DEDICATED TO

AND

TO *MY G*UIDE DR. N.P. NATARAJA

CFRTIFICATE

*This is to Certify that this dissertation entitled "**Temporal and Acoustic Analysis of Speech of Kannada Speaking Hearing Impaired Children** " is the bonafide work in part fulfilment for the second year M.Sc. (Speech and Hearing of the student with Reg. No.M9607.*

Mysore
May, 1998

Dr. (Miss) S. NTKAM
Director
All India Institute of Speech & Hearing
MYSORE - 570 006

CERTIFICATE

*This is to Certify that this dissertation entitled "**Temporal and Acoustic Analysis of Speech ofKannada Speaking Hearing Impaired Children** " has been prepared under my supervison and guidance.*

ide

Mysore
May, 1998

D N.P.NATARAJA
Professor and H.O.D.
Department of Speech Sciences
All India Institute of Speech & Hearing
MYSORE - 570 006

DECLARATION

*This dissertation entitled "**Temporal and Acoustic Analysis of Speech ofKannada Speaking Hearing Impaired Children** " is the result of my own study under the guidance of Dr. N.P. NATARAJA, Reader and H.O.D. Department of Speech Science. All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any other University for any other diploma or degree.*

MYSORE
May, 1998

Reg. No. M9607

ACKNOWLEDGEMENTS

I express my deepest gratitude and heartfelt thanks to my guide *Dr. N.P. NATARAJA*, Professor and H.O.D. Department of Speech Science, All India Institute of Speech and Hearing, Mysore, for all his inspiration, encouragement, guidance, comments, patience, listening, and unitiring effort in steering me through every aspect of the study.

I extend my gratitude to *Dr. (Miss) S.NIKAM*, Director, All India Institute of Speech and Hearing, Mysore, for permitting me to carry out this study.

My special thanks to *Mrs. N. SREEDEVI, Mrs. SANGEETHA* and *Mrs. LALITHA*, Department of Speech Science, All India Institute of Speech & Hearing, Mysore, for extending ah[1] their support in the data collection and during my analysis.

Thanks to all those innocent little kids for being so lonely and co-operative subjects for the study.

Preeti, Priya, Veena and *Visa.* Thanks for being such wonderful and lovely friends and staying by my side and sharing my troubles and happiness. A special thanks to *Priya Paul* for all her help and support at the right time.

Manoj, Raja, Sara, Binu, Shibu and ***Ratna*** **- Thank** you **for** talking, listening, understanding and comforting me. For giving me strength in my times of need and sharing with me my happiness and my excitement. A special thanks to ***Manoj. P*** for all his help.

To ***Suresha, B.*** who shared my ups and downs in dissertation work, my frenzy and fervous and laziness and laughter. Thank you.

Muthu, J.K. Chandan, Ananthan, Milind and ***B.T.(Machan)*** Thanks ! for being such great pals.

Special thanks to ***Sandhya, Kiruthika, Hema*** and ***Selva*** for their help and encouragement.

Bhumi you are **a** invaluable and rare. Your words were a constant source of encouragement and hope during my dark phase. Thanks for your helping hands.

I would like to extent my thanks to ***Mr. R.Rajapal, Spaceage Electronic Typing,*** for seeing through my work in schedule inspite of being one loaded.

Lastly, I thank **God Almighty** for all this blessings.

Reg. No.M9607

CONTENTS

INTRODUCTION

Speech may be viewed as the unique method of communication evolved by man to suit the uniqueness of this sound (Eisenson & Erwin, 1963).

Speech is a form of communication in which the transmission of information takes place by means of speech wave which are in the form of acoustic energy, (Fant 1960). It is known from the speech production studies that the speech sounds have different acoustic cues like the formant transition, formant frequencies, bandwidths, duration of closure burst, direction of transition, VOT, fundamental frequency, vowel duration and word duration etc.

The exact role usually 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 & Irwin 1958). Normal child controls his speech movements with the help of auditory and kinesthetic feedback (Whenthall and Fry, 1964).

Speech is unique to man, Its presence has made all the difference between man and the lower beings. A poor speech development may not only hamper effective communication but also the overall development of the individual. Among the many variables affecting speech development, hearing level is perhaps the most important (Ling, 1976).

Impairment of hearing leads to a number of problems. Many researchers have shown that a congenital hearing loss tends to produce speech problems the more severe the loss, the more deviant is the speech produced by the child. There are clear-cut differences between the spech of deaf and hard-of-hearing children. These differences that appear are more quantitative than qualitative (Ross, 1982).

One of the most devastating effects of congenital hearing loss is that normal development of speech is often disrupted. As a consequence, most hearing impaired children must be taught the speech skills that normal hearing children readily acquire during the first few years of Life. Although some hearing impaired children develop intelligible speech, many do not. Recent investigators have indicated that only about 20% of the speech output of the deaf is understood by the "person on the street". Poor intelligibility has been associated with various segmental and suprasegmental errors in the hearing impaired person's speech. The correlation between the errors and overall speech intelligibility is less clear.

With the current advance in technology, it is possible to overcome the lack of auditory feedback in hearing-impaired by providing a variety of other feedbacks through the other sensory modalities as well as through amplification of sounds, but before this one has to know the different characteristics and parameters of the speech of hearing impaired; a proper underestanding of which will help in deciding the selection of the different aspects of speech for providing an effective feedback.

From information on the acoustic, and articulatory correlation of these errors it should be possible to develop more effective techniques and instrumentation to eliminate those errors. Many factors like residual hearing, sequental errors, suprasegmental errors have been correlated with the poor speech intelligibility of the hearing impaired individuals speech. Hence, the present study was planned to determine the relationship between some of the suprasegmental errors and intelligibility of the Kannda speaking hearing impaired children.

Aim of the study :

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

Hypothesis - I : There is no significant difference in the utterance of normal and hearing impaired in term of acoustic and temporal parameters.

Methodology:

20 Simple byisyllabic *(CVC)* Kannada meaning full words uttered by 40 hearing impaired children (20 males and 20 females) were recorded as they read the words. Recording of utterances of some 20 Kannada words were also obtained of a matched group (for age and sex) of 40 normal hearing children.

The samples were then analyzed using compute programmes of VSS, Bangalore. The following parameters were obtained.

1) Total duration of words
2) Vowel duration
3) Intersyllabic pause duration
4) Average Fo
5) Forment 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, S.D. and significance of differences between the two groups.

Implications of the study :

The result of this study would help to understand the speech of the hearing-impaired children better.

The results of this study would help to know how the errors ctffects the intellligibility of the speech of the hearing impaired.

This study also would help to plan and develop thereapy programmes with the hearing impaired children.

REVIEW OF LITERATURE

"One form of communication which people use most effectively in inter-personal relationship is speech. Through it, human beings give out their innermost thoughts, their dreams, ambitions, sorrows and joys. Without speech, they are reduced to animal noises and unintelligible gestures, In real sense, speech is the key to human existence. It bridges the differences and helps to give meaning and purpose to their lives". (Fischer, 1975).

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 interchange [Ling, (1976)]. "It is through the auditory mode that speech and language are normally and usually effortlessly developed". (Ross & Giolas, 1978).

The term 'Normal Hearing' does not merely imply that a sound is audible but also describes the whole skill of detection, recognition and interpretation of the meaning of sounds. Hearing in this sense is not present at birth but is a special skill dependant on learning. The process of acquiring this skill, that is the processing of learning to hear, is even more exclusive than the established skill. As a result the part played by hearing in communication has been side stepped.

When a child is born hearing handicapped or becomes hearing handicapped early in life, special conditions must be provided in order that he may learn to use his limited hearing (residual hearing) to understand and produce speech. If these special conditions are not provided, the born hearing handicapped or becoming hearing handicapped in early life will be without means of communication and this is it that constitutes the very great handicap of the hearing handicapped child. Failure to receive and understand speech inevitably involves a failure to produce speech. The hearing handicapped child is thus reduced to gestures for communication and so his means of acquiring information is limited to a great extent. As a result, his emotional and intellectual developments are largely affected.

The normal child live in the world of continuous sounds. He is learning to recognize sounds and he begins to enjoy his own voice, his mother's voice and the sounds that are going on around him. In brief, he is being bathed in the world of sounds (Rama, 1972).

Normal child controls his speech movements with the help of auditory and kinesthetic feedback. (Whetnall & Fry, 1964). The exact role usually played by auditory feed back in the normal acquisition of speech is not known. Observation 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 & Irwin, 1958).

Hearing is essential for the seemingly natural development of speech .__ language, and communication is interfered by the presence of hearing loss (Stark, 1929). Several facts have been reported on the effect of hearing loss on the acquisition and maintenance of speech. It has a marked effect on a child's ability to acquire speech.

The deaf child is faced with a severe communication handicap, Normal speech is unintelligible to him and a result of lack of auditory feed back of his own speech production he has considerable difficulty in learning to speak correctly (Levitt etal, 1974; Cowie and Cowie, 1983).

One of the most recognised but least understood concomitants of deafness is a deficit of oral communication skills. The speech produced by many deaf persons is frequently unintelligible to even experienced listeners. Morever 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 unintelligible speech of deaf, the development of effective clinical statement is limited (Metz, 1982).

The oral communication skills of the hearing impaired children have long been of concern to educators of the hearing-impaired, speech pathologist and Audiologist, because the adequacy of such skills can influence the educational and carrier opportunities available to these individuals (Osberger and Mcgarr, 1982).

The ultimate goal in aural rehabilitation is, for the hearing impaired individual, to attain, as far as possible, the same communication skills as those of the normal hearing individuals. Within the last decade advances have been made in studying speech. This is largely due to the development of sophisticated processing and analysis techniques in speech science, electrical engineering and computer science. The technological advances have also been applied to the analysis of the speech of the hearing-impaired and to the development of clinical assessment and training procedures (Osbergert and Me Garr, 1982)

Several methods have been employed to study speech production in hearing impaired. These include physiological (Metz et al 1985) acoustic (Monsen, 1976 a, 1976b, 1974, 1978; Angelocein, et al 1964; Gilbert, 1975, Mc.Clumphe, 1966; Calvert, 1962; Shukla, 1985; Rajinikanth, 1986; Sheela, 1988; Jagadish, 1989) perceptual methods (Levitt, et al, 1976; Stenens, et al 1983;Hudgins and Numbers 1992; Markides, 1970; Geffner, 1980, etc).

Acoustic analysis of speech is extremely useful to researchers since the methodologies employed are typically non-invasive, relatively basine with regard to 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 a finer grained consideration of some aspects of both correct and incorrect production than would be possible using methods applied in the subjective procedures (Obserger and McGarr, 1982). It provides objective descriptions of speech of the hearing impaired. More information abut the characteristics of the speech of the hearing-impaired would help in making use of the advances in the technology with maximal effectiveness in the 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 how their speech deviates from that of normally hearing children and the effect of various errors and abnormal speech patterns on the intelligibility (Lemitt, 1978). Thus, analysis of speech of hearing impaired becomes important.

Intelligibility of speech of the hearing impaired :

Speech intelligibility refers to how much of what a child says can be understood by a listener (Obserger and McGarr, 1982).

Information on the speech production and performance of hearing impaired children is needed for things such as program, planning evaluation and research (Boothroyd 1985).

Inspite of the recent advances made in the areas of speech, education and hearing, the problem of unintelligible speech in the hearing impaired has been acknowledged by several investigators". Speech intelligibility of the hearing impaired as a measure of their speech potential has been studied by a number of investigators. There is a difference of opinion regarding the intelligibility of speech cf hearing impaired.

According to Obserger and Levitt (1982) "On the average, the intelligibility of profoundly hearing impaired children's speech is very poor. Only about one in every five words they say can be understood, by a listener who is unfamiliar with the speech of this group". On the other hand, Metz et al (1982) are of the opinion that the speech produced by many deaf persons is frequently unintelligible to even experienced listeners.

In a study of intelligibility of speech of 192 hearing impaired subjects age ranging from 8-19 years, 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 Number, 1942).

Recent studies (Brannon, 1964, Markides 1970; Smith 1973) have showed that inspite of the provision of hearing aids, speech training, the average intelligibility of speech of the severely and profoundly deaf child to the main listener is not more than 20% (Stark 1979). Markides (1970) studied 58 hearing impaired children aged 7 to 9 years, only about 31% of their words were intelligible to the teachers whereas 19% intelligible to naive listeners.

Conrad (1979) reports that about 75% of prelingually deaf children with hearing losses of 90dB or more have speech classified as "barely intelligible" or worse. Ling (1976) says the speech of profoundly hearing impaired children is usually less than 30% intelligible". Smith (1972) studied hearing impaired children in the age group of 8-10 years and 13-15 years and found that word intelligibility assessed by 120 listeners unfamiliar with the speech of hearing impairment was 18.7%.

Gold (1980) found that only about 20% of the speech output the deaf is understood by the person on the street. This lack of intelligibility is attributed to several frequently occuring sequential and suprasegmental errors. Monsen (1978) reported a relatively high mean intelligibility score of 76% however they attribute such high score to the simple test material used to study speech intelligibility.

Several other studies have shown that hearing impaired children have poor levels of speech achievement (Kerridge, 1938; Hood, 1966, Goda 1959; Quigley and Frisina, 1961; Angelocci 1962; John and Howarth, 1965; Montgomery, 1967; Tobeck, 1967; Bravernan, 1974; Conrad 1976; Kysler, 1977).

Heidenger (1972) studied the speech of 20 hearing impaired children (more than 85 dB loss in the better ear). Her 3 judges, who were exprienced teaches of deaf and know what the children were trying to say rated than less than 20% their words in short sentence as unintelligible. The results of various studies suggest that overall levels of speech intelligibility are utterly inadequate for oral communication [Ling, , (1976)]. The differences in speech intelligibility scores obtained by various studies may attributed to the differences in methodologies employed and the heterogeneity of the samples studied.

According to Ling (1976), intelligibility ratings can vary not only with the type of judge employed but also with the materials used and with the methods of analysis applied. Intelligibility ratings have been reported to be 10-15% higher when judged by teachers or experienced listeners than those by the naive listeners (Geffner et al 1978, Mangan 1961, McGarr, 1978, Monsen, 1978).

Sentences, when used as test materials tend to be more intelligible than words and sentences which are spoken directly to listener in a face to face situation are more intelligible than sentences are tape recorded. (Hudgins, 1949, Thomas, 1964). Several factors have been found to affect the intelligibility of speech.

According to Subtelny (1977) the speech intelligibility is the single most practical index of hearing impaired person's oral communication abilities. But she cautions that intgelligibility assessment cannot be used with confidence for training purposes without the knowledge of the properties of speech that influence intelligibility.

Stevens et al (1978, 1983) reinforced this notion, who suggested that the fundamental problem of speech assessment with hearing impaired person's is to identify those properties of speech that determine its intelligibility.

Identification of speech properties that determine intelligibility is a methodologically complex task (Metz et al 1980, Nickerson and Stevens. 1980) but one that clearly has utility for the development of effective remedial strategies for improvement of speech of hearing impaired.

The low speech achievement of the hearing impaired has lead to several ttempts in the part to correlate speech intelligibility with several variables related to reception and production 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 variable residual hearing (Montgomery, 1967, Elliot, 1967; Boothroyd, 1969; Mar Addes, 1970; Smith, 1975; Kyle, 1977; Monsen 1978; Stoker and Lape, 1980; Ravishankar 1985; Vasantha, 1995) and lip reading)(Stoker and Lape 1980) and tactile perception (Stroker and Lape, 1980) abilities have been studied. The results have indicated that residual hearing ability as well as one's lip reading ability, effect intelligibility. Children with lesser degree of hearing loss wre found to have better speech intelligibility. Also, hearing impaired children tend to have a better speech intelligibility when their lip reading abilities were better.

On the production side speech intelligibility has been studied with relation to segmental and suprasegmental errors. Errors involving individual speech phonemes, ie., segmental errors have been studied by Hudgins and

Numbers, 1942; Nober, 1963; Markides, 1970; Smith, 1973; McGarr, 1980; Ravishankar, 1985 etc. According to these studies there is a high negative correlation between the frequency of segmental errors on intelligibility i.e., the higher the incidence of segmental errors the poorer the intelligibility of speech (Parkaurst and Levitt, 1980).

Studies on acoustic features of speech of the hearing impaired have supported the findings of the above mentioned studies. Calvert., 1961; Monsen, 1974; 1976a, b,c, Rothman, 1976). Both consonant and vowel errors have long been recognised in the speech of the hearing impaired.

Consonant errors include:

* Voicing errors.
* Substitution errors
* Omission errors.

Vowel and dipthong errors include :

- Substitution errors
- Neutralization of vowels
- Dipthongization of vowels
- Errors involving dipthongs, either the dipthong was split into two distinctive components or the final component was dropped.

Monson (1978) examined the relationship between intelligibility and four acoustically measured variables of consonant production, three acoustic variables of vowels production and two measures of prosody. To find out which were highly correlated with intelligibility. He found that VOT and the 2nd formant frequency to be significant.

Other segmental error has been observed to have a significant negative correlation with intellegibility are ;

Omission of phoneme in word initial and medial positions, consonant substitution and unidentifiable or gross distortion of the intended phoneme (Levitt, etal 1980).

Consonant error have been generally found to be highly correlated with speech intelligibility than are the vowel error (Hudgins and Numbers, 1942).

Timing:

Rate : On the average, deaf speakers speak at a much slower rate than normal speakers (Rawlings, 1935; 1936; Voelker, 1938, Calvert, 1962; Boone, 1966; Brannon, 1986, Hood, 1966, Martony, 1965; 1966; Calton and Cooker, 1968; Boothroyd et al 1974; Wickerson et al, 1974)

Hearing impaired speakers have been found to speak more slowly than even the slowest hearing speakers. When hearing impaired speakers and normals have been studied under similar conditions, the measured rates of syllables or word omission have often differed by a factor of two or more (Hood, 1966).

Voelker (1938) compared 98 deaf and 13 normals hearing children in graded 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 69.9 and 164.4 words/minute for the deaf and normal hearing child, respectively. Nikerson, et al (1974) tested slightly older deaf and control groups on reading rate and found large differences between the groups although the mean rate for the deaf was high as 108 words/minute.

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

(i) Increased duration of phonemes, and (ii) Improper and often prolonged pause within utterances (Gold, 1980).

Hearing impaired speakers have been studied under similar conditions. The measured rates of syllables or word omission have often differed by a factor of two or more (Hood, 1966).

Increased duration of phonemes :

The duration of a phoneme bears important information in the perception of a speech message.

Durational changes in vowels serve to differentiate not only between vowels themselves but also between similar consonants adjacent to those vowels (Raphel, 1972; Gold, 1980).

There is a general tendency towards lengthening of vowels and consonants in the deaf (Angelocei, 1962; Boone, 1966; Levitt, et al 1974; Levitt and Parkburst 1978; Sheela, 1988; Rasitha, 1994).

Vowels are longer in the presence of voiced stops and continuant (House and Fair bank, 1953; Denes, 1955; Raphel, 1972); Peterson and Lehiste, 1960; Lindblom, 1968; Dix Simoni, 1974 a.b). This lengthening of the vowel contribute to the perception of the consonants. Schwartz (1969) also noted that consonant duration were lengthened when the past consonant vowel was 1:1 no matter what the preceeding vowel (in a VCV utterance). Unfortunately, however, the duration of phonemes is distorted in the speech of the deaf.

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 results of this study showed that hearing impaired speakers extend the duration of vowels, fricatives and the closure period of plosives upto 5 times the average duration for normal speakers.

Monsen (1946) studied 12 deaf and 6 normal hearing adolescents as they read 56 CVCs, containing the vowels 1:1 or |i|. He found that the deaf subjects tend to create mutually exclusive durational classes for the two vowels such that the duration of one vowel could not approximate that of the other even when they occured in the presence of different consonants. For the normal subjects, the duration of |i| was longer than |i[always, for a particular consonantal environment, but the absolute durations of the two vowels could overlap if the accompanying consonants differed. Thus, although the vowels produced by the deaf subjects were distinct in terms of duration, they were still less intelligible since the listener could not rely or normal decoding strategies to interpret the speech that was heard.

Angelocci (1962) claimed that his subject took 4-5 times as long to produce fricative as did his normal hearing subjects. The closure periods for plosives were also considrably prolonged. According to Hood (1966), training on duration of phoneme would improve intelligibility significantly if articulation was good.

Osberg and Levitt (1979) observed that syllabic prolongation in the speech of the hearing impaired was primarly due to prolongation of vowels. Duration of vowels glides and nasals were longer in the speech of deaf children. On the other hand, the duration of fricative, affricative and plosive were found to be shorter in deaf subjects.

The hearing impaired find to produce the appropriate 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 thirty normal and hearing impaired individuals 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 voicless consonant inboth the groups of subjects. However, in both the groups the difference was less than the IND for duration.

b) In both the groups vowel |a| was longest in duration when followed by a nasal sound within the voiced sounds 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 the hearing-impaired than in the speech of the normal hearing speakers.

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

e) Hearing-impaired speakers showed a greater variation in vowel durations than normal hearing speakers.

f) In the normal hearing speakers vowel |a| in the final position was longer than vowel |i| and ju| 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 increment 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 (Klatt, 1975 a, 1976).

h) Both the groups of subjects did not show any consistent change 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 durational difference between voiced and voiceless consonants were considerably reduced.

l) In normal hearing the affricates fch| 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 the consonants than the normal hearing speakers.

Sheela (1988) studied vowel duration in four normal and four normal and four hard-of-hearing individuals, and the result indicated that on the average the hearing impaired group has significantly longer durations for vowels than that of normal hearing group.

The factors leading to or related to particular difficulties with timing of speech events, prolongatory than the producing apparently high variability of timing in the speech of the hearing impaired are not known. However, one possibility is that they depend heavily upon vision and that vision simply does not operate in as rapid a time frame as audition (Carlson, 1977; Ganong, 1979). Another possibility is that auditory feedback is necessary for rapid smooth production of complex motoric sequences of speech. (Lee, 1950) and that hearing impairment limits the necessary information too severely, requiring a general slowing of the mechanism of production and imposing high instabihty upon timing.

The duration of segments also gets influenced by factor operating at the level of syllables, word and phrases.

In English changes in contrastive stress have been found to produce systamatic changes in vowel duration. When vowels are stressed, they are longer in duration than when the same vowels are unstressed (Paramenter and Trevino, 1936). This durational variations has also been found to be important for the perception of stress (Fry 1955, 1958).

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, on the average in the speech of the hearing impaired than in the speech of normal subjects. Obserger, Levitt, 1979; Stevens et al 1978). In contrast to this, Reilly (979) found larger than normal duration differences between vowels in primary and weak stress syllables produced by a group of profoundly hearing impaired children.

These studies have shown that the hearing impaired produce mostly stressed syllables and there is an overall tendency for increasing the duration of all phonemes in the speech of the hearing impaired.

Boone (1966), Jhon and Ho worth (1965), state that this is partly due to the timing, where a great emphasis is given on the articulation of individual speech sounds or isolated consonant vowel syllables.

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).

McGarr and Harris (1980) found that even though intended stressed vowels were always longer than unstressed vowels in he speech of profoundlyhearing-impaired speaker, the intended stress pattern was not always perceived correctly by a listener. Thus, the hearing impaired speaker use some other suprasegmental features to convey contrastive stress, variations in fundamental frequency would be a likely alternative. But McGarr and Harris (1980) who found that while the hearing impaired speakers produceed by systematic changes in the fundamental frequency associated with syllables stress, perceptional confusions for involving stress pattern were still observed.

Pauses :

Pauses may be inserted at syntactically inappropriate boundaries such as between two syllables in a bysyllabic word or within phrases by the hearing impaired (Osberger and McGarr, 1982; Sheela, 1988; Jagadish, 1989). 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 etc). Hearing impaired subjects tend to pause after every word and stress almost every word (Stork and Levitt, 1974).

Nickerson et al (1974) reported that total pause time in the speech of normal hearing children constituted 25% of the time required to produce the test sentence, whereas it was 40% in the speech of deaf. Bothroyd et al (1974) considered that within phrase pause were more serious problem than between phrase pause in deaf speakers.

The inappropriate use of pauses along with the timing errors leads to the perception of improper grouping of syllables and contributes to the poor rhythm perceived in the speech of the hearing impaired (Hudgins, 1946; Nickerson, et al 1974; Hudgins (1934, 1937, 1946) suggested that the frequent pauses observed in the speech of the hearing impaired may be the result of poor respiratory control. It was found that the deaf children used short, irregular breath groups, often with only one or two words per breath, 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.

Thus hearing impaired children distort many temporal aspects of speech. Inspite of these deviancies, there is evidence suggesting that hearing-impaired talkers manipulate some aspects of duration such as those involving relative duration, in a manner similar to that of a speaker with normal hearing.

Voice Qualify:

There seems to be general agreement that the deaf speakers have a distinctive voice quality, (Bodycomb, 1946; Calvert 1962; Boone, 1966). However, it is not easy to define this characteristic voice quality of the hearing impaired. Hearing impaired are often reported to have a breathy voice quality. Hudgins (1937) and Peterson (1946) attributed this largely to inappropriate positioning of the vocal cords and poor control of breathing during speech. A large glottal opening in the hearing-impaired may be due to the failure of the vocal cords to close properly, this result in large expenditure of air and a voice of poor quality (Hudgins, 1937).

Calvert (1962) found 52 different adjectives that had been used in the description of deaf persons speech. A few of them include tense, flat, breathy, harsh, throaty, etc. He also attempted to determine if 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 the recorded speech sound vowel and dipthongs in isolation, non-sense syllables, words and sentences) had been produced by profoundly deaf speakers, normal hearing speakers initiating deaf speakers, speakers simulating harsh and breathy voice or by normal hearing speakers. Isolated vowels from which onset and termination characteristics had been clipped could not be distinguished as to source, but the source of the sentences were identified with

70% accuracy. Calvert (1971) concluded that deaf voice quality is identified not only on the basis of relative intensity, fundamental frequency and the harmonies, but also by the dynamic factors of speech such as transition gestures that change from one articulatory position into another.

Pitch and Intonation:

(1) Fundamental Freqnency : The fundamental frequency (Fo) often loosely called pitch of the voiced sound varies considerably in the speech of given speaker, hi normal speaker, the average fundamental frequency decrease with increase in age untill adulthood for both males and females. (Fairbank, 1940; Usha, 1979; Gopal 1980).

For any given age, average individual Fo span over a considerable range but about 90% would be expected within plus or minus 30-40 Hz of the population norm (Fairbank, 1940; Fairbank et al, 1959).

Hearing impaired speaker often tend to vary the pitch much less than the normal hearing speaker and the resulting speech has been described **on** monotone (Calvert, 1962; Hood, 1966).

The poor pitch control of the hearing impaired individual may be due to two reasons:

- Inappropriate average Fo

- Improper intonation - it is characterized by - little variation in Fo resulting in flat monotonus speech.

- Examine or errate pitch variation.

(2) Average fundamental frequency :

Among the most noticeable speech disorder of the hearing impaired are those involving Fo.

Several investigators have reported that hearing impaired speaker have a relatively high average pitch than normal hearing speakers of comparable ages (Angelerocci, 1962; Calvert, 1962; Thonton, 1964; Boone, 1966; Martony, 1968; Campbell, 1980).

Angelerocci et al (1964) found that mean Fo of hearing impaired adolscent between 11 to 14 years was 43 Hz higher than that of normally hearing impaired children. The vaiability of Fo is much greater in the hearing in the impaired, than the normal hearing speaker.

Whitehead and Markides, 1977 reported that on the average speaking Fo was higher for deaf adult, than for the normal hearing adult, a majority of the deaf adult have a speaking Fo value that fell within the normal range. These findings were also been supported by these studies ermonich, 1965; Grwanewal, 1966; Shukla, 1987 etc.

These differences may vary in a function of age or sex of the hearing impaired speaker, while there was no significant differences in average Fo between young normal hearing and hearing impaired children aged 6-12 years (Boone, 1966; Green, 1956; Monsen, 1979) differences have been reported between groups of older children (7-18 years old male)

Osberg (1981) found the differences 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 speaker, ranged between 250-300 Hz which is about 75 Hz higher than that observed for the normal hearing females.

Meckfessel and Thornton (1964) reported the fundamental frequency while speaking (SFF) values in post-pubertal hearing impaired male to be higher than those for normal hearing post pubertal males.

However, Greene (1956) found a similar value for 2 groups Guilbert and Campbell (1980) studied SFF in three groups (4 - 6 years; 8-10 years; 16-25 years) of hearing impaired individual, and reported that the values are higher in the hearing impaired group when compared to the values reported in literature.

Osberg (1981) stated that "The average Fo value of the utterances of male hearing impaired speaker was slightly lower than that of normal hearing male for the first part of utteraaces. The Fo value for the hearing and hearing impaired male speakers overlapped for the last half of utterances.

Rajinikanth (1986) reported that when compared to normals the hearing impaired in general showed a higher SFF. He also noted that there was a significant difference between males and females and also between two groups studied i.e., 10-15 years and 16-20 years.

Sheela, (1988) reported that as a whole, the hearing impaired children exhibited higher average Fo than that of normal hearing group.

Several explanation here offered explain 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; Boothroyd, 1970).

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

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

Fo Variation :

Inappropriate Fo variation (intonation) is another problem of voice that the deaf individual present. The two major types of Fo variation in the speech of the hearing impaired individual are :

1) Lack of variation of Fo, and

2) Excessive variation of Fo.

Several investigations have shown that the hearing impaired speakers to produce pitch variation, but the average range was less than the range of the normal speakers (Green, 1956; Calvert 1962; Martony. 1968; Nandyal, 1981). This would result in the monopitch observed in the speech of the hearing impaired.

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

Hearing-impaired speakers who tend to produce each syllable with equal duration may also generate a similar pitch contour (mono) on each syllable (Nickenson, 1975).

It has been suggested that some of the unusual pitch variations seen may result from attempts to increase the amount of proprioceptive feedback during speech (martone, 1968).

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

These speakers may raise or lower the Fo by 100 Hz or more, within the same utterance. These are reports that often, after a sharp rise in Fo the hearing-impaired speaker losses all phonatory control and thereafter there is a complete cesssation of phonation (Smith, 1975; Stevens, et al, 1978).

"Monsen (1979) while studying the manner in which Fo changes over time, using a spectrographic technique observed from types of Fo con.........in the speech of the hearing-impaired children of 3-6 years age, they are :

a) A falling contour, characterized by a smooth decline in Fo at an average rate greater than 10 Hz per 100 msec.

b) A short falling contour, occuring or words of short duration. The Fo change may be more than 10 Hz per 100 msec. But the total change may be small.

c) A falling flat contour characterized by a rapid change in frequency at the beginning of a word, followed by a relatively unchanging flat portion.

d) A changing contour, characterized by a change in frequency, the duration of which appears uncontrolled, and extends over relatively large segments.

Monsen (1962) found that *the* type of contours appeared to be an important characterist separating the better from poorer hearing-impaired speaker.

"The hearing-impaired showed almost double the frequency ranges as compared with normals, accompanied with individual variations" (Rajinikanth, 1985).

(6) Segmental influence on Fo Control:

It is seen that some hearing children produce the vowels |i| |i| and |u| with a higher Fo than 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 format of the vowel (House and Fairbanks, 1953, Peterson & Barney, 1952).

Angelocci, et al (1964) first examined some of the vowel changes in Fo in the speech of the hearing-impaired. They found that the average Fo and intensity for all vowels were considerably higher for the hearing-impaired than for normal hearing 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 by articulatory man.........as in 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 manewers used by normal hearing speakers Bush (1981) found that vowel to vowel variation produced by the hearing impaired speakers were in same way, a consequence of the same articulatory maneuver used by normal speakers n vowel production. Bush has postulated that because of the non linear nature of the stress train 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.

From the above studies it is clear that pitch deviation is present in the speech of the hearing-impaired. The abnormal pitch variation have been considered to be the major cause of faulty intonation in 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:

Vemn of soft palate functions as a gate between the oral and nasal cavities, it lowers to open the passage to the naso-pharynx 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 be recognized as a source of difficulty in the speech of the deaf (Beehm, 1922; Hudgin, 1934). Miller (1968) has speculated that the type of hearing loss may be a coausative factor in some nasalization problems. Hyponasality, he suggests may be more prevalent *among* people with conductive *loss than those* with senson neural loss because nasal sounds may appear excessively loud to the former due to the transmittability of nasal resonances via bone conduction. Individuals with sensory-neural loss on the other hand may welcome the additional cues provided by the nasal resonances and therefore tend to nasalize sounds that should not be nasalized.

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

Raising and lowering the velum is not a visible gesture and is threfore . not detectable by lip.

The Vowel Formants :

Angelocci et al (1964) found vowel formants of hearing-impaired adolescent between 11-14 years. He found that means of formant one frequency (Fi) for deaf were higher than for normal-hearing for the vowels |i|, |i|, | |, |u|, |r|, and | | and lower for the vowels | |, |a|, | |, and |v|.

Potter et al (1947) and Fairbanks et al, (1961) found that F1 rose in frequency as it progressed form |i| to |a|, where it reached its maximum frequency, position, and then it lowered in frequency as it progressed from |a|, **to** |u|. The exception to this was seen in F1 of | | for normal hearing subjects the range of means for F1 for vowels of the normal hearing was 655 cps while that for the deaf was only 330 cps.

Formant frequency two :

Angelocci et al (1964) revealed that F_2 for deaf was lower than for the normal hearing for the front vowels |i|, |i|, | |, and | | F2 for the deaf was higher than for the normal hearing for the back and neutral vowel e/s |a|, | |, |U|, |u|, |r|, and | |. The range of F_2 means for the normal hearing subjects for the vowels was 1715 cps, while the comparable figure for the deaf was 1148 cps.

Formant frequency three:

Angelocci et al (1964) found that F_3 for the deaf was higher than for the normal hearing for all vowels except |i|, |u|, and |r|, The position of F_3 offered less information word vowel differentiation than did F_1 and F_2, the normal hearing had a F_2 of 3251 cps for |i|. This dropped 2 77 cps to |i| to |i| with a frequency of 2974 cps.

Fairbanks et al, 1961; Potter et al, 1947 have reported the similar findings. In contrast, F_3 for the deaf did not follow the pattern reported by Angelocci et al (1964). Between |i| at 3099 cps and |i|at 3091 cps, there was a drop of only 8 cps. leaving velar control is difficult for the hearing-impaired children because :

- Raising and lowering measurements of the velum are not detectable are via lipreading.

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 researcher have suggested that such factors as misarticulation pitch variation and speech tempo affect the proper judgement (Colton, and Cooper, 1968).

For these reasons, subjective 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 (Fijimura, 1960; House, 1961) and enhanced amplitude of the lower harmonics (Delathre, 1955).

The activity of the velmn 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 misarticulation, 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 format (Fujimura, 1960; House, 1961) and enhanced amplitude of the lower hormonis (Delattre, 1955). Attempts to detect nasalization directly have included the measurement of acoustic energy radiated from the nostrils (Fletcher, 1970; Shelton, Knox, 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.

The Vowel Formants :

Angelocci et al (1964) found vowel formants of hearing-impaired adolescent between 11-14 years. He found that means of formant one frequency (Fi) for deaf were higher than for normal-hearing for the vowels |i|, |i|, | |, |u|, |r|, and | | and lower for the vowels | |, |a|, | |, and |v|.

Potter et al (1947) and Fairbanks et al, (1961) found that Fi rose in frequency as it progressed form |i| to |a|, where it reached its maximum frequency, position, and then it lowered in frequency as it progressed from |a|, to |u|. The exception to this was seen in *F* of | | for normal hearing subjects the range of means for Fi for vowels of the normal hearing was 655 cps while that for the deaf was only 330 cps.

Formant frequency two :

Angelocci et al (1964) revealed that F_2 for deaf was lower than for the normal hearing for the front vowels |i|, |i|, | |, and | | F_2 for the deaf was higher than for the normal hearing for the back and neutral vowel e/s |a|, | |, |U|, |u|, |r|, and | |. The range of F_2 means for the normal hearing subjects for the vowels was 1715 cps, while the comparable figure for the deaf was 1148 cps.

Formant frequency three:

Angelocci et al (1964) found that F_3 for the deaf was higher than for the normal hearing for all vowels except |i|, |u|, and |r|, The position of F_3 offered less information word vowel differentiation than did F1 and F_2, the normal hearing had a F_2 of 3251 cps for |i|. This dropped 2 77 cps to |i| to |i| with a frequency of 2974 cps.

Fairbanks et al, 1961; Potter et al, 1947 have reported the similar findings, In contrast, F_3 for the deaf did not follow the pattern reported by Angelocci et al (1964). Between |i| at 3099 cps and |i|at 3091 cps, there was a drop of only 8 cps. leaving velar control is difficult for the hearing-impaired children because :

- Raising and lowering measurements of the velum are not detectable are via lipreading.

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 researcher have suggested that such factors as misarticulation pitch variation and speech tempo affect the proper judgement (Colton, and Cooper, 1968).

For these reasons, subjective 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 (Fijimura, 1960; House, 1961) and enhanced amplitude of the lower harmonics (Delathre, 1955).

Attempts to detect nasalization directly have included the measurement of acoustic energy radiated from the nostrils (Fletcher, 1970, Shelton, Knox, Arudt and Echert, 1967) and measurement of the vibration on the surface of the nose (Holbwook and Crawford, 1970; Stevens, Kalikow and Willemain, 1974). Ravishankar (1983) found that the intonation errors were most frequent followed by errors in pitch rate of speech, nasality and voice quality.

The role of supra segmental features of speech in the intelligible verbal discourse has been well documented by several investigations (Gisenson, 1971; Licherman, 1972; Geers, 1978). The suprasegmental errors that are studied in relation to speech intelligibility are timing errors, pitch and intonation errors and errors in nasality. Most of these errors have been found to be determined to speech intelligibility.]

Studies that have attempted to determine the role of deviant suprasegmental production and unintelligible speech are of two types:

1) Correlational studies ie., where the intelligibility of speech is correlated with the number of errors in speech.

2) Causal studies ie., studies that attempted to determine the cause and effect relationship. These studies can be sub-divided into two major categories.

a) Studies in which hearing-impaired chidlren receive intensive training for the correction of a particular type of error.

b) Studies in which the errors are corrected in hearing-impaired children's recorded speech samples using modern signal processing techniques.

Correlational studies :

The suprasegmental errors examined most extensively in relation to intelligibility have been those involving timing. One of the earliest attempts to determine the relationship between drawout timing patterns and intelligibility is the study by Hudgins and Numbers (942).

Although they correlated rhythm errors with intelligibility many of these errors appear to be due to poor timing control and erroneous Fo (Osberger and McGarr, 1982).

They found that sentences spoken with correct rhythm were substantially more intelligible than those that were not. The correlation between speech rhythm and intelligibility was 0.73. The other correlational studies have shown a moderate negative correlation between excessive prolongation of speech segments and intelligibility (Mousen, Leiter, 1975; Levitt, 1978)

Reilly (979) reported that the better the profoundly hearing-mpaired speaker was able to produce the segmental/lexical and syntactic structure of the utterance, the more intelligible the utterances likely to be.

Data reported by ParkBurst and Levitt (978) indicated that another type of timing error, the insertion of short pauses at synctactically appropriate boundaries had a positive effect on intelligibility. The presence of these pauses actually helped to improve the intelligibility. They added that excessive or prolonged pauses appeared to have a secondary effect in reducing the intelligibility.

Atempts have also been made to determine the relationship between errors involving Fo control and intelligibility. The inability to control Fo while speaking contributes to the low intelligibility of the speech of the hearing-impaired (Boothroyd and Decker, 1975).

"Suprasegmental aspects of phonation have been emphasized by some investigators as indicators of speech intelligibility" (Levitt, 1974) McGarr et al (976) found that the hearing-impaired children who were unable to sustain phonation and showed pitch breaks and marked fluctuations in pitch were consistently judged to have poor intelligibility. Such children were also reported to draw riming errors and very low phoneme production scores in continuous speech. They found a significant correlation between speech intelligibility and noted pitch deviancy on subjective evaluation in their hearing-impaired subjects.

McGarr and Osberger (978) found that for the majority of the children studied, there seemed to be no simple relationship between pitch deviancy and intelligibility. Some children where pitch was judged appropriate for their age and sex had intelligible speech, while others did not. The exception of this pattern were the children who were unable to sustain phonation and whose speech contained numerous pitch breaks. Their speech has consistantly judged to be unintelligible, Monsen (1979) found that pitch contours correlate significantly with voice quality ratings, and suggested that significant correlation with intelligibility will only be found when intonation patterns are taken into account.

"The speech intelligibility socres showed a high negative correlation with suprasegmental errors". (Ravishanker 1985). His study indicated that the suprasegmental errors were strong deterrants to speech intelligibility. Among the error types, intonation errors showed the highest correlation followed by errors in pitch, errors in rate of speech, errors in voice quality, and the presence of nasality.

The effect of prosody on deaf speech intelligibility has been evaluated mainly by correlational techniques. In studies using subjective ratings of all prosodic features combined (Fo, temporal structure and intonation), it was found that errors in rhythm (Hudgins and Numbers, 1942) poor phonatory control (Smith, 1975), and staccato prosody (McGarr and Osberger, 1978) or syllable speech (Levitte, et al 11976) all show moderate to high negative correlations with speech intelligibility (Pavel, 1984).

Studies that attempted to determine the cause and effect relationship between speech intelligibility have dealt primary with timing (Osberger and McGarr, 1982).

METHODOLOGY

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

Subject and test material:

Forty normal and forty hearing impaired children between 7-11 years were selected for the study, each group consisted of 20 males and 20 females.

The hearing impaired children were selected from the cases who were attending special school at Mysore city and therapy clinic at AIISH. They satisfied the following conditions:

1. Had congenital bilateral hearing loss (PTA of greater than 70 dB - 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 Kannada.
4. All the children were attending speech therapy and were regular users of hearing aid.

The normal children for the study were from a different primary schools at Mysore City. 40 children with normal hearing were selected to match each age group of hearing impaired subject in terms of age and sex.

The test material consisted of 20 bisyllabic Kannada words having the vowels |a|, |a:|, |i|, |I:|, |u|, |u:|, |e| and |o:|. These words could be picturized, each picture representing each word and the word were written on cards (6" x 4"). Words/picture were simple so that both normal and hearing impaired children could read them (Given in Appendix -1).

Data Collection:

The speech samples of children of both the groups were recorded using a sony tape recorder with H.L egend external microphone. The recording were made in a quite room of the school building using the tape recorder. All subjects were confortably seated and microphone was kept at a distance of 10 cms. from the mouth of the subject. They were instructed to look at picture card and then name the picture card or read from the card presented to them. One card at a time was presented to the children. Each child named the picture or read the word three times each. The same was recorded on a C-90 sony cassette. Thus all the words said/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 each of the all subject of both the groups. Subject was made to repeat after the experimenter, whenever the subject had difficulty in finding the target word.

Instrumentation: (Block Diagram)

SIU————• A/D - D/A connector————• Computer —•

————• Amplifier and speaker.

The classic training study that attempted to determine the causal relationship between timing errors and intelligibility was conducted by John and Hawarah (1965). They reported a significant improvement in the intelligibility of profoundly hearing-impaired children's speech after the children had received intensive training focussed only in the correction of timing errors.

Honde (1973) observed a decrement in intelligibility when timing errors of hearing-impaired speakers were corrected, and the results of a similar study by Boothroyd et al (1974) were equivocal.

Thus the studies on speech of the hearing impaired show that:

Overall levels of speech intelligibility are utterly inadequate for oral communication Ling (1976). Hence, the above spectrographic parameters such as formants, vowel duration, intra-word pause duration, total word duration were taken up for study.

Very few investigators have studied this speech characteristics of the hearing impaired in Kannada i.e., Rajanikanth (1986), Shukla (1987), Sheela (1988), Jagadish (1989), Swomya. N. (1992) and Rahul (1997). The purpose of the present study is to compare speech of hearing impaired to that of the normals. This will be help in synthesis of speech and in the improvement of speech intelligibility of the hearing impaired children.

METHODOLOGY

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

Subject and test material:

Forty normal and forty hearing impaired children between 7-11 years were selected for the study, each group consisted of 20 males and 20 females.

The hearing impaired children were selected from the cases who were attending special school at Mysore city and therapy clinic at AIISH. They satisfied the following conditions:

1. Had congenital bilateral hearing loss (PTA of greater than 70 dB - 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 Kannada.
4. All the children were attending speech therapy and were regular users of hearing aid.

The normal children for the study were from a different primary schools at Mysore City. 40 children with normal hearing were selected to match each age group of hearing impaired subject in terms of age and sex.

The test material consisted of 20 bisyllabic Kannada words having the vowels |a|, |a:|, |i|, |I:|, |u|, |u:|, |e| and |o:|. These words could be picturized, each picture representing each word and the word were written on cards (6" x 4"). Words/picture were simple so that both normal and hearing impaired children could read them (Given in Appendix -1).

Data Collection :

The speech samples of children of both the groups were recorded using a sony tape recorder with H.L egend external microphone. The recording were made in a quite room of the school building using the tape recorder. All subjects were confortably seated and microphone was kept at a distance of 10 cms. from the mouth of the subject. They were instructed to look at picture card and then name the picture card or read from the card presented to them. One card at a time was presented to the children. Each child named the picture or read the word three times each. The same was recorded on a C-90 sony cassette. Thus all the words said/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 each of the all subject of both the groups. Subject was made to repeat after the experimenter, whenever the subject had difficulty in finding the target word.

Instrumentation: (Block Diagram)

SIU ——————• A/D - D/A connector ——————• Computer —•

——————• Amplifier and speaker.

Photograph showing the instruments used for analysis of speech

Analysis of the data :

The computer software "speech science lab" (SSL) and "Vaghmi" (both from "Voice and Speech systems") loaded, on a PC with 100 Mh_z pentium processor with SIU and AD/DA convertor were used for analysis of the data. For all analysis a block duration of 30 msec, and a block slift of 10 msec was used. The speech samples were digitized using 12 bit ADC/DAC board at the sampling frequency of 16000 Hz and were stored in computer memory. The acoustic parameters were measured using wide band spectrography (300 Hz/600 Hz). The words were analysed for :

Total word duration.

Vowel duration

Fundamental frequency

Intra syllabic pause duration

Formant frequencies (F1, F_2 and F_3)

1) Total word duration :

The word duration was measured directly from the speech waveform?) The waveform was displayed on the computer monitor using the "DISPLAY[1,]" programme of SSL. The total word were identified based upon the regularity of the waveform. *The* total word was considered to extend from the beginning of the periodic signal to the end of the periodicity for the word. The duration was highlighted through the use of cursors. The highlighted portion was played back through headphones, to confirm that the word under study has been highlighted and then the duration has been marked correctly. Once this was confirmed the duration of the highlighted portion was read from the display on the monitor directly.

2) Vowel duration :

The "DISPLAY" programme of SSL was used to measure vowel duration also. The vowel duration was considered to extend from the begining of the periodic marking to the end of the periodicity. This duration was highlighted, through the use of cursors. The highlighted portion was played back through head phones, to confirm that the vowel under study has been marked correctly and thus the duration has been identified correctly. Once this was confirmed, the duration of the highlighted portion was read from the display on the monitor directly. (Fig. 1)..

3) Determining the Fundamental frequency :

For measurement of fundamental frequency the "INTON" programme, in Vaghmi was used. The utterances were first analysed and then displayed to obtain the F_o contour and also the mean value of fundamental frequecy of the word analyzed (Fig. 2)..

4) Pause Duration :

The "DISPLAY" programme of SSL was used from the waveform, a gap between two periodic signal were highlighted using cursors. The highlighted portion was played to confirmed that the pause has been marked correctly when the silence was perceived, then it was taken as pause. Once this was confirmed, the duration of the highlighted portion was read from the display (See Fig.3).

5) Extration of Formant Frequencies :

To extract the vowel formats (frequencies (F_1 F_2, F3) the 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 format frequencies were determined by using sectioning method use the linear predictive coding (LPC) method. By moving the horizontal cursor, on the display of sectional portion of the signal, to the peaks the (lowest - F_1 next F_2 and the next peak F_3). Formant frequencies were read, digitally, from the display on the monitor This was done with 18 LPC Co-efficients.

Thus, all the utterances of all subjects of both the groups were analysed to obtain word duration, vowel duration, pause duration, formant frequency,(3 formants) fundamental frequency. Thus the total of 9600 (80 x 6 x 20) data points were obtained and subjected for statistical analysis..

Problems faced while analysing :

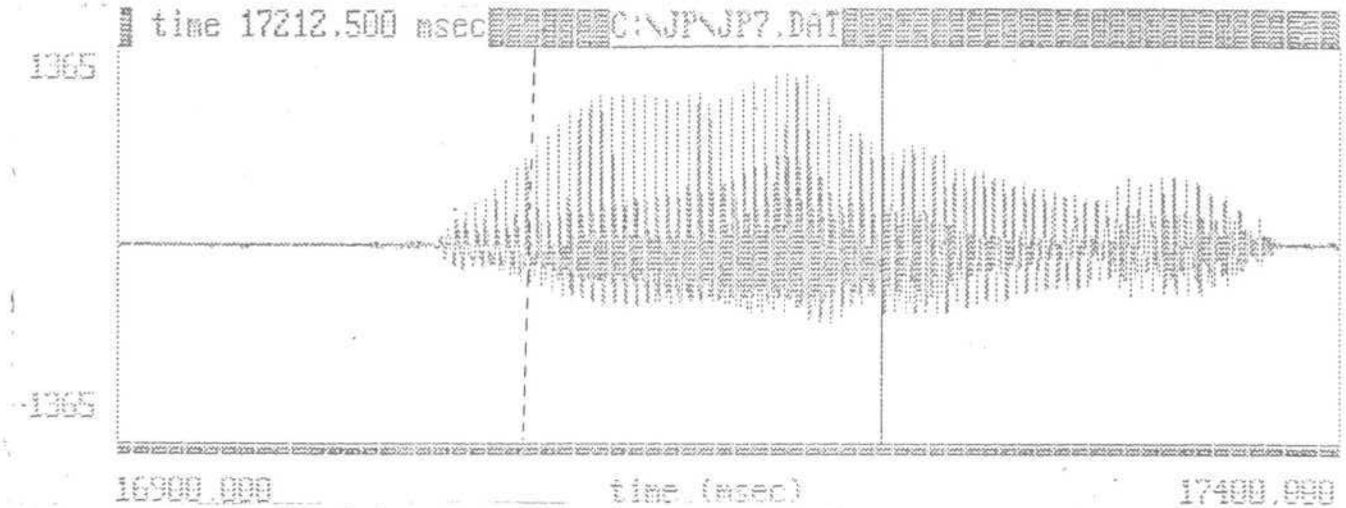
1. Some of the hearing-impaired subjects tended to distort most of the vowels which in turn made the measurement of the formant frequencies difficult.

Statistical Analysis :

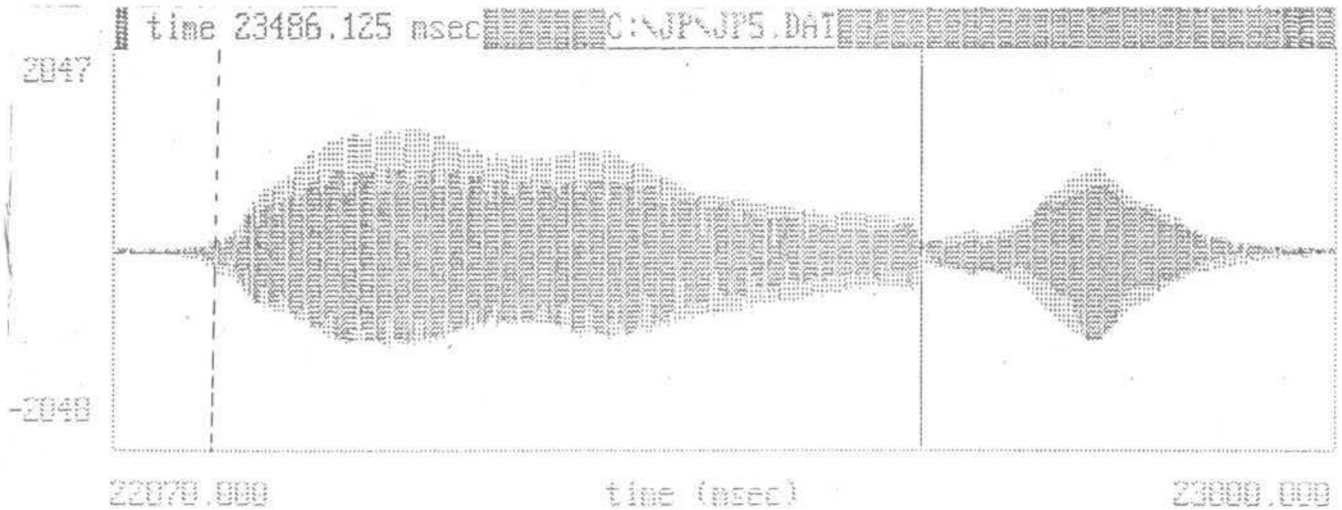
Discriptive statistics consisting of mean, standard deviation, minimum and maximum values were obtained for all the seven parameters.

To check whether there were any significant differences between the values of the normal hearing group and hearing impaired group. Student 't' test was applied.

FIGURE – 1

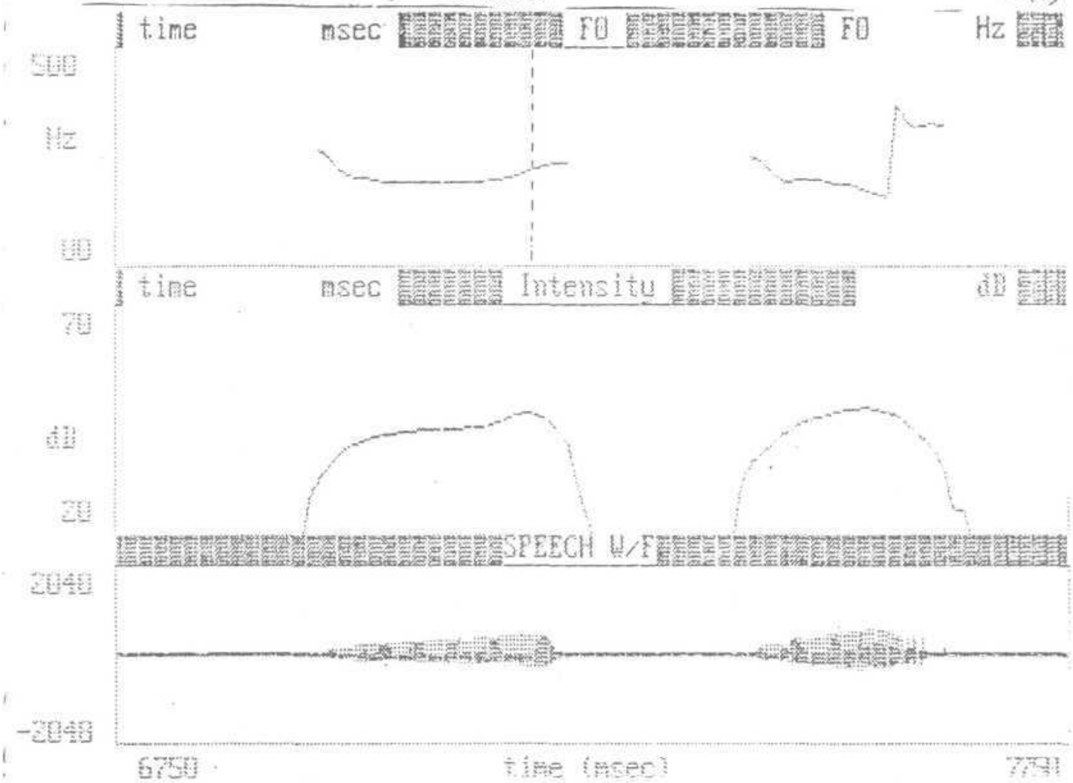


A. Representation of Vowel spectrum in speech of normal hearing

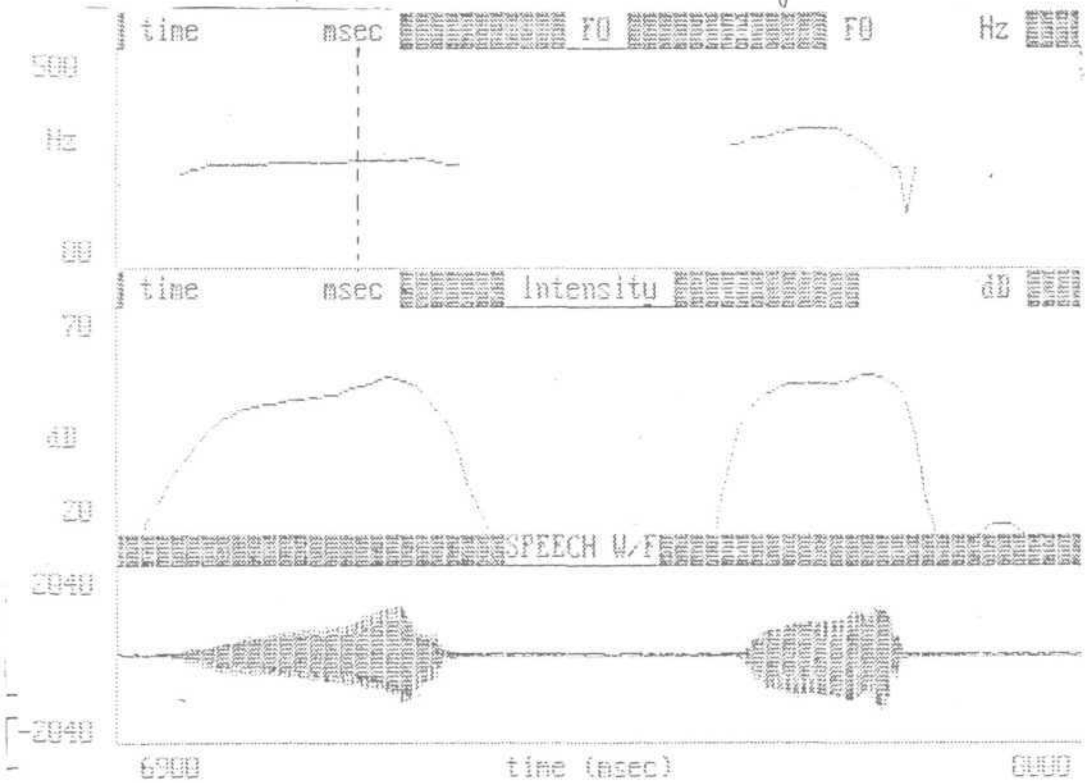


B. Representation of vowel spectrum in speech of hearing impaired.

FIGURE-2

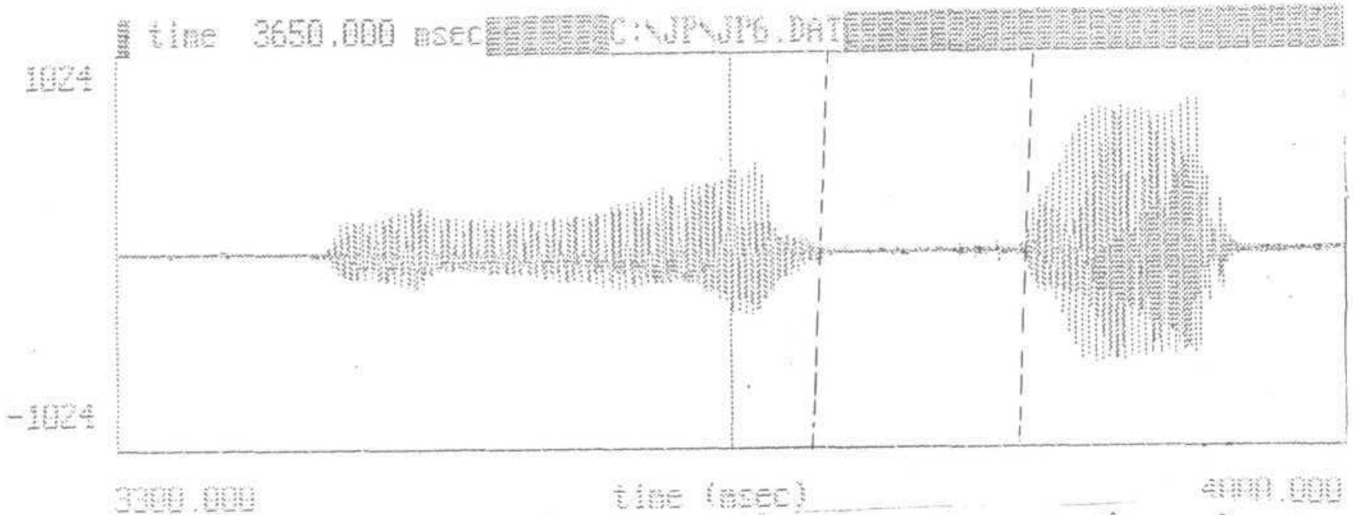


A. Representation of average fundmental frequency in normal hearing

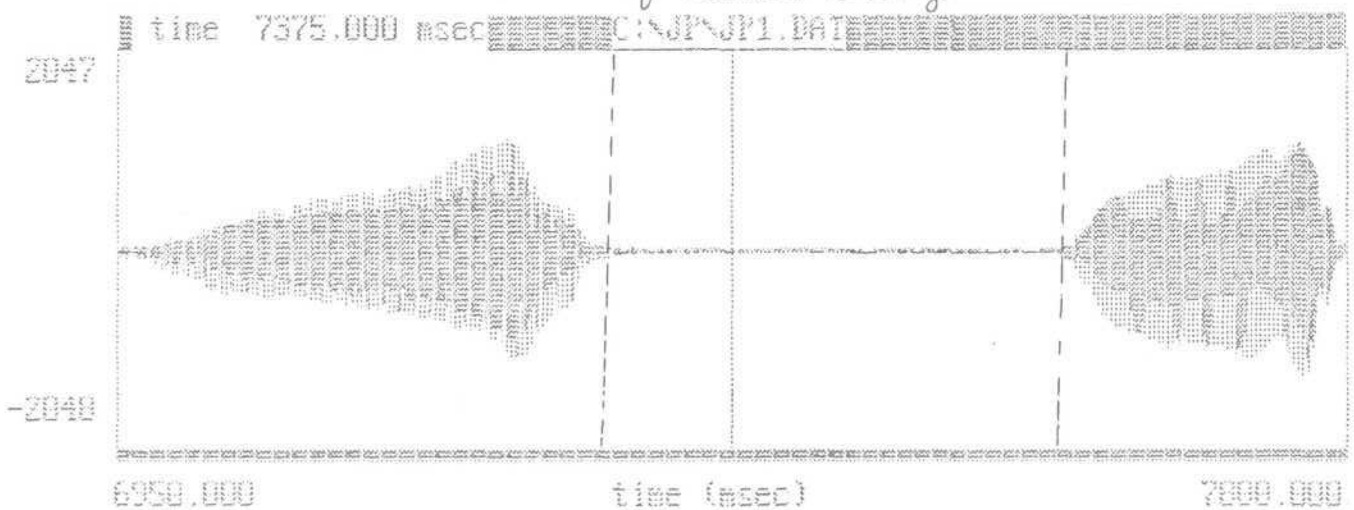


B. Representation of average fundamental frequency in hearing impaired.

FIGURE- 2



A. Representation of Intraword pause duration spectrum in speech of normal hearing



B. Representation of Intraword pause duration spectrum in speech of hearing impaired.

RESULTS AND DISCUSSION

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

Acoustic analysis :

Twenty bisyllabic words uttered by fourty severely hearing impaired and fourty normal hearing children were analysed to obtain the following acoustic parameters.

1. Total word duration
2. Vowel duration
3. Fundamental frequency
4. Intrasyllabic pause duration
5. Formate frequency, F_1, F2 and F3
6. Bandwidth, BW_1 BW_2 and BW_3.

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

1. Total word duration :

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 - 1.

Table -1 : Depicts mean values for total word duration in normal and hearing impaired group.

	Normal group			Hearing impaired group		
	Males	Females	Mean difference	Males	Females	Mean differenc
Mean (msec)	567.60	604.82	37.22	1084.28	1207.50	122.58
Sd	94.42	116.01	-	141.92	149.50	-

The Table - 1 shows mean word duration produced by hearing impaired males (1084.28 msec.) were found to be higher than that of normals (567.60 msec). The mean word duration produced by hearing impaired females 1207.50 msec were found to be higher than that of normals hearing by 604.82 msec. The hearing impaired subjects both males and females showed greater variability than normal subjects.

The 'T' test performed showed significant differences between :

1. Normal hearing males and hearing impaired males and
2. Normal hearing females and hearing impaired females at 0.05 level of signifance in terms of word duration.

Whereas the statistical testshowed no significant differences 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 (a) hearing impaired males and hearing impaired females and (b) normal males and normal females in terms of word duration is accepted.

Vowel duration:

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

All the seven vowels measured in case of hearing impaired [a, a:, i, i:, u, u:, e, o:] had longer vowel duration then the normal subjects.

Table 2 (a): Depict the mean and standard deviation values for vowel duration in normal and hearing impaired males.

	Normal males		Hearing impaired males		
Vowel	Mean (msec)	SD	Mean (msec)	**SD**	Mean difference hearing impaired and normals(msec)
a	163.5	28.39	312.92	142.02	149.42
a:	227.62	34.13	418.12	135.39	190.50
i	214.80	46.72	448.42	198.74	233.62
u	184.42	39.54	259.29	114.29	74.87
u:	248.41	37.84	466.61	155.39	218.2
e	179.31	43.16	361.48	212.03	192.17
o:	233.19	33.33	473.54	153.79	240.4

Table 2(a) and Graph 2(a) shows the normal male group among the seven vowels studied the vowel |u:| had the longest duration (248.41 msec) followed by | 0:| (233.14 msec) |a:| (227.62 msec), |i| (214.80 msec), |u| (184.92 msec), |e| (179.31 msec), |a| (163.5 msec).

In the case of hearing impaired males the vowel |o:| had the longest duration (4~3.54 msec) followed by |u:| (466.61 msec), |i| (448.42 msec) |a:| (418.12 msec), |e| (361.48 msec), |a| (312.92 msec) |u| (259.29 msec).

Table 2 (b): Showing the mean, SD in both normal and hearing impaired females.

	Normal Females		Hearing impaired Females		
Vowel	Mean (msec)	SD	Mean (msec)	SD	Mean difference hearing impaired and normals(msec)
a	182.15	43.96	385.42	378.88	176.27
a:	246.42	26.42	496.29	384.78	249.87
i	212.92	56.61	390.09	320.81	177.17
u	204.21	31.61	373.54	298.08	177.54
u:	256.52	34.36	398.04	359.36	193.83
e	196.00	45.36	474.52	247.98	218.0
o:	242.18	34.59	444.27	274.68	202.03

Table 2(b) and Graph 2(b) presents, similarly in the normal female group, the vowel |u:| had the longest duration (256.52 msec). It was followed by |a:| (246.42 msec) |o:| (242.18 msec) |i| (212.92 msec), |u| (204.21 msec), |e| (196.00 msec), |a| (182.15 msec). In the case of hearing impaired females vowel |a| had the longest duration (496.29 msec) and others as follows: |u:| (474.52 msec), |o:| (444.21 msec), |u| (398.04 msec), |i| (390.09 msec) |e| (373.54 msec), |a| (358.42 msec).

In both normal and hearing impaired group vowel |a| had the shortest duration. In case of the normal male group minimum and maximum mean values ranged from 163.50 to 248.41 msec and for the hearing impaired male group the mean values ranged from 312.92 to 473.54 msec. In the normal female group minimum and maximum mean values ranged from 182.15 to 256.52 msec and for hearing impaired female group 358.42 to 496.29 msec.

The mean vowel duration produced by the hearing impaired males were found to be higher than that of normals by 74.87 msec - 240.4 msec, the mean difference between hearing impaired males and normals for the vowels |aj, |a:|, |i|, |u|, |u:|, |e|, |o:| were' 149.42 msec, 190.5 msec. 233.52 msec, 74.87 msec, 218.2 msec, 182.17 msec, 240.4 msec, respectively.

Normal male group had vowel duration in the decreasing order as follows: u:> o:> a:> I:> e> a. 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 normal females by 176.27 to 249.87 msec. The mean difference between hearing impaired females and nmormals for the vowels a, a:, i, i:, u, u:, e, o: were 176.27 msec, 177.17 msec, 177.54 msec, 193.83 msec, 202.03 msec, 218.0 msec, 249.87 msec, rspectively.

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

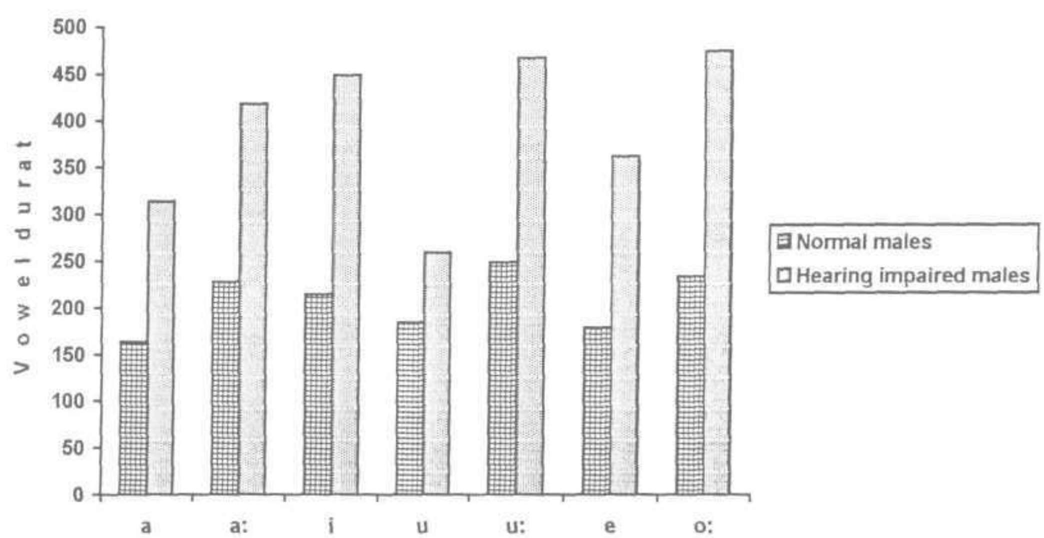
Statistical test performed showed a significant difference betwen the

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

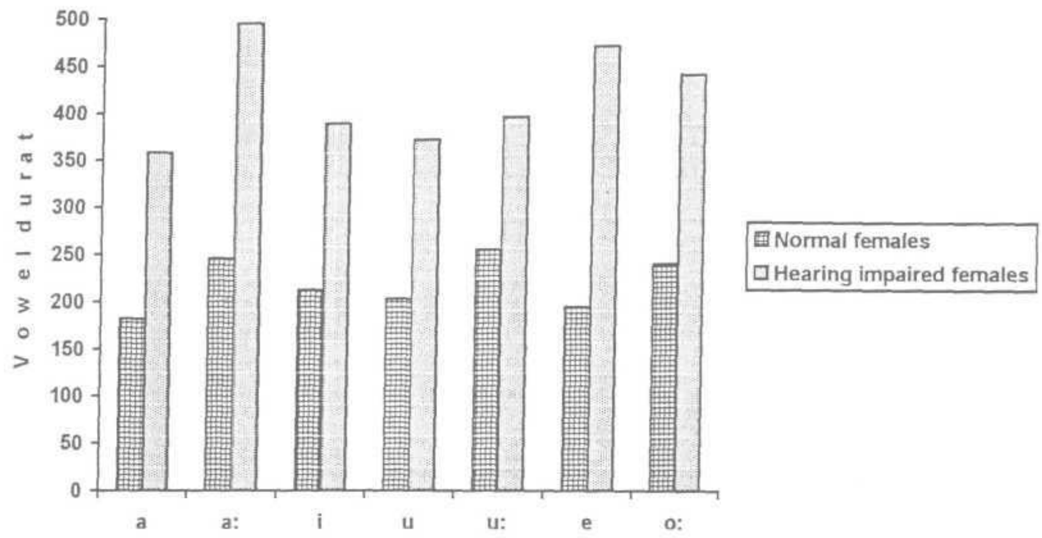
The student 'T'test performed also showed, no significant difference between (1) hearing impaired males and hearing impaired females (2).normal males and normal females at 0.05 level of significance in terms of vowel duration.

Thus the hypothesis (1) staring mat mere is no significant difference between normal and hearing impaired subjects in terms vowel duration is rejected.

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



Graph 2 (a): shows the mean values for vowel duration in normal and hearing impaired males.



Graph 2(b): Shows the mean values for vowel duration in normal and hearing impaired females.

3. Average fundamental frequency :

Table 3: (a) Depict mean values and standard deviation for fundamental frequency in normal and hearing impaired males.

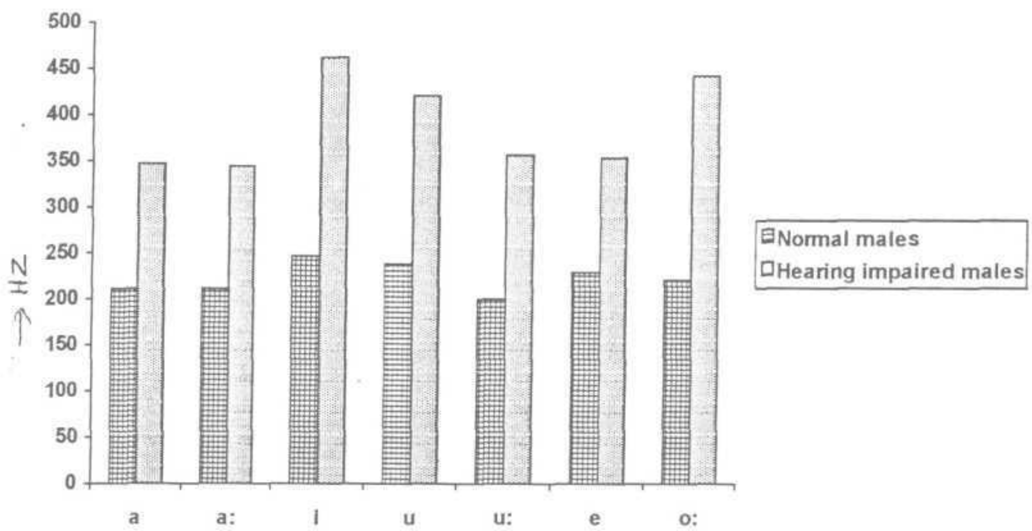
	Normal males		Hearing impaired males.		
Vowel	Mean *(Hz.)*	SD	Mean *(Hz.)*	SD	Mean difference hearing impaired and normals*(Hz.)*
a	212.89	21.0	347.70	40.12	124.81
a:	212.01	30.12	343.29	34.76	131.28
i	248.11	24.91	462.49	43.73	214.38
u	236.92	23.84	419.19	56.12	182.27
u:	200.82	24.84	356.52	44.75	155.7
e	230.12	24.35	351.82	40.57	121.70
o:	221.12	19.60	440.4	50.12	219.28

variation in range were more for all the vowels except for |a:|, |i[, |e|, |o:| than in the normal female group.

The statistical test indicated significant difference between the two groups at 0.05 level of significance in terms of F_o.

Thus the hypothesis (1) stating that there is no significant difference between the hearing impaired and normal children, both males and females in terms of average fundamental frequency of the vowels is rejected.

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



Graph 3(a): Shows mean values for fundamental frequency in normal and hearing impaired males.

The hearing impaired children had higher F_o than that of normal hearing children. Table 3(a) and Graph 3(a) shows in the normal hearing male group, the high F_o was for vowel |i| (248.11 Hz) followed by |u| (236.92 Hz), |e (230.12 Hz) |o:| (221.12 Hz) |a| (212.89 Hz), |a:| (212.01 Hz) |u:| (200.82 Hz). In the hearing impaired male group the highest F_o was for the vowel |i| (462.49 Hz) followed by |o:| (440.42 Hz) |u| (419.19 Hz), |u:| (356.52), |e| (352.82 Hz) |a| (347.70 Hz), a: (343.29 Hz).

Table 3(b): Depict mean values for fundamental frequency in normal and hearing impaired females.

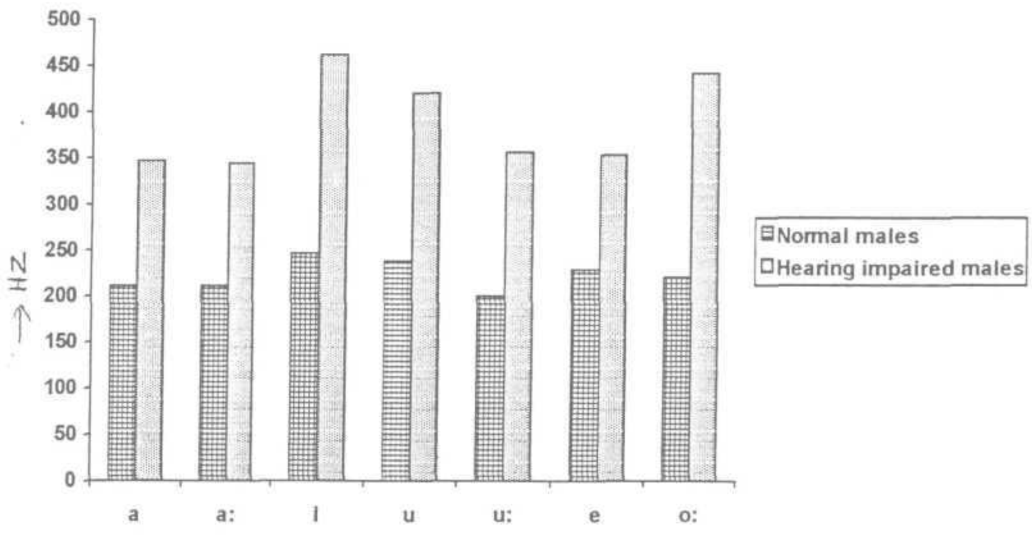
	Normal females		Hearing impaired females.		
Vowel	Mean *(Hz.)*	SD	Mean *(Hz.)*	SD	Mean difference hearing impaired and normals*(Hz.)*
a	262.16	26.69	446.00	69.15	183.15
a:	249.16	49.12	349.15	27.22	99.99
i	271.02	22.92	486.21	18.91	215.19
u	252.39	13.11	382.12	21.14	129.73
u:	252.93	15.92	374.96	16.81	122.03
e	260.12	19.06	355.00	37.03	94.88
o:	250.12	32.42	351.92	18.26	101.80

Table 3(b) and Graph 3(b) presents similarly in both normal and hearing impaired female groups highest F_o was for vowel |i|. In the normal groups, rninimum and maximum mean values ranged from 200.82 Hz - 248.11 Hz, whereas in the hearing impaired group values ranged from 343.29 - 440.42 Hz. Variation in range was mroe in the hearing impaired male group compared to that of the normal male group. In the female hearing impaired group, the variation in range were more for all the vowels except for |a:|, |i|, |e|, |o:| than in the normal female group.

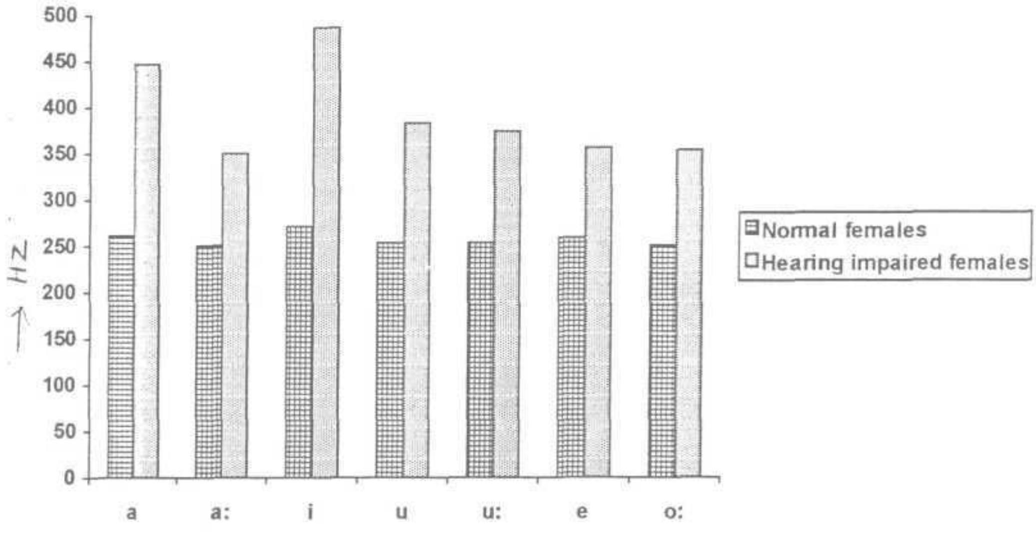
The statistical test indicated significant difference between the two groups at 0.05 level of significance in terms of F_o.

Thus the hypothesis (1) stating that there is no significant difference between the hearing impaired and normal children, both males and females in terms of average fundamental frequency of the vowels is rejected.

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



Graph 3(a): Shows mean values for fundamental frequency in normal and hearing impaired males.



Graph 3(b): Shows mean values for fundamental frequency in normal and hearing impaired females.

4. Formant frequency characteristics of vowels :

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

Table 4:(a) Depict mean and SD values for first formant frequency in normal and hearing impaired males.

	Normal males		Hearing impaired Males		
Vowel	Mean *(Hz.)*	SD	Mean *(Hz.)*	SD	Mean difference hearing impaired and normals,*(Hz.)*
a	883.30	52.93	936.03	162.16	52.73
a:	796.01	156.99	986.18	98.99	190.17
i	482.97	71.09	612.92	196.26	130.01
u	504.22	69.53	690.00	281.76	185.49
u:	498.92	72.20	676.28	142.06	127.94
e	502.80	80.25	698.29	186.50	195.49
o:	714.06	80.45	785.00	102.10	70.94

Significant at 0.05 level of significance.

Table 4(a) and Graph 4(a) shows in general the hearing impaired children had higher F1 than those of the normal hearing group. The means of first formant frequency (F1) for the hearing impaired male subjects were higher than for the normal hearing subjects for all the vowels. The mean difference F1 values for these vowels varied from 52.73 to 195.49 Hz. The mean difference of F1 values between hearing impaired males and normals males for the vowels |a|, |a:|, |i|, |u|, |u:|, |e|, |o:| were 52.73 Hz, 190.17 Hz, 130.01 Hz, 185.78 Hz, 127.94 Hz, 195.49 Hz, 70.94 Hz, respectively. However, a significant mean difference between hearing impaired males and normals was found only for vowels |i|, |u| and |u:|.

Table 4 (b) depicts mean and SD values for first formant frequency in normal and hearing impaired females.

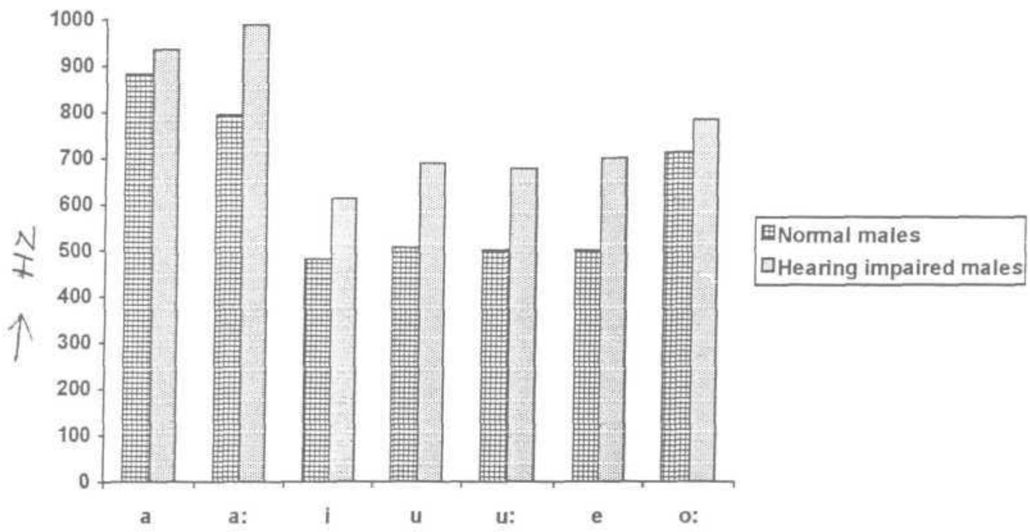
	Normal females		Hearing impaired females		
Vowel	Mean *(Hz.)*	SD	Mean *(Hz.)*	SD	Mean difference hearing impaired and normals*(Hz.)*
a	802.85	99.9	906.12	162.27	103.27
a:	776.94	140.06	962.80	186.83	103.27
I	398.42	53.52	586.10	99.06	185.86
u	504.99	38.92	582.22	98.96	109.04
u:	489.86	65.20	524.30	115.00	77.23
e	489.02	56.67	598.06	101.85	187.68
o:	786.86	94.82	802.06	159.94	34.44

Significant at 0.05 level of significance.

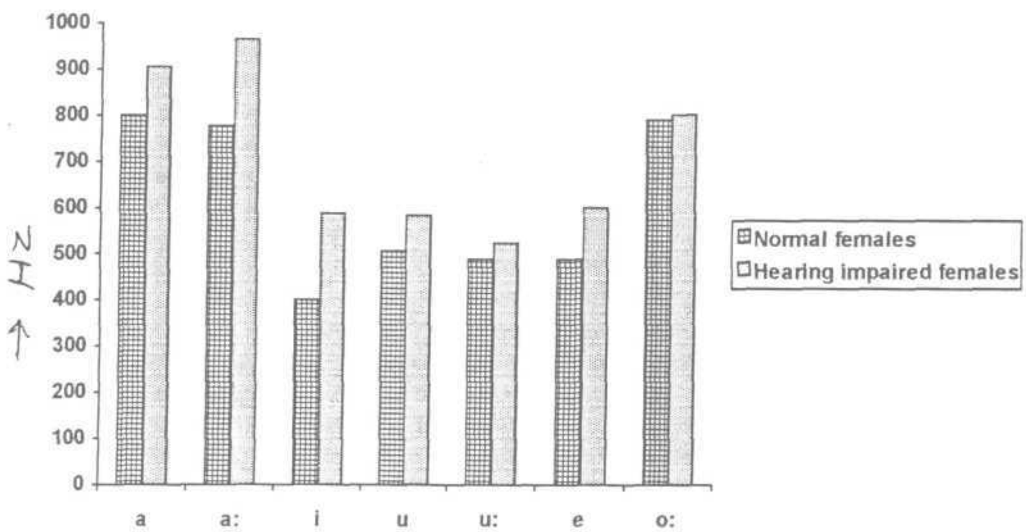
Table 4(b) and Graph 4(b) shows that hearing impaired females had higher F1 values than that of normals for all the vowels. The difference between means of hearing impaired females to that of normals females for the vowels, |a|, |a:|, |i|, |u|, |u:|, |e|, |o:|. Were 103.27 Hz, 185.86 Hz, 187.68 Hz, 77.23 Hz, 34.44 Hz, 109.04 Hz, 15.2 Hz respectively. However, a significant mean difference between hearing impaired females and normal females was found only for vowels |a|, |i|, |e|.

It was found that vowels |i|, |a|, |u| in both the groups showed significant mean difference between hearing impaired and normal hearing groups (both males and females). The hypothesis stating that there is no significant difference between the means of F1 values of vowels of the hearing impaired males and normal hearing males was rejected for |i|, |u|, |a:| and |e| accepted for

The hypothesis that there is no significant difference between the means of F1 vcalues of vowels of the hearing impaired females and normal hearing females was rejected for |i|, |a:|, |uj and accepted for |a|, |u:|, |o:| and |e|. Thus it can concluded that in general the hearing impaired subjects, both males and females, show higher first formant frequency than the normal subjects.



Graph 4(a) : Shows that mean and SD values for first formant frequency in normal and hearing impaired males.



Graph 4(b): Shows that mean and SD values for first formant frequency in normal and hearing impaired females.

Second formant frequency :

Table 5(a) Depict mean and SD values for second formant frequency in normal and hearing impaired males.

	Normal males		Hearing impaired males		
Vowel	Mean ***(HZ)***	SD	Mean (Hz.)	SD	Mean difference hearing impaired and normals*(Hz.)*
a	1538.70	82.27	1794.80	332.82	256.9
a:	1616.80	376.40	1860.07	289.93	243.27
i	1798.91	328.44	1441.98	418.96	- 356.93
u	1356.18	140.68	1509.26	428.14	153.08
u:	1284.86	164.28	1428.92	264.96	144.07
e	1484.96	384.12	1534.09	499.06	49.13
o:	1266.04	128.26	1318.61	305.61	52.12

Significant at 0.05 level.

Table 5(a) and Graph (a) shows the mean F_2 values of vowels a, a:, I, u, u:, e, o: were found to be higher for the hearing impaired males compared to normals. The mean difference between normals and hearing impaired were 256.1 Hz, 243.27 Hz, - 356.93 Hz, 153.08 Hz, 144.07 Hz, 49.13 Hz, 52.12 Hz respectively for |a|, |a:|, |i|, |u|, |u:|, |e| and |o:| mean difference for these vowels ranged from - 356.93 to 256.1 Hz. The mean F_2 value of vowel |i| was found to be lower for hearing impaired males than that of normal hearing male group. However, significant difference between means for hearing impaired and normal hearing males were found for only vowel |a| and not for others.

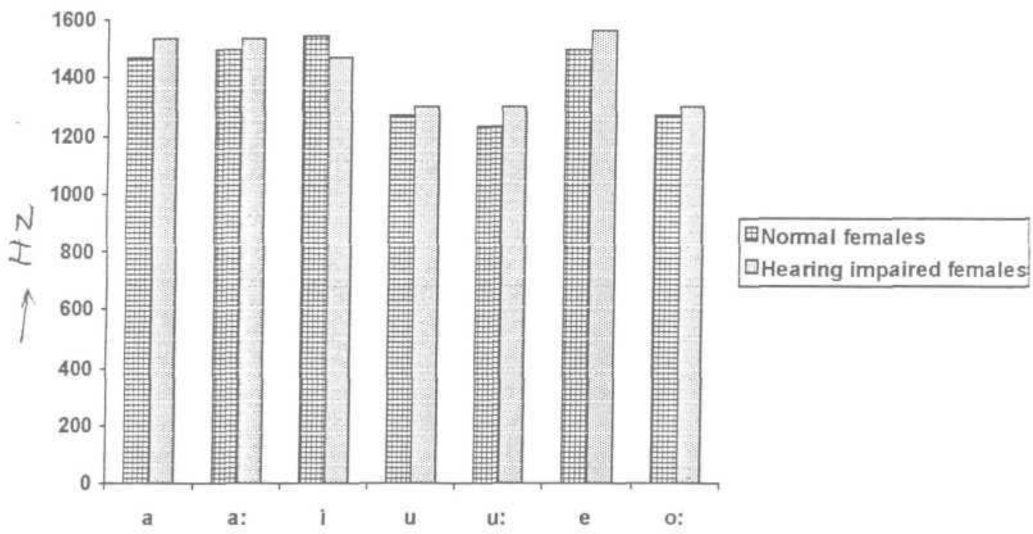
Table 5(b) Depicts mean and SD values for second formant frequency in normal and hearing impaired females.

	Normal females		Hearing impaired females		
Vowel	Mean *(Hz.)*	SD	Mean (HZ)	SD	Mean difference hearing impaired and normals*(Hz.)*
a	1467.00	213.14	1538.10	80.86	71.10
a:	1498.80	184.56	1583.83	306.94	85.03
i	1540.00	199.89	1466.18	486.34	-13.07
u	1268.10	169.14	1296.24	276.06	28.14
u:	1230.00	338.52	1294.85	315.45	64.85
e	1499.25	515.68	1565.80	490.80	66.55
o:	1266.90	242.73	1296.52	284.82	29.62

Significant at 0.05 level.

Table 5 (b) and Graph 5 (b) shows the mean F2 values for vowels |a|, |a:|, i|, |u|, |u:|, |e| and |o:| were higher for hearing impaired female group than that of normal hearing females. The mean differences for both female group for the vowels |a|, |a:|, |i|, |u|, |u:|, |e| and |o:| were 71.1 Hz 85.03 Hz, - 73.07 Hz, 66.55 Hz, 28.14 Hz, 64.85 Hz and 29.62 Hz respectively. The mean difference values ranged from - 73.07 Hz to 85.04 Hz. The mean F_2 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.

Overall similar pattern for mean F2 seen among males and females of hearing impaired groups. It was found that generally among hearing impaired males and females none of the vowels showed significant difference in mean F2



Graph - 5(b): Shows mean values for second formant frequency in normal and hearing impaired females.

Third formant frequency :

Table 6(a) Depict mean and SD values for third formant frequency in normal and hearing impaired males.

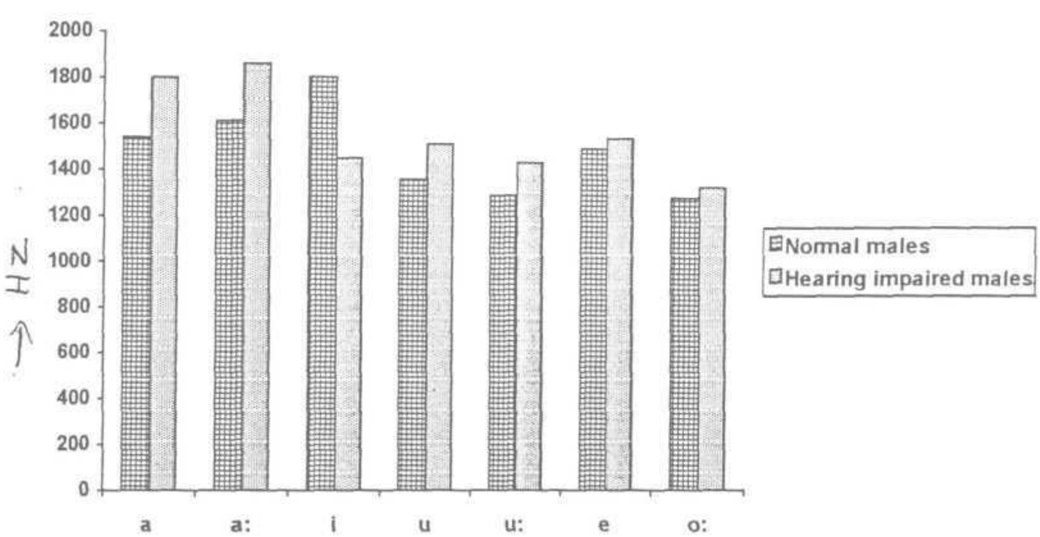
	Normal males		Hearing impaired males		
Vowel	Mean *(Hz.)*	SD	Mean *(Hz.)*	**SD**	Mean difference hearing impaired and normals*(Hz.)*
a	1941.80	399.41	2792.60	477.88	850.80
a:	2117.80	527.52	2767.10	723.22	569.30
i	2180.80	438.43	2002.50	415.34	-175.30
u	2197.80	178.11	2085.14	610.06	-92.00
u:	2104.20	456.21	2200.80	383.16	96.60
e	2789.90	387.80	1589.90	415.55	-1195.50
o:	2174.80	363.50	2275.90	414.57	101.10

Significant at 0.05 level

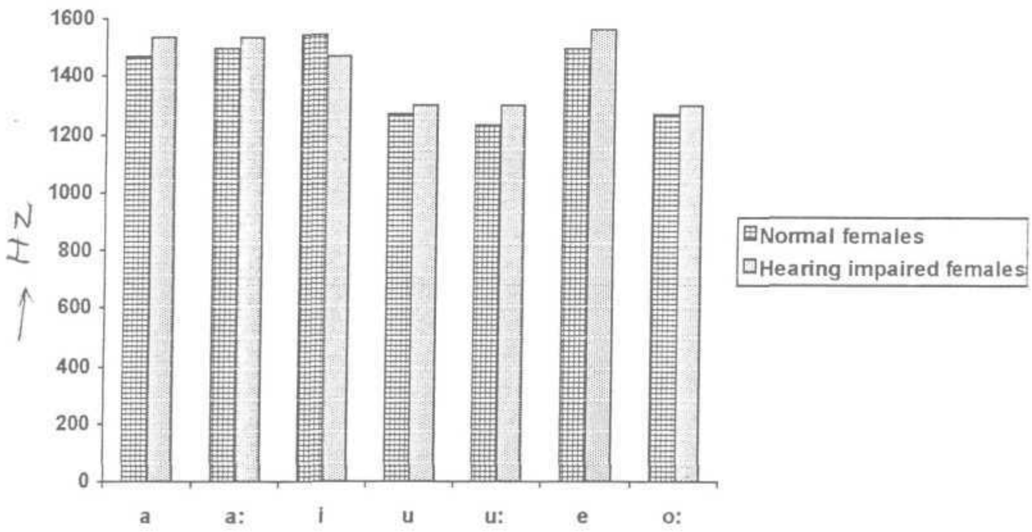
when compared to normal hearing males and females excpt for vowel |i| being higher in the hearing impaired male group than in female group.

Thus the hypothesis that there is no significant difference between the means of F_2 values of the hearing impaired males and normal hearing males was accepted for all the vowels \i\, |u|, |u|: |e|, |o|: and rejected for |a| and |a:.

The hypothesis that there is no significant difference between the means of F_2 values of the hearing impaired females and normal hearing females was accepted for all the vowels a, a:, I, u, u:, e, and o:, Then it can be concluded that the mean F_2 is not significantly different in the vowels produced by hearing impaired to that of normal group. Hypothesis (2) stating that there is no significant different between (a) hearing impaired males and hearing impaired females and (b) normal males and normal females in terms of second formant frequency is accepted.



Graph - 5(a): Shows mean values for second formant frequency in normal and hearing impaired males.



Graph - 5(b): Shows mean values for second formant frequency in normal and hearing impaired females.

Third formant frequency :

Table 6(a) Depict mean and SD values for third formant frequency in normal and hearing impaired males.

	Normal males		Hearing impaired males		
Vowel	Mean (Hz)	SD (Hz)	Mean	SD	Mean difference hearing impaired and normals(Hz)
a	1941.80	399.41	2792.60	477.88	850.80
a:	2117.80	527.52	2767.10	723.22	569.30
i	2180.80	438.43	2002.50	415.34	-175.30
u	2197.80	178.11	2085.14	610.06	-92.00
u:	2104.20	456.21	2200.80	383.16	96.60
e	2789.90	387.80	1589.90	415.55	-1195.50
o:	2174.80	363.50	2275.90	414.57	101.10

Significant at 0.05 level

Table 6(a) and Graph 6(a) shows, it was found that F_3 values for the hearing unpaired males was higher than that of normal males except for vowels |i|, |u| and |e|. The mean difference of F_3 values for vowels varied from - 175.3 - 850.8 Hz. The greatest group difference in the mean of F_3 values was for the vowel |a| in which the normal hearing males had F3 of 1941.8 Hz and the hearing impaired male 2792.62 Hz. The normal hearing males had a high F_3 than hearing impaired males for vowels |o|, |u| and |e|. The mean difference between both groups for these values weere - 175.3 Hz. - 92.0 Hz and - 119.5 Hz respectively. A significant mean difference between hearing impaired and normal hearing males was found for vowel |a|.

Table 6(b) depicts mean and SD values for third formant frequency in normal and hearing impaired females.

	Normal females		Hearing impaired females.		
Vowel	Mean (Hz)	SD	Mean (Hz)	SD	Mean difference hearing impaired and normals(Hz)
a	2486.50	398.98	2416.80	379.21	-69.70
a:	2458.30	383.04	2432.80	399.14	-25.50
i	2830.96	346.48	2575.90	434.04	-255.06
u	2401.30	408.80	2236.80	189.83	-164.50
u:	2416.40	305.11	2349.10	405.68	-67.30
e	2738.73	208.14	2767.40	356.86	28.67
0:	2194.24	186.14	2249.50	408.36	55.26

Significant at 0.05 level of significance.

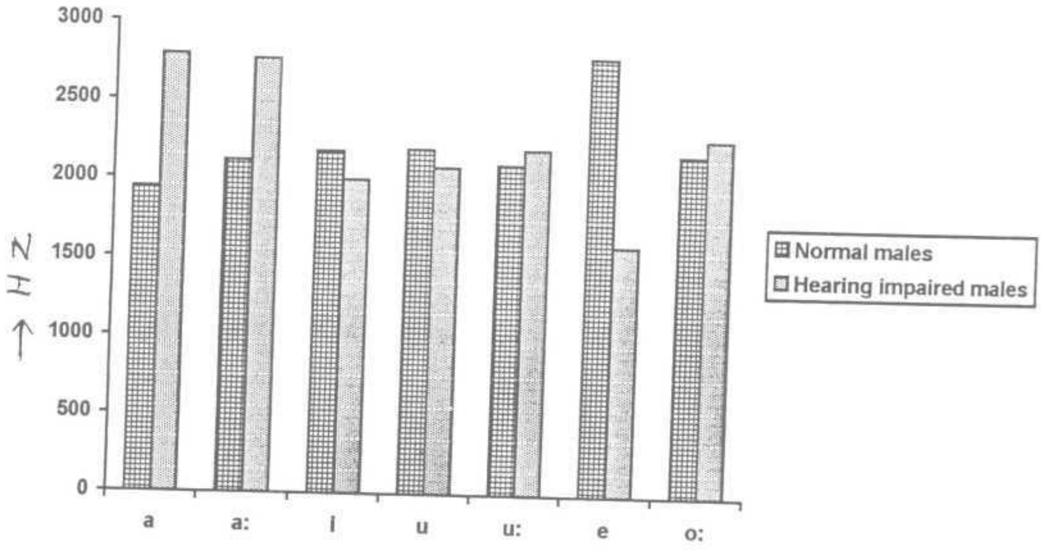
Table 6 (b) and Graph 6 (b) shows, generally it was seen that hearing impaired females had lower F3 values than normal hearing females for vowels |u|, |a:|, |i|, |u| |u:|. The mean difference between two groups varied from -255.06 to 55.26 Hz. Largest group difference in the mean of F3 was for the vowel |o:| 55.26 Hz. A significant mean difference between the hearing impaired and normal hearing females was seen for vowel |i|. 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 staring 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|.

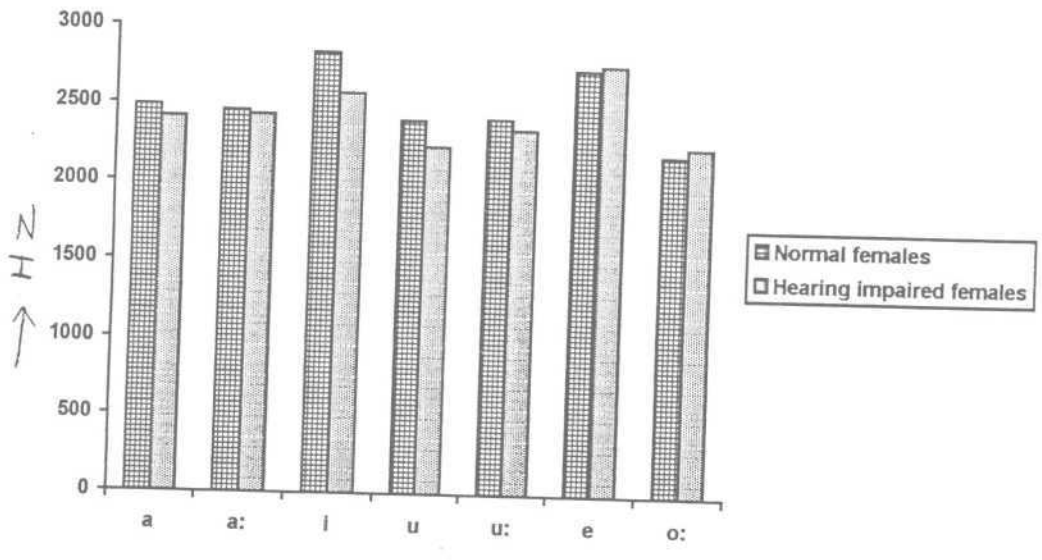
Thus different trends in hearing impaired malesd and females are observed in terms of F3 values. The hypothesis stating that there is no significant difference between the means of F3 values of vowels of the hearing impaired and normals hearing females is rejected for vowel |i| and accepted for vowel |a|, |a:|, |u|, |u:|, |e|, and |o:|.

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

Previous researchers (Potter etl.al., 1947, Angelocci et.al, (1964) have indicated that the first three formants contribute the greatest part of vowel information. Three formant values namely F1, F2 and F3 for each vowel were obtained. This result has also been supported by current study.



Graph 6 (a): Shows mean values for third formant frequency in normal and hearing impaired males.



Graph 6 (b): Shows mean values for third formant frequency in normal and hearing impaired females.

Band Widths:

The three band widths B_1 B_2 and B_3 were determined for all the vowels. The hearing impaired children had smaller values of band width.

The student 'T' test performed did not show a significant difference between the two groups at 0.05 level of significance for BW_1 bW_2 and BW_3.

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 band width is accepted.

Pauses :

The analysis of inter syllabic pauses revealed that normal subjects did not show any pauses, whereas pauses were observed in utterances of some hearing impaired subjects. It was found that twenty eight out of fourty hearing impaired children exhibited pauses in their utterances, sixteen were males and twelve were females.

It was found that more number of hearing impaired males exhibited, pauses for the word |to:p:| (6/7) and the pause duration varied from 186 msec to 496.5 msec. Twelve of the male subjects exhibited pause only for one word while other four exhibited pauses for 2 words. In the hearing impaired male groups, pauses were exhibited on the words |to:p;| (8/16), |na:kv| (3/16), |ka:ge| (2/16), |dabba| (2/16), |pa:pu|(l/16). Similarly in the female hearing impaired group, the maximum number of subjects exhibited pauses on the word |to:pi|

(6/12) |dabba| (3/12), |ka:ge| (3/12) and the pause duration varied from 210 msec - 686.50 msec six of the females subjects exhibited pause on one word, three subjects exhibited pause for four words and three subjects exhibited pause for four words. In the hearing impaired female group pauses were exhibited on |to:pi| (6/12), |dabba:| (3/12) |ka:ge| (3/12).

The hypothesis stating that there is no significant difference between normals and hearing impaired subjects interms of pauses was rejected.

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

Gender Effects :

No significant difference was found between males and females in both the normal and the hearing impaired groups on all parameters measured. Thus the hypothesis 2(a) and (b) stating that :

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

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

Thus the hypothesis, stating that there is no significant difference in the utterance of normal and hearing impaired subjects in terms of

Total word duration was rejected

Vowel duration was rejected

Averagefundamental frequency was rejected

Inter syllabic pause duration was rejected

First formant frequency was rejected for majority of the vowels (|i|, |u|, |u:| in males on |a|, |o|, and |e| in females)

Second formant frequency was rejected for majority of vowels ||a| in males and was accepted for all the vowels in females).

Third formant frequency was rejected for most of the vowels |a| in male and |i| female).

Bandwidths (Bi, B_2, B_3) 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 Ho wart, 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 that 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 V fold muscles.

Further it has 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 is 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 F_o.

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 F1 values for all the vowels were found tob e higher in the hearing impaired group compared to the normal group. Similar remits were reported by Sheela (1988). Sowmya (1982) and Rasitha (1994).

The difference in the mean Fi values obetween the normals and hearing impaired group was significant only for the front vowels |i| and |e| and back vowels |u| and |o|.

Regarding the mean F_2 values ing eneral the hearing impaired had higher mean F_2 values compared to that of the normal except for vowel |i|. However, no significant difference was found between the two groups. The mean F_{3e} 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 bertween 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), Shukia (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 F_1 and F_2.

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

SUMMARY AND CONCLUSION

Present study aimed at determining some of acoustic characteristics of Speech of (Kannada speaking) hearing impaired children. Forty congenitally hearing impaired children between 7-11 years were selected. Control group consisted of forty normal children in the same age range and language. All the hearing impaired children had severe to profound sensori neural hearing loss and were using of hearing aids and had speech therapy. All these children were able to read simple bisyllabic words in Kannada.

The speech samples (20 bisyllabic meaningful simple words) of all the children were recorded and the samples were analyzed using computer programmes of VSS, Bangalore. The parameters analysed were the following :

1) Total duration of words
2) Vowel duration
3) Intersyllabic pauses
4) Average F_o
5) Formant frequency (F_1, F2 and F3)
6) Bandwidths (B_1 B_2 and B_3)

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. Total duration of words uttered by the hearing impaired children were significantly longer that of the normal hearing group.
2. The hearing impaired group had significantly longer vowel duration than that of the normal hearing group.

3. Normal hearing children did not show any inter syllabic pauses (Intraword) whereas 28 out of 40 children in the hearing impaired group inserted intersyllabic pauses at least once in each word.
4. In general hearing impaired children had higher first formant (F_1 than normal hearing group.
5. 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.
6. The F_3 values were found to be either above or below than that of the normal values.
7. The three bandwidth B1, B2 and B3 were determined for the all the vowels. The hearing impaired childfren had smaller values of bandwidth. However, there was no significant difference between two groups at 0.05 level of significance.

The result of the present study shows that the temporal and acoustic characteristic of speech of hearing impaired in terms of word duration, vowel duration, intra-word pause duration, formant frequencies were difference from that of normals. This warrants the therapy to hearing impaired needs to be focussed on correction of the temporal and acoustic characteristics to improve the speech of the hearing impaired. Further, the results are useful in noting the general characteristics of speech of hearing impaired speaking in different languages.

Recommendations: 1) To carry out the study to note other temporal and acoustic characteristics in speech of hearing impaired.

2) To study the changes in characteristics :

a) age, b) With therapy.

BIBLIOGRAPHY

Angelocci, A.A. (1962). "Some observations on the speech of the deaf. The Volta Review, 64, 403 - 405.

Angeloeci, et al (1964). "The vowel formants of deaf and normal hearing II to 14 years old boys". Journal of Speech and Hearing Disorders, 29, 156 - 170.

Boone, D.R. (1966). "Modification of the voices of deaf children". The Volta Review, 68, 686 - 694.

Boothroyd, A. (1975). "Evaluation of speech production of the hearing impaireed and some benefits of forced - choice testing". Journal of Speech and Hearing Research, 28, 185 - 196.

Boothroyd, A. et al (1974). "Temporal patterns inn the speech of the deaf - study in emedial training". Northampton Mass; C.V. Hudgins Diagnosti and research centre, Clark School for the deaf, as cited by, Oeberger, M.J. and McGarr, N.S. (1982) in "Speech Production Characteristics of the hearing impaired", Status report on Speech Research, Jan - March, Hasking Lab, New Haver, Conn. 227 - 290.

Brannon, J.B. (1964). "Visual feedback of glossal motions and its influence upon the speech of deaf children". Unpublished Ph.D. Dissertation, Northwestern University.

Bush, N, (1981). "Vowel articulation and laryngeal control in the speech of the deaf. Unpublished doctomi dissertation, Massachusetts Institute of Technology, a cited by Osberger, M.J. Ind McGarr, N.S. (1982).

Calvert, D.R. (1961). "Some acoustic characteristics of the speech of profoundly deaf individuals" Ph.D. thesis, Stanford University, cited by Harris, K.S., and McGarr, N.S. (1980).

Calvert, D.R. (1962). "Speech sound duration and the consonant error". The volta Review,64, 401 - 403.

Chjermak, G.D. (1981). "Speech sound duration and the consonant error". The Volta Review, 64, 401 - 403.

Cowie, R.I.D., and **Cowie,** E.D. (1983). "Speech production in profound post lingual deafness", cited in M.E. Lutman, and M.P. Maggard (Eds.), Hearing science and Hearing disorders, London: Academic Press, 183-231.

Dences, P. (1955). "Effacti of duration on the perception of vpicting". Journal of Acoustical Society of America, 27, 769 - 773.

Engleberg, M. (1962). "Correction of falsetto voice in deaf adult". Journal of Speech and Hearing Disorders, 27, 162 - 164.

Fry, D.B. (1958). "Experiments on the perception of stress". Language and Speech, 1, 126 - 152.

Gefiner, D. (1980). "Feature characteristics of spontaneous speech production young deaf adults", Journal of Communication Disorders, 13, 443 - 454.

Gold, T. (1980). "Speech production in hearing impaired children". Journal of Communication Disorders, 13, 397 - 418.

Green, D.S. (1956). "Fundamental frequency of the speech of profoundly deaf individuals". Unpublished doctoral dissertation, Purdue University, cited.

Gruenwald, B.E. (1966). "A comparison between vocal characteristics of deaf and normal hearing individuals". Unpublished Doctoral dissertation, University of Kansas.

Heidinger, V.A. (1972). "An explanatory study of procedures for improving temporal patterns in the speech of the deaf children". Unpublished doctoral dissertation, Teachers College, Columbia University, as cited by Ling, D.(1976).

Hood, R.B. (1966). "Some physical cosconitast of the perception of speec rhythm of the deaf'. Ph.D., thesis, Stanfond University.

Chjermak, G.D. (1981). "Speech sound duration and the consonant error". The Volta Review, 64, 401 - 403.

Cowie, R.I.D., and **Cowie, E.D.** (1983). "Speech production in profound post lingual deafness", cited in M.E. Lutman, and M.P. Maggard (Eds.), Hearing science and Hearing disorders, London: Academic Press, 183 - 231.

Dences, P. (1955). "Effacti of duration on the perception of vpicting". Journal of Acoustical Society of America, 27, 769 - 773.

Engleberg, M. (1962). "Correction of falsetto voice in deaf adult". Journal of Speech and Hearing Disorders, 27, 162 - 164.

Fry, D.B. (1958). "Experiments on the perception of stress". Language and Speech, **1,** 126 - 152.

Gefiner, D. (1980). "Feature characteristics of spontaneous speech production young deaf adults", Journal of Communication Disorders, 13, 443 - 454.

Gold, T. (1980). "Speech production in hearing impaired children". Journal of Communication Disorders, 13,397-418.

Green, D.S. (1956). "Fundamental frequency of the speech of profoundly deaf individuals". Unpublished doctoral dissertation, Purdue University, cited.

Gruenwald, B.E. (1966). "A comparison between vocal characteristics of deaf and normal hearing individuals". Unpublished Doctoral dissertation, University of Kansas.

Heidinger, V.A. (1972). "An explanatory study of procedures for improving temporal patterns in the speech of the deaf children". Unpublished doctoral dissertation, Teachers College, Columbia University, as cited by Ling, D.(1976).

Hood, R.B. (1966). "Some physical coscomtast of the perception of speec rhythm of the deaf'. Ph.D., thesis, Stanfond University.

House, A and **Fairbanks, G.** (1953). "The influence of consonant environment upon the secondary acoustical characteristics of vowels". Journal of Acoustical Society of America, 25, 105 - 113.

Hudgins, C.V. and **Numbers, F.C.** (1942). "An investigation of the intelligibility of tlie speech of tlie deaf. Genetic Psychology Monograph", 25, 289 - 392 as cited by Osberger, M.S., and McGarr, N.S.

Huntington, D. et al (1968). "An electromyographic study of consonant articulation in hearing impaired and nonnal speaders". Journal of Speech and Hearing Research 11, 147- 158.

Jagadish (1989). "Analysis and Synthosis of hearing impaired speech" Unpublished Masters dissertation submitted to the Umversity of Mysore.

John, J.D. Jr. and **Howrath, N.J.** (1965). "Tlie effect of timedistortions on the intelligibility of deaf children's speech Language and Speech", B. 127 - 134, as cited by Osberger, M.J., and McGarr, N.S. (1982).

Klatt, D.H. (1974). "Cited in R.S. Nickerson. Characteristics of die speech of deaf persons". The Volta Review, 77, 342 - 362.

Leeper, H.A., Perez, D.M., and **Mencke, E.D.** (1987). "Influence of utterance length upon temporal measures of syllable production by selected hearing impaired children". Folia Phoniatrical, 39, 230 - 243.

Levitt, H., Smith, R. (1972). "Errors of articulation in tlie speech of profoundly hearing impaired children". Journal of Acoustical Society of America, 51, 102.

Ling, D. (1976). "Speech and the hearing impaired child: theory and practice. First edition". The A.G. Bell Association for the deaf Inc. Washington, D.C.

Maassen, and **Povel, D.J.** (1985). "The effect of segmental and suprasegmental correction on the intelligibility of deaf speech". Journal of Acoustical Society of America, 78 (9), 877 - 887.

Markides, A. (1970). "The speech of deaf and partially - hearing children with special reference to factors affecting intelligibility". British Journal of Communication Disorders, 5, 126 - 140.

Martony, J. (1960). "On the correction of the voice pitch level for severely hard of hearing subjects". American Annals of the Deaf. 113, 195 - 202.

Martony, J. (1977). "Some aspects of speech errors in deaf children". Papers from the Research Conference on Speech Processing Aids for the Deaf, Gallaudet College.

McGarr, N.S., and **Osberger, M.J.** (1978). "Pitch deviancy and intelligibility of deaf speech". Journal of Communication Disorder, 11, 837 - 847.

c/Metz, D.E., Samar, V.J., Schiavetti, N., Sitler R., and **Whitehead, R.L.** (1985). "Acoustic dimensions of hearing impaired speakers intelligibility". Journal Speech and Hearing Research, 28, 345 - 355.

flftetz, D.E., Whitehead, R.L., Mahsie, J.J. (1982). "Physiological correlates of the speech of the deaf. A preliminary view. In Sims, D.S., Walter, *G.G.*, Whiltehead, R.L. (Eds.) Deafness and Communications : Assessment and training 1st edition, Baltimore, Williams and Wilkins, 75 - 89.

Miller, M.A. (1968). "Speech and voice patterns associated with hearing impairment Audecibel", 17, 162 - 167.

Monsen, R.B. (1974). "Normal and reduced phonological space in the production of English vowels by deaf adoloscents", Journal of Speech and Hearing Research, 17, 189 - 198.

Monsen, R.B. (1974). "Durational aspects of vowel production in the speech of deaf children". Journal of Speech and Hearing Research, 17, 386 - 398.

Monsen, R.B. (1978). "The production of English stop consonants in the speech of deaf children". Journal of Phonetics, 4, 29 - 41.

Monsen, R.B. (1978). "Toward measuring how well deaf children speak". Journal of Speech and Hearing Research, 21, 197 - 219.

Monsen, R.B. (1979). "Acoustic qualities of phonation in young hearing impaireed children". Journal of Speech and Hearing Disorders. 22, 270 - 288.

Monsen, R.B., and **Leiter,** E. (1975). "Comparison of intelligibility with duration and pitch control in the speech of deaf children". Journal of Acoustical society of America, Society of America, Suppl. 1, 57, 569 (a).

Nickerson, R.S. et al. (1974). "Some observations on timing in the speech of deaf and hearing speakers". BBN Report No.2905, Cambridge, M.A.

Nickerson, R.S. (1975). "Characteristics of the speech of deaf persons". The Volta Review, 77, 342 - 362.

Osberger, M.J. and **Levitt, H,** (1979). "The effect of timing errors on the intelligibility of deaf children's speech". Journal of Acoustical society of America, 66, 1316- 1324.

Osberger, M.J. and **McGarr, N.S.** (1982). "Speech production characteristics of the hearing impaired. Status report on speech research", Jan - Mar. Hasking Laboratories, New Haven, Conn. 227 - 290.

Parkhurst, B., and **Levitt, H.** (1978). "The effect of selected prosodic errors on the intelligibility of deaf speech". Journal of communication Disorders, 11, 249 - 256.

Philips et al (1968). "Teaching intonation to the deaf by visual pattern matching American Annals of the Deaf. **1**13, 239 - 246.

Pickett, J.M., (1968). "Sound patterns of speech: An introductory sketch. American Annals of the deaf," 113, 239 - 246.

Rajanikanth, B.R. (1986). "Acoustic analysis of the speech of the hearing impaired Unpublished masters dissertation", University of Mysore.

Raphael, L.J. (1972). "Preceding vowel duration as a cue to the perception of the voicing charactereistics of word-final consonants in American English". Journal of Acoustical Society of America, 51. 1296 - 1303.

Ravishankar, K.C. (1985). "An examination of the relationship between speech intelligibility of the hearing impaired and receptive and productive variables". Unpublished docotal thesis. University of Mysore.

Reilly, A.P. (1979). "Syllabic nucleus duration in the speech of hearing and deaf children". The City University of New York.

Ross, M., and **Giolas, T.G.** (1978). "Auditory management of hearing impaired children". University Park Press 1-14.

Rothinan, H.B. (1977). "An electromyographic investigation of articulation and phonation patterns in the speech of deaf adults". Journal of Phonetics, 5, 369 - 376.

Slieela (1988). "Analysis and Synthesis of hearing impaired speech" Unpublished Masters dissertation submitted to the University of Mysore.

Shukla, R.S. (1985). "Objective measurements of the speech of the hearing impaired. Unpublished doctoral thesis, University of Mysore.

Shukla, R.S. (1989). "Phonological space in the speech of **the** hearing impaired" Journal of Communication disorders, 22, 317 - 325.

Smith, C.R. (1972). "Residual hearing and speech production in deaf children". Unpublished Ph.D. dissertation. City University of New York, as cited by Ling, D. (1976).

Smith, C.R. (1975). "Residual hearing and speech production in deaf children". Journal of Speech and Hearing Research, **18,** 795 -811.

Stark, R.E., and **Levitt, H.** (1974). "Prosodic feature reception and production in deaf children". Journal of Acoustical Society of Ametical, 55, 363 (Abstract).

Thomas, W.G. (1964). "Intelligibility of the speech of deaf children Proc. Int.Congr. on Education of the deaf, Washington, D.C. U.S.Govt. Printing Office, (245 - 261) a cited by Ling, D. (1976).

Thorton. A. (1964). "A spectogiapliic compaiison of connected speech of deaf subjects and hearing subjects" Unpublished Master's Thesis. Lawrence las quoted by Gulbeit, H.R., (1978).

Vasantha, B. (1995). "Phonological space for vowel production in Telugu Deaf children. A spectrographic study" Journal of Acoustical society of India, 23, 36 - 47.

Voelker, C.H. (1938). "An experimental study of the comparative rate of utterance of deaf and normal hearing speakers". American Annals of die Deaf, 38, 274 - 284.

Vhernall, E., and Fry, **D.B. (1964).** "The deaf child. 1st Ediction", London William Heinemann Medical Books Limited.

Whitehead, R.L., and **Hones, K.D.** (1978). "The effect of vowel environment on duration of consonants produced by normal hearing impaired and deaf adult speakers". Journal Phonetica, 6, 77-81.

Whitehead, R.L., and **Maki, J.E.** (1977). "Fundamental vocal frequency characteristics of the adults hearing impaired" ASHA, Chicago, as cited in Monsen, R.B. (1979).

Willemain, T.R., and Lee, F..F. 1971). Tactile pitch feedback for deaf speakers". The Volta Review, 73, 541 - 554.

Zimmerman, G., and **Rettaliata, P.** (1981). "Articulatory patterns of speaker" : Implications for the rule of auditoiy information in speech production. Journal of speech and Hearing Research, 24, 169 - 178.

APPENDIX - 1

ಕಾಗೆ	ka:ge
ನಾಕು	na:ku
ಟೋಪಿ	ṭo:pi
ಆಟ	a: ṭa
ಡಬ್ಬ	ḍabba
ಗಾಡಿ	ga:ḍi
ತಲೆ	t̪ale
ತಾತ	t̪a:t̪a
ದನ	d̪ana
ಪಾದ	pa:d̪a
ನಾಯಿ	na:yi
ಅನ್ನ	anna
ಪಟ	paṭa
ಪಾಪು	pa:pu
ಬಲೆ	bale
ಬಾಬಾ	ba:ba:
ಮೂರು	mu:ru
ಆಮೆ	a:me
ಲಾರಿ	la:ri
ಕಾಲು	ka:lu

APPENDIX - 1

ಕಾಗೆ	ka:ge
ನಾಕು	na:ku
ಟೋಪಿ	ṭo:pi
ಆಟ	a:ṭa
ಡಬ್ಬ	dabba
ಗಾಡಿ	ga:di
ತಲೆ	t̪ale
ತಾತ	t̪a:t̪a
ದನ	d̪ana
ಪಾದ	pa:d̪a
ನಾಯಿ	na:yi
ಅನ್ನ	anna
ಪಟ	paṭa
ಪಾಪು	pa:pu
ಬಲೆ	bale
ಬಾಬಾ	ba:ba:
ಮೂರು	mu:ru
ಆಮೆ	a:me
ಲಾರಿ	la:ri
ಕಾಲು	ka:lu