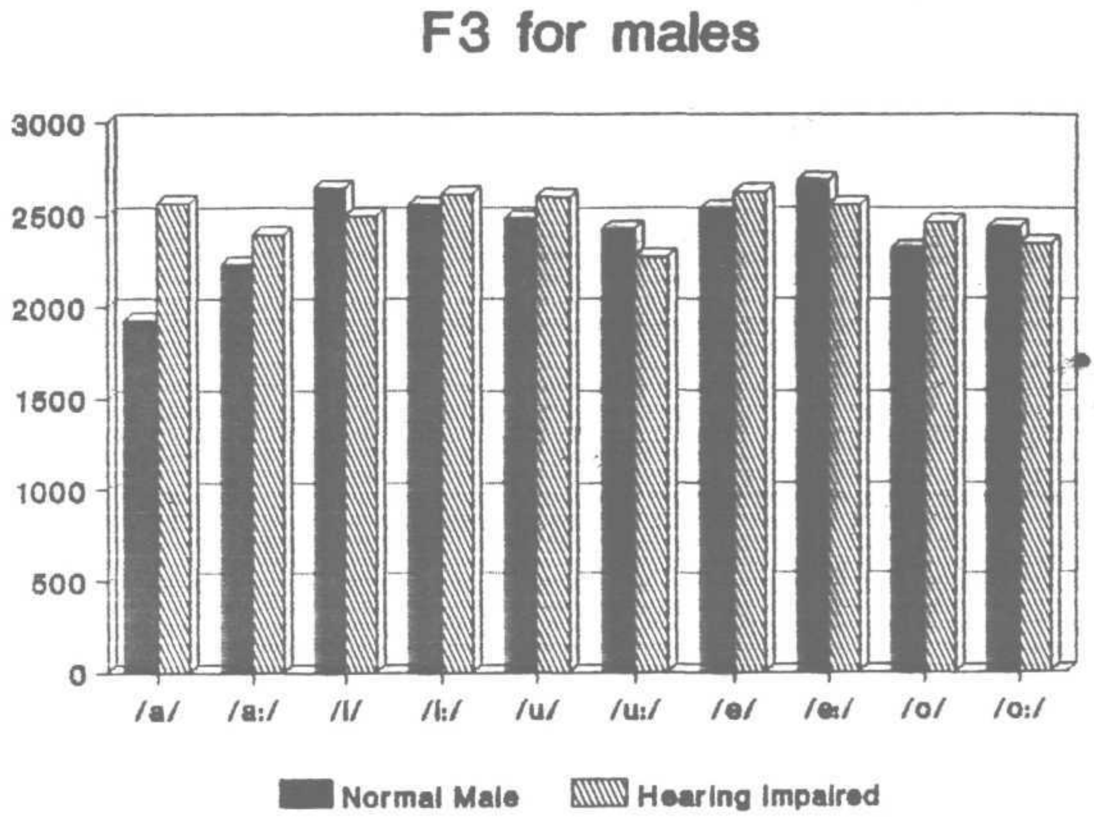
A significant mean difference between hearing impaired and normal hearing males was found for vowel /a/.

Table 6: [b] and Graph 6(b) depict mean values for third formant frequency in normal and hearing impaired females.

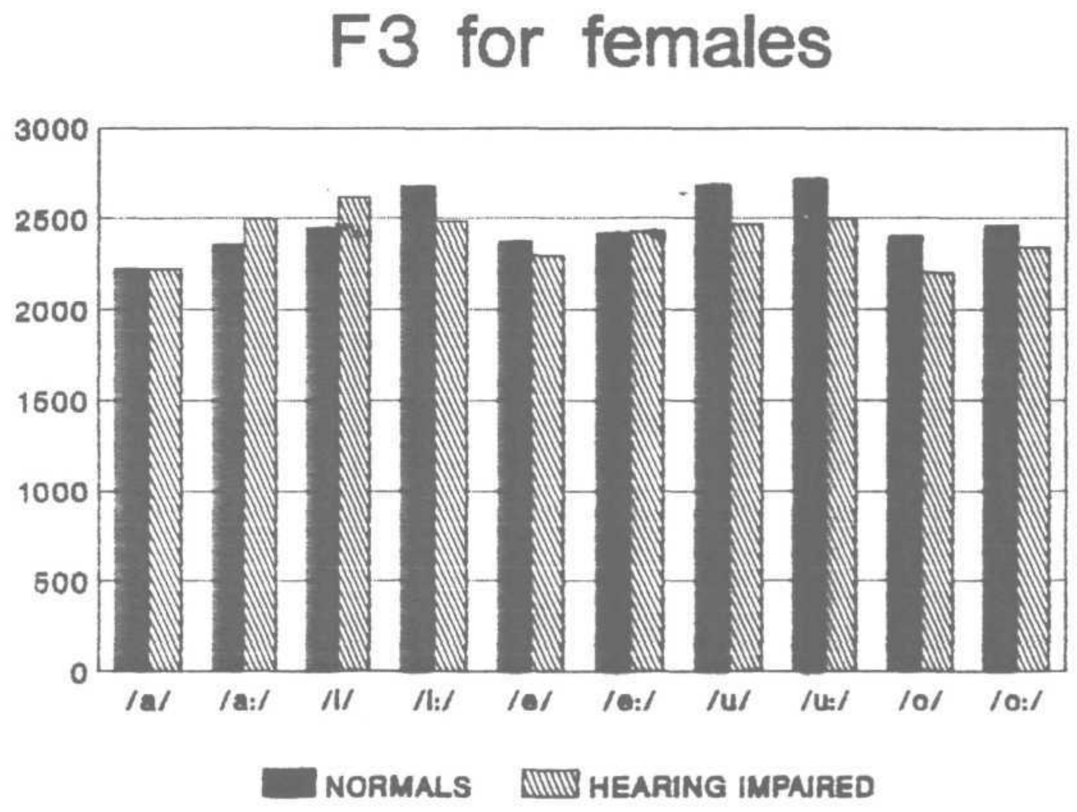
Table 6(b)

Vowels	Normal females Mean (Hz)	Normal females Standard deviation	Hard of hearing females Mean (Hz)	Hard of hearing females Standard deviation	Mean difference HI & Normals (Hz)
a	2222.10	348.75	2223.70	347.04	1.6
a:	2354.90	480.40	2496.50	471.21	141.6
i	2447.40	280.38	2618.20	427.01	170.8
i:	2675.10	343.44	2479.70	423.60	-195.4
u	2373.30	338.83	2294.00	224.11	-79.3
u:	2418.60	325.15	2425.80	249.28	7.2
*e	2680.60	212.39	2469.00	255.45	-211.6
e:	2716.20	202.45	2498.20	313.47	-218.0
o	2403.90	360.16	2199.10	214.72	-204.8
o:	2456.90	317.03	2339.50	222.87	-117.4

* Significant at 0.05 level of significance



GRAPH 6a : Mean values for F3 in normal and hearing impaired males



GRAPH 6b : Mean values for F3 in normal and hearing impaired females

Generally it was seen that hearing impaired females had lower F3 values than normal hearing females for vowels /i:/, /u/, /e/, /e:/, /o/ and /o:/. The mean difference between two groups varied from -218 to 170.8 Hz. Largest group difference in the mean of F3 was for the vowel /i/ 170.8.

A significant mean difference between the hearing impaired and normal hearing females was seen for vowel /e/.

So it was concluded that hearing impaired males and females did not show a similar pattern regarding the F3 values when compared to normals.

Thus the hypothesis stating that there is no significant difference between the means of F3 values of vowels of the hearing impaired males and normal hearing males is accepted except for vowel /a/.

The hypothesis stating that there is no significant difference between the means of F3 values of vowels of the hearing impaired and normals hearing females is rejected for vowel /e/ and accepted for vowels /a/, /a:/, /i/, /i:/, /e:/, /u/, /u:/, /o/ and /o:/

Hypothesis (2) stating that there is no significant difference between hearing impaired males and hearing impaired females and normal males and normal females in terms of III formant frequency is accepted.

Band widths:

The three band widths Bl, B2 and B3 were determined for all the vowels. The hearing impaired children had smaller values of bandwidth.

The Mann whitney U test performed did not show a significant difference between the two groups at 0.05 level of significance for BW1, BW2 and BW3.

Thus the hypothesis stating that there is no significant difference in the utterances of children with normal hearing and hearing impaired children in terms of bandwidth is accepted.

Hypothesis (2) stating that there is no significant difference between hearing impaired males and hearing impaired females and normal males and normal females in terms of bandwidth is accepted.

PAUSES:

The analysis of intraword (or inter syllabic) pauses revealed that normal subjects did not show any pauses, whereas pauses were observed in the utterances of some hearing impaired subjects. It was found that fourteen out of twenty hearing impaired children exhibited pauses in their utterances, seven were males and seven were females.

It was found that more number of hearing impaired males exhibited, pauses for the word /i:cha/ (6/7) and the pause durations varied from 100 msec to 312.5 msec. Four of the male subjects exhibited pauses only for one word while other three exhibited pauses for 2 words.

In the hearing impaired male groups, pauses were exhibited on the words i:cha (6/7), onnu (2/7), u:nal (1/7) and o:la (1/7) .

Similarly in the female hearing impaired group the maximum number of subjects exhibited pauses on the word i: cha (5/7) and the pause duration varied from 150 msec -550 msec. Four of the females subjects exhibited pause on one, word, two subjects exhibited pause for two words and one female subject had pauses for five words. In the hearing impaired female group pauses were exhibited on i:cha (5/7), anan (2/7), ila (2/7), e:ni (1/7), o:la (1/7), u:nal (1/7), and uri (1/7).

Concluding the hypothesis stating that there is no significant difference between normals and hearing impaired subjects in terms of pauses was rejected.

Hypothesis (2) stating that there is no significant difference between hearing impaired males and hearing impaired females and normal males and normal females in terms of pauses is accepted.

* Hypothesis stating that.

a) There is no significant difference in the utterance of normal males and normal females on all the parameters measured.

b) There is no significant difference in the utterance of hearing impaired males and hearing impaired females and on all the parameters measured was accepted.

DISCUSSION

The hearing impaired children had longer vowel duration when compared the normal hearing group. This finding is in agreement with the studies of Angelocei, 1962; Calvert 1962, John and Howart, 1965; Boone,1966; Hevitt et al, 1974; Osberger and Hevitt 1979; Rajanikanth, 1986; Heeper et al, 1987; Shukla,1987; Sheela 1988; Jagadish,1989. Rasitha 1994.

These studies reported that a general tendency towards lengthening of vowels and consonant was seen in the speech of hearing impaired. Results of the present study are similar to the results obtained by the previous investigators as listed above. It was also observed that the hearing impaired children showed more variability when compared to normal hearing children. These findings are in agreement with the reports of Monsen (1974), Osberger (1978) Rajanikanth (1985) Shukla (1987), Sheel (1988), Jagadish (1989)

Studies have reported a relationship between fundamental frequency and vowel duration. Nataraja and Jagadish (1984) reported that vowel durations was longer at lower and higher fundamental frequency than at optimum frequency.

The longer vowel durations reported in case of hearing impaired children can also be attributed to this because it was seen that on the average, these children had higher fundamental frequency than that of the normal hearing children. It may also be due to higher tension of vocal fold muscles.

Further, it ha3 been reported that the profoundly hearing impaired speakers insert more pause and pauses of longer durations that do speakers with normal hearing. Boone (1966), Boothroyd (1974)" Heidinger (1972), Stevens (1978), Osberger and McGarr (1982) Sheela (1988). Jagadish (1989, Rasitha (1994).

In the present study it was found that out of 20 hearing impaired children 14 inserted pauses between two syllables whereas 6 subjects did not do so. The frequent pauses observed in the speech of the hearing impaired may be the result of poor respiratory control. Foraer and Hixon (1977) found that the muscle activity to be normal for deaf individuals during quiet breathing but noted that they do not take enough air while breathing for speech.

In the present study it was also seen that the total duration of words were longer in the hearing impaired group when compared with the normal hearing children. Similar findings have been reported by Leeper (1987). Total duration of words would be more in hearing impaired children as they prolong the speech segments. Osberger and McGarr (1982) reported prolongation of speech segment present in the production of Phonemes, syllables and words in the speech of hearing impaired.

Results of the present study show that hearing impaired children had higher fundamental frequency when compared to the normal hearing children. Few explanations have been put forward in order to explain the higher fundamental frequency in case of hearing impaired. Pickett (1968) suggested that the increase in fundamental frequency in due to increased subglottal pressure and tension of the vocal folds. Thus his opinion has been that the increased vocal effort is directed at the laryngeal mechanism for kinesthetic feedback and thus leading to increase in Fo.

Willemain and Lee (1971) hypothesized that the deaf speakers use extra vocal efforts to get an awareness of the onset and progress of voicing and this becomes the cause of the high pitch which is observed in their speech.

In the present study the mean Fl values for all the vowels were found to be higher in the hearing impaired group compared to the normal group. Similar results were reported by Sheela (1988), Sowmya (1992 and Rasitha (1994).

The difference in the mean Fl values between the normals and hearing impaired group was significant only for the front vowels /i/ and */&/* and back vowels /u/ and /o/.

Regarding the mean F2 values in general the hearing impaired had higher mean F2 vales compared to that of the normal except for vowel /i/. However no significant difference was found between the two groups. The mean F3 values of hearing impaired were found to be similar to that of the normal or either above or below that of the normal values. No significant difference was observed between the normal and hearing impaired group in terms of the third formant frequency.

Additionally no gender effects were seen on all the parameters measured in both normal and hearing impaired groups. Similar studies were carried out in the past by Rajanikanth (1986), Shukla (1987), Sheela (1988), Jagadish (1989), Sowmya Narayanan (1992), Rasitha (1994) and Rahul (1997) on the same parameters discussed above. The present results are in accordance with the results of the previous studies on all the parameters except for the formant frequencies Fl and F2.

Therefore the results of the present study obtained from Malayalam speaking children are similar to the results obtained from the studies on Kannada, Tamil, Punjabi and English speaking children for the parameters vowel duration, word duration, pause duration and average fundamental frequency.

SUMMARY AND CONCLUSIONS

"Great strides have been made in understanding the speech of the hearing" impaired, but our knowledge in this area is far from complete". (Oberger and McGarr, 1986).

Present study aims at determining some of the acoustie characteristics of speech of Malayalam speaking hearing impaired children. Twenty congenitally Malayalam speaking hearing impaired children between 7-10 years were selected. Control group consisted of twenty normal children in the same age range, sex and language. All the hearing impaired children had severe to profound sensori neural hearing loss and using hearing aid and had speech and language. All these children were able to read simple bisyllabic words in Malayalam.

The speech samples of all the children were recorded and the samples were analyzed using computer programmes of VSS, Bangalore. The parameters analysed were the following:

1. Vowel duration
2. Intersy1labic pauses
3. Total duration of words
4. Average Fo
5. Formant frequency (Fl, F2 and F3)
6. Bandwidths (Bl, B2 and B3)

The obtained data was subjected to statistical analysis to determine the mean, SD and significance of difference between the two groups.

Results of the present study showed that:

1. The hearing impaired group had significantly longer vowel duration than that of the normal hearing group.

2. Normal hearing children did not show any inter syllabic pauses (Intraword) whereas 14 out of 20 children in the hearing impaired group inserted intersyllabic pauses at least once in each word.

3. Total duration of words uttered by the hearing - impaired children were significantly longer that of the normal hearing group.

4. Hearing impaired children had higher average Fo than that of the normal hearing group.

5. In general hearing impaired children had higher first formant (Fl) than normal hearing group.

But significant difference was seen between the two groups only for the front vowels /i/ and /e/ and back vowels /i/ and /e/ and back vowels /o/ and /u/.

6. Hearing impaired children also exhibited higher second formant frequency (F2) values compared to the normal

groups. However, no significant difference was found between the two groups in terms of F2.

7. The F3 values were found to be either above or below than that of the normal values.

RECOMMENDATIONS:

1. Similar study on a larger population can be undertaken.

2. Additional parameters like VOT, closure duration, formant amplitude etc can be studied using various CVC combinations.

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APPENDIX - I

/anan/

/a:na/

/ila/

/i:cha/

/uri/

/u:nal/

/eli/

/e:ni/

/onnu/

/o:la/

Malayalam has eleven vowel phonemes /i/ /i:/ /e/ /e:/ /a/ /a:/ /o/ /o:/ /u/ /u:/ and /U/. The short vowels /i/ /e/ /a/ /o/ and /u/ in the word final position are a little longer than in other environments. In additions to the above 3ix vowels, there is a low front vowel / / which occurs with length in certain borrowed words from English. Its distribution is limited only to medial position (Shyamala Kumari, 1972).