ACOUSTIC ANALYSIS OF SPEECH OF PUNJABI SPEAKING HEARING IMPAIRED CHILDREN

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REG. NO. M9610

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

ALL INDIA INSTITUTE OF SPEECH AND HEARING
MYSORE - 570 006

MAY 1998

DEDICATED

TO MY

LORD JESUS

CERTIFICATE

This is to certify that this Dissertation entitled: *"ACOUSTIC ANALYSIS OF SPEECH OF PUNJABI SPEAKING HEARING IMPAIRED CHILDREN"* is a bonafide work in part fulfillment for the final year M.Sc, (Speech and Hearing) of the student with *Reg. No. M9610.*

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This is to certify that this Dissertation entitled: *"ACOUSTIC ANALYSIS OF SPEECH OF PUNJABI SPEAKING HEARING IMPAIRED CHILDREN"* has been prepared under my supervision and guidance.

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DECLARATION

This dissertation entitled *"ACOUSTIC ANALYSIS OF SPEECH OF PUNJABI SPEAKING HEARING IMPAIRED CHILDREN"* is result of my own study under the guidance of **Dr.N.P. Nataraja,** Professor and head of the Department of speech sciences, All India Institute of speech and hearing, Mysore, and has not been submitted earlier at any university for any other Diploma or Degree.

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May 1998

Reg. No. M9610

ACKNOWLEDGMENT

My deepest gratitude, reverences and heart felt thanks to ***Dr. N.P.NATARAJA,*** Professor and Head of the Department of Speech Sciences, All India Institute of Speech and Hearing, Mysore, for his excellent guidance.

Thanks to ***Dr. (Ms). S.NIKKAM,*** Director, AIISH for permitting me to carry out this study.

Sir. (Dr.Raghunathan) and ***Maam (Dr. (Mrs.) Raghunathan),*** you can not expect what I feel about you, just in few words I express that if you were not there, I would not have been achieved what I have today. Thanks very-very much.

My overflowing affection to those lovely, kids, my dear subjects of the study, who co-operated with full zest and enthuse as much as I wanted.

No words are there in my heart for you, my *adorable parents,* for inspiring me in my life and showering all the love and affection throughout.

Sonia, my lovely, cute, sweet sister no words can suffice to explain what you mean in my life and will be there forever.

My elder *Brother* *and* ***Sisters*** and their ***lovely kids,*** thanks a lot for constant support throughout with your phone calls and letters.

Sanjay *and* ***Sarbjeet,*** very few true friends exist these days, and you both have shown with your constant help that you are the two of those few true friends. Thanks very much.

Susan, Deepa, I think you people made my stay at AIISH very exiciting and lively. Always remember you.

A special thanks to *MARUTHI COMPUTERS FOR NEAT AND FAST WORK,* Thanks a lot.

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INTRODUCTION

"I am just as deaf as I am blind wrote Helen Keller.

The problems of deafness are deeper and more complex, if not more important than those of blindness. Deafness is a much worse misfortune. For it means the loss of the most vital stimulus the sound of the voice that brings language, sets thoughts astir, and keeps us in the intellectual company of man," (Stevens and Warshofsby, 1971).

Man is highly dependent on his senses. Through his senses come the sensation which constitute his experience, a sensory deprivation limits the world of experience. The degree of the senosry impairement, the age at which it is sustained and other factors,influence the extent and nature of the shift which the organism undergoes (Mykelbust, 1968).

"The ear is the organ of education wrote aristotle centuries ago. Had he understood more about the innate nature of language learning is humans he would likely have phrased it the ear is the organ of language learinig" (Northern and Downs 1978).

The deaf child recieves sensation, precieves and he develops images, symbolization and concepts. However, when audiotory sensations are lacking or present only to a minimal degree the nature of his perception, imagery symbols and concepts are altered. The levels of symbalization and conceptualization are most affected. development of certain types of abstract behaviour is impeded (Mykelbust, 1968).

"According to the importance of normal hearing is thus vital to the development from birth of our uniquely human langyage skills. The auditory linked acquisition of language is further unique to human beings because, it is a time locked function, related to early maturational periods in the infants life" (Northern and Downs 1978).

"Early hearing impairment has definite effects on language development. As shown by Quigley and Thomure (1968), Goetzinger (1962), Harrison (1964) and others, even very mild impairments of hearing (less than 30dB) are often related to language and other educational deficits. This relation of hearing impairment and language deficit is evident in all aspects of langauge-phonological, morphological, syntatic and Semantic" (Ociglecy, 1978). "The longer the auditory language is delayed, the less efficient will be the language facility" (Northern and Downs 1978).

"The speech of the deaf differs from that of normals in all regards (Balack, 1971). In all the studies of speech of the hearing impaired, attention is drawn to the fact that, to a greater or lesser degree, the hearing impaired individuals do not produce speech as well as those who hear" (Monsen, 1974).

Without a clear understnding of the underlaying nature of the deaf's unintelligible speech, the development of effective clinical strategies is limited (Metz 1982) Development of effective remidial strategies would be enhanced by analysing normal and deviant speech production from an acoustical perspective (Zimmer man and Rettaaliater, 1981).

Various studies have been carried out to understand the speech of the hearing impaired (Hudgins and Numbers 1942; Angelocci, 1964; Rajani Kanth, 1986; Shukla, 1978; Sheela, 1988; Jagdhish, 1989; Whitehead, 1991; Sowmya, 1992; Rajitha, 1994; Rahul, 1997; Nober, 1967; McGarr, 1978; Geffner, 1980; Stoel Gammon, 1982). But the knowledge in this area is far from complete. The present study was undertaken since the speech related parameters are language specific, there is a need for more studies in all Indian languages. There was no study in this direction in Punjabi language. Therefore it was considered that it will be useful to study the acoustic aspects of speech of Punjabi speaking hearing impaired. This would help in planning providing better therapy for hearing impaired children specifically of Punjabi language.

AIM OF STUDY:

This study was undertaken to study the acoustic characteristics of the speech of Punjabi speaking hearing impaired children in terms of word duration, vowel duration, voice on set time (VOT), fundamental frequency (F0), formant frequencies (Fl, F2, F3), Bandwidths (B, B2, B3), and inetr syllabic pauses.

HYPOTHESIS:

There is no significant differences in terms of the speech of the hearing impaired children to "that of the normally hearing children in terms of:

la) Duration of vowels

b) Duration of words

c) Average FO

d) VOT voice onset time of stop consonants

f) Formant frequencies (Fl, F2, F3)

g) Band widths (Bl, B2, B3).

h) Intersyllabic pauses

2. There is no significant difference between hearing impaired males and females as well as in normal hearing males and females in terms of above stated Parameters.

IMPLICATIONS OF THIS STUDY

There is no significant diffeences between hearing impaired males and females and normal hearing males and females.

Speech samples (10 CVC Punjabi words) from 10 hearing impaired Punjabi speaking children were takena nd matched for their age and sex. Seven acoustic parameters (vowel duration, word duration, F0, VOT, Formant frequencies, Band width and Intersyllabic pauses) were analysed.

1. The results of this study would help in better understanding of the speech of the hearing impaired children speaking an Indian language, Punjabi.

2. The results of this study would provide data regarding the acoustic characteristics of speech of the hearing impaired children in general.

3. This information would also help in planning and developing therapy programmes for the hearing-impaired.

LIMITATIONS OF THE STUDY

1. The study was limited to only 20 subjects.

2. Individual differences existed in the hearing impaired children in terms of severity hearing loss, hearing aid usage, therapy duration, parental participation in therapy and motivation for therapy.

3. The stimulus material used for this study were limited to ten CVC combinations words only.

REVIEW OF LITERATURE

Communication is fundamental to human society as the very existence of the human society is largely dependent upon effective communication. The communication ability of humans is highly developed and this has been a big leap from those of his nearest neighbors on the evolutionary scale. Such enhanced communication abilities are through the medium of "speech", which is an ability exclusively to human beings.

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 can not 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).

Hearing is esential for the acquisition of speech and language. It is through continuous auditory stimulation of speech and other sounds in the environment that a child is able to acquire language. Wehetnell and Fry, 1964. The hearing mechanism is also essential for monitoring one's own speech production. In addition, hearing also enables an individual to make judgements regarding to the location of the different sound sources in the environment (Yost, 1994).

Impairment of hearing therefore not only renders a person to appreciate the different sounds present in his environment, but also reduces his capacity to understand and produce speech.

Speech provides the means through which we commi\unicate ideas and transmit information and emotions. Speech and language are usually acquired through hearing. As hearing loss can cause individual speech and lnaguage systems to be disorded. The resultent communication problems are some of the most serious and challenging to confront. Significant hearing disability not only signals difficulty in understanding the sounds of the environment, but also correlates with serious language, voice and articulation dificits (Oyer, 1994).

The ultimate goal in oral rehabilitation is, for the hearing impaired individual, to attain, as far as possible, the same communication skills as those of the normal hearing individual. Within the last decade, advances have been made in studying the speech. Thi3 is largely due to the development of sophisticated processing and analysis techniques in speech science and computer science. These 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. (Osberger & Mc Garr, 1982).

Several methods have been employed to study speech production in the hearing impaired. These include physiological (Metz et al. 1985), acoustic (Monsen, 1976a, 1976b, 1974, 1978; Angelocci, et al. 1964; Gilbert, 1975; Calvert, 1962; Suukla, 1987; Rajnikanth, 1986; Sheela, 1988; Jagdish, 1989; Rasitha, 1994; Rahul, 1997) and perceptual methods (Levitt, etal 1976; Stevens, etal 1983; Hudgins & Numbers 1992; Markides, 19 70; Geffner, 1980).

Use of acoustic analysis of speech for studying the speech production skills, offers several advantages as it is non-invasive, needs relatively simple instrumentation, may be used routinely to depict changes in the physical characteristics of frquency, intensity and the duration of speech segments (Leeper, et al 1987). Acoustic analysis of speech of hearing impaired permits finer grained consideration of some aspects of both correct and incorrect production than would be possible using methods applied in the subjective procedures (Osberger and Mc. Garr, 1982). It provides objective description of speech of the hearing impaired. More information about the characteristics of the speech of the hearing impaired would help in making use of the advances in the technology with maximal effectiveness in 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 (Levitt, 1978). Thus, analysis of speech of hearing - impaired becomes important.

So far little work has been done to study normal and abnormal speech patterns in Punjabi language. Punjabi is the native langauge of the state Punjab in India and the state Punjab in Pakistan. There are number of regional dialects of Punjai in both India as well as in Pakistan. The main regional dialects of Punjabi in India are: 1) Majhi, 2) Malwai, 3) Puwadhi, and 4) Doabi. Therefore it was considered worthwhile to make an attempt to understand segmental features of hearing speakers and normal speakers in Punjabi.

SPEECH INTELLIGIBILITY OF HEARING - IMPAIRED

Speech intelligibility refers to the ability to understand the speech by a listener. As the hearing impaired have difficulty in co-ordination of the timing of targeted articulatory movements and transition from one articulatory target to the other, their speech is not intelligible or clear.

Various studies have showed differences in terms of intelligibility of speech of the hearing impaired. According to Osberger and Levitt (1982) on the average the intelligibility of speech of the hearing impaired children is very poor. Only about one in every five words can be understood by a listener who is unfamiliar with the speech of the hearing impaired subject.

On the other hand Metz et al (1982) are of the opinion that the speech produced by many deaf persons is frequently intelligible to even experienced listeners. Several studies (Brannon, 1964, Markides, 1970 and Smith (1973) have shown that inspite of the provision of hearing aids, speech training, the average intelligibility of speech of the severely and profoundly deaf child to the naive listener is not more than 20% (Stark, 1979). Conrad (1979) reports that about 75% of pre-lingually deaf children with hearing losses of 90dB or more have speech classified as barely intelligible or worse. "The speech of profoundly hearing impaired children is usually less than 30% intelligible" (Ling, 1976).

Hudgins and Numbers (1949) who did the first quantitative assessment of the speech intelligebility of hearing impaired children. Four groups of experienced listeners classified consonantal errores in to errors of omission, errors of substitutuion and consonant cluster errors. The mean score of the group was found to be 29%. They also observed that the most common errors in the consonants were in voiced and voiceless distinction. Markides (1970) studied 58 hearing impaired children who were 7 & 9 years old. About 31% of their words were intelligibile to their teachers, where as only 19% were intelligible to naive listeners. According to Smith (1972) who studied 40 hearing impaired children in the age groups 8-10 and 13-15 years, word intelligibility as assessed by 120 listeners unfamiliar with the speech of the hearing impaired children was 18.7%.

Monsen (1978) using shorter sentences and more familiar vocabulary found the intelligibility scores of profoundly hearing impaired and severely hearing impaired children as 76% and 91% respectively.

The speech intelligibility scores correlate well with the hearing level of the individual. Monsen (1978) found that all children he studied with hearing loesses of 95 dB HTL or less had intelligible speech but children with losses greater than 95dB HTL did always have poor or unintelligible speech. Smith (1975) observed a systemic decrease in intelligibility with poor hearing level until a level of about 85dB HTL.

On the average the intelligibility of speech of the profoundly hearing impaired children is very poor. The speech production performance was found to be good for children of higher socioeconomic status, and for better hearing aid users (Weisel and Reichstein, 1989).

Consonant errors have been generally found to be highly correlated with speech intelligibility than are the vowel errors (Hudgins and Number, 1942). Hudgins and Numbers (1942) and Smith (1975) reported a high negative correlation between speech intelligibility and total number of consonant and vowel errors. Among consonant errors omissions of initial consonants, voiced -voiceless confusion, and errors involving compound consonants clusters had most detrimental effect on speech intelligibility. Substitution errors, nasality errors, omission of final consonants and errors involving substitution of consonants had a lower correlation with intelligibility and contributed to a much lesser extent to the reduced intelligibility of speech of hearing impaired children.

Monsen (1978) examined the relationship between intelligibility of four acoustically measured variables of consonant production, three acoustic variable of vowel production and two measures of prosody. Three variables were highly correlated with intelligibility. Those were:

1) The difference in VOT between /t/ and /d/
2) The difference in second formant location between /i/ and /I/.
3) Acoustic characteristics of the nasal and liquid consonants.

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

As stated by Brown, Goldberg, (1990) the intelligibility of speech of the hearing impaired was related to the variables such as consonant duration, VOT and relative formant frequency distribution. They reported that in the intelligible utterances of the hearing impaired, VOT was the most consistently comparable measure, consonant closure duration was somewhat more variable, formant frequency distribution of the vowels was the least compatible. VOT functioned as a critical factor in syllables recognition.

Thus the results of various studies suggest that overall levels of speech intelligibility are utterly inadequate for oral communication (Ling 1976). Hence the above spectrographic parameters such as formants, vowel duration and VOT were taken up for study.

So far no investigations have been done to study the speech characteristics of Punjabi speaking hearing impaired children. The purpose of the present 3tudy is to compare speech of the hearing impaired to that of the normals. This will be of help in synthesis of speech and in improving the intelligibility of speech the hearing impaired children.

TIMING

RATE:

Physical measures of speaking rate have shown that profoundly hearing - impaired speabers on average take 1.5 to 2.0 times longer to produce the same utterances as do normal hearing speakers (Boone, 1966; Hood, 1966; Howosth, 1965; Voelter, 1935).

Hearing - impaired speakers have been found to speak more slowly than even the slowest speakers with normal hearing. 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). 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 as high as 108 words/min. The problem of reduced rate of speaking in the deaf speaker seems to be related to two separate problems. i) Increased duration of phonemes, vowels, and ii) Improper and often prolonged pause within utterances (Gold, 1980).

INCREASE DURATION OF PHONEMES AND VOWELS

The duration of a phoneme and a vowel bears important information in the perception of a speech message. Each vowel has an intrinsic duration which is influenced by the physical properties of the speaker's production mechanism. Even prior to the age of three, children can recognize important parameters of the language (Peterson and Lehiste, 1960). There is a general tendency towards lengthening of vowels and consonants in the deaf (Angelocci, 1962; Boone, 1966; Levitt, et al., 1974; Levitt and Parkburst, 1978).

Smith (1978) found that even children (four year olds and two year olds) like adults showed final syllable vowel lengthening than non final syllable vowel. Konetal et al., (1982) reported that the prepausal lengthening effect identified for adults were also found in young children's spontaneous utterances.

Durational changes in vowels serve to differentiate not only between vowels themselves but also between similar consonants adjacent to those vowels (Raphael, 972; Gold, 1980). Sandhu (1986) attempted to investigate the durational features of Punjabi stops in different vowel contexts (i, a, and u) in three adul native speakers. The duration of burst measured in CV combination revealed that it is most intense and longer before /i/ than before other vowels. Duration was found to be around 15-20 sec before /i/ and 8-12 usec. before /a/ and /u/.

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 closure period of plosives up to 5 times the average duration for normal speakers.

Lengthening or shortening of a vowel or any speech segment can be done by altering the particular context. House and Fairbanks (1953) showed that the duration of a vowel in English varies systematically from shorter to longer in the following order; a stressed vowel preceding a voiceless Stop lessthan Voiceless fricative lessthan nasal lessthan voiced stop lessthan voiced fricative.

Disimoni (1974) making Oscillographic measurements of vowel and consonant durations in CVC and VCV utterances of 3, 6, 9 years old children concluded that:

1) Variability of the duration tended to decrease with age.
2) The vowel duration in the voiceless consonant environments remained relatively constant for all ages tested, while in voiced consonant environments, it was found to increase with age.
3) Vowel duration values for both voiced and voiceless consonant environments were found to be significantly different in six and nine year old subjects, but not in 3 year old subjects.

In English the duration of the vowel is phonetic in nature where as in Malayalam, Jenson and Menon (1972) demonstrated that it will lead to change in meaning.

Rashmi (1985) determined the vowel duration of /i/ in /idu/ in children and found that:

Age (Yrs)	Vowel duration (Ms)
5-6	158.07
6-7	121.79
7-8	111.32
8-9	88.31
9-10	87.28

Males and females showed a consistent decrease in the vowel duration as a function of age. Savithri (1984) found that a low vowel had longer duration than a high vowel in Kannada.

Monsen (1946) studied 12 deaf and 6 normal hearing adolescents as they read 56 CVCs words containing the vowels /i/ or /l/. 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 occurred in the presence of different consonants. For the normal subjects, the duration of /i/ was always longer than /I/ for a particular consonantal environment, but the absolute 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 on normal decoding startegies to interpret the speech that was heard.

The vowel duration also varies with reference to the voice - voiceless distinction of the following consonant. The hearing - impaired fail to produce the appropriate modifications in the vowel duration as a function of voicing characteristics of the following consonant. Hence the frequent voice-voiceless confusion observed in their speech may actually be due to vowel duration errors (Clavert, 1961).

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

a) On the average the duration of vowel /a/ was longer when followed by a voiced consonant than when followed by a voiceless consonant in both the groups of subjects. However, in both the groups the difference was less than the JND 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 msecs., 195 msecs and 185 msecs respectively. In the hearing-impaired speakers /i/ and /u/ tended to be longer than in normal speakers and vowel /a/ tended to be either longer or shorter when compared to the length of 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 /u/ whereas in the hearning - impaired speakers, vowel /a/ was shorter than vowel /i/ and /u/.

g) The 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 changes in the duration of the vowels depending on the preceding consonants.

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

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

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

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

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

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

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

Several investigations have shown that while hearing - impaired speakers make the duration of unstressed syllables shorter than that of the stressed syllables, the proportional shortening is smaller, in the speech of the hearing-impaired than in the speech of normal hearing subjects (Levitt, 1979; Stevans, et al., 1978).

Osberger and Levitt (1979) found the mean ratio for the duration of the stressed and unstressed vowels to be 1.49 and 1.28 for the normal hearing children and the deaf children and the deaf children respectively. The reduced ratio for the deaf children indicates that while the average duration of unstressed vowels is shorter than the duration of stressed vowels in the speech of the deaf children, the proportional shortening of unstressed vowels is lesser, in the deaf child's speech. These studies have shown that the hearing-impaired produce mostly stressed syllable and that there is an overall tendency for increasing the duration of all phonemes in the speech of the hearing-impaired.

Boone (1966), John and Howorth (1965), state that this is partly due to the training, 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 the speech of profoundly hearing-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. Variation in fundamental frequency would be a likely alternative, but McGarr and Harris (1980) also found that while the hearing-impaired speaker produced the systematic changes in the fundamental frequency associated with syllable stress, perceptual confusions involving stress pattern were 3till observed.

Pauses:

Pauses have been found to be inserted at synthetically inappropriate boundaries, such as between two syllables in a bisyllabic word or within phrases by the hearing-impaired speakers (Osberger and McGarr, 1980; Sheela, 1988; Jagdish, 1989) Profoundly hearing-impaired speakers 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.). Strok and Levitt (1974) reported that the deaf subjects tended to pause after every word and stress almost every word.

Nickerson et al. , (1974) reported that the total pause time in the speech of normal hearing children constituted 25% of the time required to produce the test sentences, whereas it was 40% in the speech of the deaf. Boothryod, et al. , (1974) considered that within phrase pauses were more serious problems then between phrase pauses 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 Quality:

There seems to be general agreement that the deaf speakers have a distinctive voice quality, (Boothroyd, 1976; Calvert, 1962; Boone, 1966). However it is not easy to define this characteristic voice quality often hearing-impaired. Hearing-imparied 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. Thi3 result in a 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 speech deaf persons 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 sounds (vowels and diphthongs in isolation, non-sense syllables, words and sentences) had been produced by profoundly deaf speakers, normal hearing speakers imitating deaf speakers, speakers simulating harsh and breathly 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 sources of the sentences were identified with 70% accuracy. Clavert (1971) concluded that deaf voice quality is identified not only on the basis of relative intensity, fundamental frequency and the harmonics, but also by the dynamic factors of speech such as transition gestures that change from one articulatory position to another.

Fundamental Frequency:

In normal hearing speakers, the average fundamental frequency (Fo) decreases with increasing age until adulthood for both males and females (Fairbanks, 1940; Usha, 1979; Gopal, 1980). Hearing-impaired speakers often tend to vary the pitch much less than the normal hearing speakers and the resulting speech has been described as flat or monotone (Calvert, 1962; Hood, 1966; Martony, 1968).

The poor pitch control in the hearing - impaired individuals may be due to two reasons:

1) Inappropriate average Fo.
2) Improper intonation - This maybe characterized by:
    a) Little variations in Fo resulting in flat and monotonous speech
    b) Excessive or erratic pitch variations.

AVERAGE FUNDAMENTAL FREQUENCY:

Several investigators have reported that the hearing-impaired speakers have a relatively high average pitch than the normal hearing speakers of comparable ages (Angelocci, 1962; Calveret, 1962; Thornton, 1964; Boone, 1966; Campbell, 1980). Also, the variability of Fo is much greater in the hearing-impaired, than in the normal hearing speakers (Angelocci, et al., 1964). Whitehead and Make (1977) reported that on the average the speaking Fo was higher for deaf adults, than for the normal hearing adults, a majority of the deaf adults had speaking Fo values which fell within the normal range. These findings have also been supported by the findings of other studies such as by Ermovick (1965), Gruanewald (1966), Shukla (1987) etc.

These differences may vary as a function of the age or sex of the hearing-impaired speakers. While there were no significanct difference 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 males). Osberger (1981) found that the difference in Fo between hearing-impaired speakers in the 13-15 years age range was greater for females than for males. The Fo for female hearing-impaired speakers ranged between 250-300 Hz. which is about 75 Hz, higher than that observed for the normal hearing females.

Meckfeseal and Thornton (1964) reported the Fundamental frequency while speaking (FFS), values in post-pubertal hearing-impaired males to be higher than those for normal hearing post-pubertal males. However, Greene (1956) found similar value for the two groups. Gilbert and Campbell (1980) studied FFS in three groups (4-6 years; 8-10 years; 16-25 years) of hearing-impaired individuals, and reported that the values were higher in the hearing - impaired groups when compared to values reported in the literature for normally hearing individuals of the same age and sex.

"The average Fo value of the utterances of the male hearing-impaired speakers was slightly lower than that of the normal hearing males for the first part of the utterance. The Fo valuss for the hearing and hearing-impaired males speakers overlapped for the last half of the utterance" (Osberger, 1981).

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

Several explanations have been offered to 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 into the articulators. He opined that since the tongue muscles are attached to the hyoid bone and the cricoid and thyroid cartilages, extra effort in their use would result in tension and change of position in the laryngeal structure. This would ultimately cause a change in pitch. Willeman and Lee (1971) hypothesized that the deaf speakers use extra vocal effort to give them an awareness of the onset and progress of voicing and this becomes the cause for the high pitch observed in their speech.

Fundamental Frequency Variation:

The speech of hearing-impaired individuals is characterized by the extremes of Fo variations, i.e. either:

a) Lack of variation of Fo, or

b) Excessive variation of Fo.

Several investigations have shown that the hearing-impaired speakers do produce pitch variations, 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.

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

Hearing-impaired speakers who tend to produce each syllable with equal duration may also generate a similar pitch contour (Monopitch) on each syllable (Nickerson, 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 (Martony, 1968).

Pitch problem vary considerably from speaker to speaker. While insufficient pitch variation has been noted as a problem for some speakers, excessive variations has been reported for others (Martony, 1968). Such variations are not simply normal variations that have been somewhat exaggerated but, rather, pitch breaks and erratic changes that do not serve the purpose of intonation. 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 loses all phonatory control and thereafter there is a complete cessation 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 four types of Fo contrues 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, occurring on 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 types of contours appeared to be an important characteristic separating the better from poorer hearing-impaired speaker.

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

Segmental Influence on Fo Control:

It is seen that some hearing-impaired 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 and 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 maneuvers 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 maneuver used by normal speakers in vowel production. Bush has postulated that because of the nonlinear nature of the stress strain relationship for vocal fold tissue, increase in vocal fold tension may be greater in magnitude when the tension on the vocal fold is already relatively high (as in the case with hearing-impaired) resulting in some what larger increases in Fo during the articulation of high vowels.

From the 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.

FORMANT FREQUENCY CHARACTERISTICS OF VOWELS:

The vowel production in an individual is influenced by vocal tract configuration. This modifies the spectrum of the vowels in the following ways:

1. Length - The frequency of all formants become low as the length of the vocal tract increases.

2. Lip rounding - Increased constriction of the labial port also lowers all formant frequencies.

3. Anterior oral constriction - Elevation of the front of the tongue lowers the first formant and raises the second formant.

4. Posterior oral constriction - Raising the posterior part of the tongue tends to lower the second formant.

5. Pharyngeal constriction - Narrowing the pharynx raises the frequency of the first formant.

6. Nasalization - The effects of coupling the nasal resonant space to the vocal tract are very complex. Not only are the resonant frequencies altered, but antiresonances are introduced. The overall result is highly variable.

Formant frequencies of vowels were studied in children by various researchers like Peterson and Barney (1952) Eguchi and Hirsh (1969). The formant frequencies especially the first (Fl) and second (F2) formants are traditionally used to provide an acoustic description of vowels. The higher formants other than Fl and F2 are of less importance to determine the phonetic quality of vowel sounds. For speech intelligibility second formant is more important as it lies within the most sensitive range of human hearing. Fl represents the tongue height. Fl increases and then decreases as the vowels go from /i/ to /u/. F2 decreases from /i/ to /u/ which represents the constriction of the tongue in the front-back plane.

Peterson and Barney (1952) evaluated a population of 33 men, 28 women and 15 children (ages unspecified) that had been studied earlier by Potter and Steinberg (1950). Each speaker did two readings of a list of 10 words: heed, hid, head, had, hod, hawed, who'd, hud, and heard. The data for children are depicted below:

	i	I	ɛ	æ	a	ɔ	ʊ	u	ʌ	ɝ
Fo	272	269	260	251	256	263	276	274	261	261
Fl	370	530	690	1010	1030	680	560	430	850	560
F2	3200	2730	2610	2320	1370	1060	1410	1170	1590	1820
F3	3730	3600	3570	3320	3170	3180	3310	3260	3360	2160

Angelocci et al., (1964) found vowel formants of Hearing Impaired adolescent between 11-14 yrs. He found that means of Formant frequency one (Fl) for deaf are higher than for normal - hearing for the vowels /i/, /I/, /æ/, /u/, /ʌ/, and /3/ and lower for the vowels /ɛ/, /a/, /ɔ/, and /ʊ/.

Potter et al., (1947) and Fairbanks et al., (1961) found that Fl rose in frequency as it progressed from /i/ to /a/, where it reached the maximum frequency, position, and then it lowered in frequency as it progressed from /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 Fl of /x/ for normal hearing subjects. The range of means for Fl for vowels of the normal hearing was 655 cps while that for the deaf was only 330 cps.

FORMANT TWO FREQUENCY:

Angelocci et al., (1964) revealed that F2 for deaf was lower than for the normal hearing for the front vowel /i/, /I/, /ɛ/ and /æ/; F2 for the deaf was higher than for the normal hearing for the back and neutral vowels /a/, /ɔ/, /u/, /ʊ/, and /3/. The range of F2 for the normal -hearing subjects for the vowels was 1715 cps, while the comparable figure for the deaf was 1148 cps.

FORMANT THREE FREQUENCY:

Angelocci et al., (1964) found that F3 for the deaf was higher than for the normal - hearing for all vowels except /i/, /u/, and /ʌ/. The position of F3 offered less information with respect to vowel differentiation than did Fl and F2. The normal hearing had a F2 of 3251 cps for /i/. This dropped 277 cps to /I/. Fairbanks et al., (961); Potter et al., (1947), have reported similar findings. In contrast F3 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 drops of only 8 cp3. Eguchi and Hirsh (1969) studied formant frequencies of vowels of children of both the sexes and age 3 to 13 and the mean formant frequencies of vowels produced by children of 5 to 10 years are tabulated:

Age	Fl	F2	Fl	F2	Fl	F2	Fl	F2	Fl	F2
5	408	3235	642	2418	643	2423	01	1530	452	1477
6	397	3108	512	2281	611	2238	689	1308	431	1385
7	411	3204	664	2280	736	2299	870	1398	481	1525
8	397	3104	585	2195	685	2222	743	1359	450	1437
9	403	3106	308	2296	647	2295	836	1352	469	1392
10	403	3028	645	2193	735	2255	814	1336	469	1351

Levitt (1976) from a study of the acoustic and perceptual characteristics of speech of the deaf children concluded that the formant frequency values were typical of the schwa vowel.

Sheela (1988) studied four congenital deaf children of 8-10 years. She found that the hearing impaired had higher Fl and F2 and low F3 value than those of normal group. The hearing impaired group showed higher variability than normals.

VOICE ONSET TIME (VOT):

VOT is defined as the time equivalent of the space from the onset of stop release burst to the first vertical striation representing glottal pulsing (Liberman, Delattre and Cooper, 1952, Lisker and Abramsobn, 1964, 1967). The release of the oral occlusion relative to the onset of glottal pushing is termed the VOT that consonant and it helps in achieving voice-voiceless distinction (Lisker and Abramson, 1964).

Voiced plosives in English have a short VOT (less than 20-30 msec). Than Voiceless plosives, on the other hand due to greater intraoral breath pressure resulting in the increase of airflow rate causing friction at the glottis thus preventing the vibration of the vocal folds will have VOTs larger than 50 msec. Thus the measurement of VOT in voiced and voiceless stop consonants provides an index of the ability to co-oridnate laryngeal and oral articulatory movements, the accuracy of articulatory movements the distinctiveness of phonemes, transition of articulatory postures, neuromuscular co-ordination (Till and Strivers, 1991).

Increase in VOT is noted when the place of articulation moves backward in the oral cavity as in English, (Lisker and Abramson, 1964); in French (O' Shaughnessy, 1981); in Japanese (Homma, 1981") and in Kannada (Basu, 1979; Shukla, 1987; and Ravi Shankar, 1981).

VOT values either overlapped or VOT was found to be longer for voiceless stops than voiced stops. VOT measurements for /k/, /g/ were found to be more complex than that of /p/, /b/ and /t/ and /d/ implying that the subjects did not distinguish VOT among stops based on place of articulation. More segments were produce das voiced ones by the hearing impaired. Those who had clear demarcation of the voiced-voiceless categories tended to have high speech intelligibility. The developmental aspect of VOT as stated by Ohde (1985) may not be foreseen. In English speaking child's first production of stop consonants generally represent a single category centered on short VOT values but by age 6, a bimodal distribution of VOT values emerges. The variability of VOT values for voiced and voiceless stops are still greater in 6 year olds than in adults. But by 8 years variability in the production of VOT appears to reach an adult like minimum.

In Kannada, there have been studies on VOT of normals by Ravishankar (1981); Kushal Raj and Nataraja (1984). The results are stated as follows: There was no significant difference in the VOT values with the increase in age. There was no significant difference between males and females of the same age group. VOT values were found significant for 4-5 years aged children.

For Males:

	/P/		/t/		/k/	
	R.S.	NPN	RS	NPN	RS	NPN
4-5	18.4	18.9	22.4	35	41	28.07
5-6	18	13.77	18.4	26.1	42.4	20.93
7-8	18.4	15.66	17.4	23.21	38.6	19.43
9-10	16.00	15.90	23.00	23.80	40.00	21.30

Savithri and Sridevi (1990) unpublished research on VOT in normal children of 5-8 years have been displayed below:

Words	I Child VOT Lead	I Child VOT Lag	II Child VOT Lead	II Child VOT Lag	III Child VOT Lead	III Child VOT Lag	IV Child VOT Lead	IV Child VOT Lag
upa /p/	0	0	0	0	0	0	0	8
Ati /t/	0	10	0	0	0	0	0	0
iike /k/	0	12	0	19	0	0***	0	0
aake /k/	0	0	0	0	0	0	0	23
uba /b/	91	on	109	on	89	on	83	on
eedi /d/	63	on	29	on	30	on	67	0
adu /d/	84	on	72	0	71	on	83	on
aga /g/	76	18	105	0	106	0	87	on
iiga /g/	64* (45)	0	51	on	92* (61)	0	63* (49)	8

* Cessation of Voicing;
*** Tiple/Multiple Burst
( ) Voicing Duration within the Closure Period

Monsen (1976b) by measuring VOT spectrographically for 36 profoundly hearing impaired children on word initial stops (/P/, /t/, A/) and (/b/, /d/, /g/) revealed the following: Some of the children distinguished the cognates in the normal manner. VOT values are longer for the voiceless than voiced segments and VOT contrasts were longer for velars than for alveolars and bilabials. However most of the hearing impaired speakers did not observe the voiced voiceless distinction and deviated from normal speakers in a similar way.

Leeper et al (1987) studied 9 hearing impaired subjects with the mean age of 10 years 11 months and found that there was no significant difference in VOT for hearing impaired normal hearing children as a prerequisites startegy for evaluating the length of an upcoming utterance.

Shukla (1987) studied VOT in hearing impaired adults and concluded that both the hearing and hearing impaired speakers had positive VOT values for voiceless stops. But VOT for the hearing impaired speakers showed negative VOT values for voiced stops, while in a majority of hearing impaired speakers negative VOTs were absent. Mean VOT values produced by both the groups increased as the place of articulation moved backward in the oral cavity. But no study was available to the investigator in terms of VOT of hearing impaired children in Kannada.

VELAR CONTROL:

Improper control of velum has long been recognized as a source of difficulty in the speech of the deaf (Beehm, 1922, Hudgin, 1934). Miller (1968) had speculated that the type of hearing loss may be a causative factor in some nasalization problems. Hyponasality, may be more prevalent among people with conductive loss than those with sensori-neural loss because nasal sounds may appear excessively loud due to the transmitability of nasal reassurance 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.

Learning velar control is difficult for a hearing-impaired child because:

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

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

Improper velar control is difficult to judge subjectively, in part because the distinctive perceptual features of nasalization have not been clearly defined and in part because the perception of nasality may be affected by factors in addition to the activity of the velum. Some researchers have suggested that such factors as misarticulation, pitch variation and speech tempo affect the proper judgement (Colton and Cooper, 1988).

For these reasons, objective measures that correlate with the velar activity are put forward. Acoustic properties of nasal sounds that have been investigated include shifted and split first formant (Fujimura, 1960; House, 1961) and enhanced amplitude of the lower harmonics (Delattre, 1955). Attempts to detect nasalization directly have included the measurement of acoustic energy radiated from the nostrils (Gletcher, 1970; Shelton and Elbert, 1967) and measurement of the vibration on the surface of the nose (Crowford, 1970; Sevens, Valikow and Willemain, 1974).

Thus it is seen that the speech of the hearing impaired is charecterized by several errors, which make it highly unintelligible. While several investigators have attempted to determine the contributions of the various errors to the poor speech intelligibilily, it is through modern speech analysis and synthesis techniques that the researchers have found it possible to finely control the many variables in speech. The present study is aimed at analysing the speech of the hearing impaired Punjabi speakers, to see how it varies from that of the normal in segmental aspects.

METHODOLOGY

The main objectives of this study was to find out the difference in the speech of Punjabi speaking normal and hearing impaired children who were using hearing aid and undergoing speech therapy.

I. PARAMETERS STUDIED:

The following parameters have been studied:

1) Vowel duration of /a/, /a:/, /i/, /i:/, /u/, /u:/, /e/, /e:/, /o/, /o:/.
2) Word duration
3) Fundamental frequency (Fo)
4) Voice onset time of stop consonants /p, /b/, /t/, /d/, /k/, /g/.
5) Formant frequencies (Fl, F2, F3) of vowels /a/, /a:/, /i/, /i:/, /u/, /u:/, /e/, /e:/, /o/, *[/o:/.]*
6) Bandwidth (Bl, B2, B3).
7) Duration of pauses (intraword if any)

II. SUBJECTS:

Ten normal hearing and ten hearing impaired Punjabi speakers between 8-12 years were selected for the study. The hearing impaired subjects were selected from among the children who were attending special school in Chandigarh. They satisfied the following conditions.

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

2. Had no other problem or deviations other than that directly related to the hearing impairment.

3. Were able to read simple monosyllabic words (CVC) in Punjabi. Theses were examined by qualified speech and hearing specialists and confirmed the hearing loss and found speech and language to be deviant.

Five males and five males with normal hearing were selected to match each hearing-impaired subject in terms of age and sex. The subects were examine dby a qualified speech and hearing specialists and considered these children as normal interms of speech, langauge and hearing.

Table showing age and hearing thresholds for the subjects of control group.

a) Normal hearing group:

	Male		Female	
Sl. No.	Age	Audiological screening at 500Hz 1kHz, 2kHz)	Age	Audiological screening at 500Hz 1kHz, 2kHz)
1.	8.8 Years	Normal Limits	8.8 Years	Normal Limits
2.	9.6 Years	Normal Limits	9.2 Years	Normal Limits
3.	9.3 Years	Normal Limits	10.5 Years	Normal Limits
4.	10.5 Years	Normal Limits	19.8 Years	Normal Limits
5.	11.8 Years	Normal Limits	11.5 Years	Normal Limits

Mean age of boy's group was 50/5 = 10 yrs.

Mean age of girl's group was 50.8/5 = 10.16 yrs.

Table showing age and hearing the thresholds for the subjects of Experimental group,

b) Hearing Impaired Group:

	Male			Female		
Sl. No.	Age	Right (dB)	Left (dB)	Age	Right (dB)	Left (dB)
1.	8.6 Years	100	105	8.7 Years	110	110
2.	10.5 Years	107	110	9.6 Years	99	105
3.	11.6 Years	90	98	10.3 Years	86	98
4.	9.8 Years	88	95	10.7 Years	108	115
5.	9.5 Years	110	100	11.5 Years	115	105

Mean age of boy's group was 50/5 = 10 yrs.

Mean age girl's group was 50.8/5 = 10.16 yrs.

III. **MATERIAL**:

To elicit the speech, commonly spoken monosyllabic Punjabi words (CVC) were selected as test material. These ten words were simple so that both normal and hearing impaired childrencould read them.

The target sounds and vowels that were used for acoustic analysis are presented below as they occurred in words.

SL.NO.	WORD	CONSONANT	VOWEL
1.	/Kal/	/k/	/a/
2.	/pa:p/	/P/	/a:/
3.	/dig/	/d/	/i/
4.	/bi:d3/	/b/	/i:/
5.	/dul/	/d/	/u/
6.	/bu:t/	/b/	/u:/
7.	/tek/	/t/	/e/
8.	/pe:r/	/P/	/e:/
9.	/gol/	/g/	/o/
10.	/ko:n/	/k/	/o:/

IV. DATA COLLECTION:

The recordings were made in a quiet room of the school building. Subjects were comfortably seated and recordings were made with the portable tape recorder (Panasonic, Model RQ-A170). Each subject was asked to read the list of ten

Punjabi words in front of unidirectional microphone which was placed at about six inches away from subjects mouth.

V. **INSTRUCTIONS**:

The children were asked to read in Punjabi with the carrier phrase /eh/ meaning THIS.

The subjects were given an opportunity to be familiar with the list.

The subjects were made to repeat after the experimenter, whenever they had difficulty in reading particular words.

VI. INSTRUMENTATION:

Analysis principally involved the following instruments:

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

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

3) Personal computer with Intel Pentium 200 MHz processor.

4) Software for analysis of speech (developed by voice speech system, Bangalore).

5) Amplifier and speaker (2011 SOIS Ampli speaker).

VII. ANALYSIS OF THE DATA:

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

1. WORD DURATION:

Word duration: is the time between initiation and termination of a word, was measured directly from the speech waveform. The waveform was displayed on the computer monitor using the "DISPLAY" programme of SSL. The words were identified based upon the continuity of the waveform. The word duration was considered to extend from the beginning of the periodic signal to the end of the periodic signals. This duration was high lighted through the use of cursors. The highlighted portion was played back through headphones, to confirm that it contained the word under study. Once this was confirmed, the duration of the highlighted portion was read from the display and considered as the duration of that particular word.

2. VOWEL DURATION:

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

3. EXTRACTION OF FORMANT OF FREQUENCIES:

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

4. BAND WIDTH:

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

5. VOICE ONSET TIME (VOT):

VOT was defined as the time equivalent space from the onset of the stop release burst to the first vertical striation representing glottal pulsing (Liberman, Delattre, and Cooper, 1952; Lisker and Abramson, 1964, 1967), VOT was measured for the six stop consonants in the target word from the spectrograms. The cursor was moved to the first indication of energy associated with the stop oral release and the cursor was moved to the beginning of the regularly appearing waveform of the vowel following that stop. The real time value (in msec) between these two markings provided the VOT for particular consonant.

6. PAUSE DURATION:

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

7. DETERMINING THE FUNDAMENTAL FREQUENCY:

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

Thus the following parameters:

1) WORD DURATION 2) VOWEL DURATION 3) FORMANT FREQUENCY

5) VOT 7) FUNDAMENTAL FREQUENCY

were measured for 10 words uttered by each normal and hearing impaired subject. So a total of 126 Data points for hearing impaired and 126 for ormals were obtained.

VIII. STATISTICAL ANALYSIS:

Descriptive statistics consisting of mean, standard divation, minimum and maximum values, were obtained for all the parameters analyzed. To check whether there were any significant differences between the values of the normal hearing group and hearing impaired group, the Wilcoxen signed Ranks test and applied. All the statistical analyses were carried using the statistical software package "SPSS"

RESULTS

Aim of the present study was to investigate the acoustic characteristics of the speech of Punjabi speaking hearing impaired children.

ACOUSTIC ANALYSIS:

Ten VCV words uttered by ten hearing impaired and ten normal speakers were taken for acoustic analysis to obtain the following acoustic parameters.

1. **Vowel duration**
2. **Word duration**
3. **Average fundamental frequency**
4. **Voice onset time (VOT) of stop consonants**
5. **Formant frequencies (F1, F2, F3)**
6. **Pause duration**
7. **Band widths (B1, B2, B3)**

Descriptive and Inferential statistical analysis were carried out. The mean, standard deviation, and range, values were calculated for all the parameters.

1. VOWEL DURATION:

Table-1 and Graph-1 -show the mean, SD and range respectively for all the subjects.

The hearing impaired subjects had mean vowel duration longer for both short and long vowels than that of the control group.

As Shown in Table l(a): In the normal group, it was seen that all the females had longer vowed durations than males.

Among females the vowel /i:/ had the longest duration (257.2 msec) followed by /o:/ (239.6msec), /o/ (220.6 msec), /e:/ (214.8 msec, /u:/ (207.2 msec), /a:/ (205.2 msec), /i/ (203 msec), /u/(193 msec), /e/ (164 msec), and /a/ (130 msec).

So the girls had the vowel duration in the following decreasing order i:>o:>o>e:>u:>a:>i:>u>e>a.

In normal group of males, the vowel /0:/ had longest duration (223.4msec) followed by /a:/ (210.8msec), /i:/ (195.4msec), /o/ (190.8 msec), /e:/ (182.6 msec), /i/ (180.6msec), /u:/ (179msec), /e/ (176msec), /u/ (158.6msec) and /a/ (108 msec).

In both normal groups vowel /a/ had shortest duration. So males had the vowel duration in the following decreasing order. o:>a:>i:>o>e:>i>u:>e>u>a.

Hearing impaired group did not follow the same pattern as that of control group. Significant differences between normal and hearing impaired in the mean values of all vowel durations were seen.

Hearing impaired males and females more or less followed the same pattern in terms of vowel duration. Hearing impaired

Table l(a) The mean, S.D values of vowel duration in hearing impaired and normal group female in (Msec)

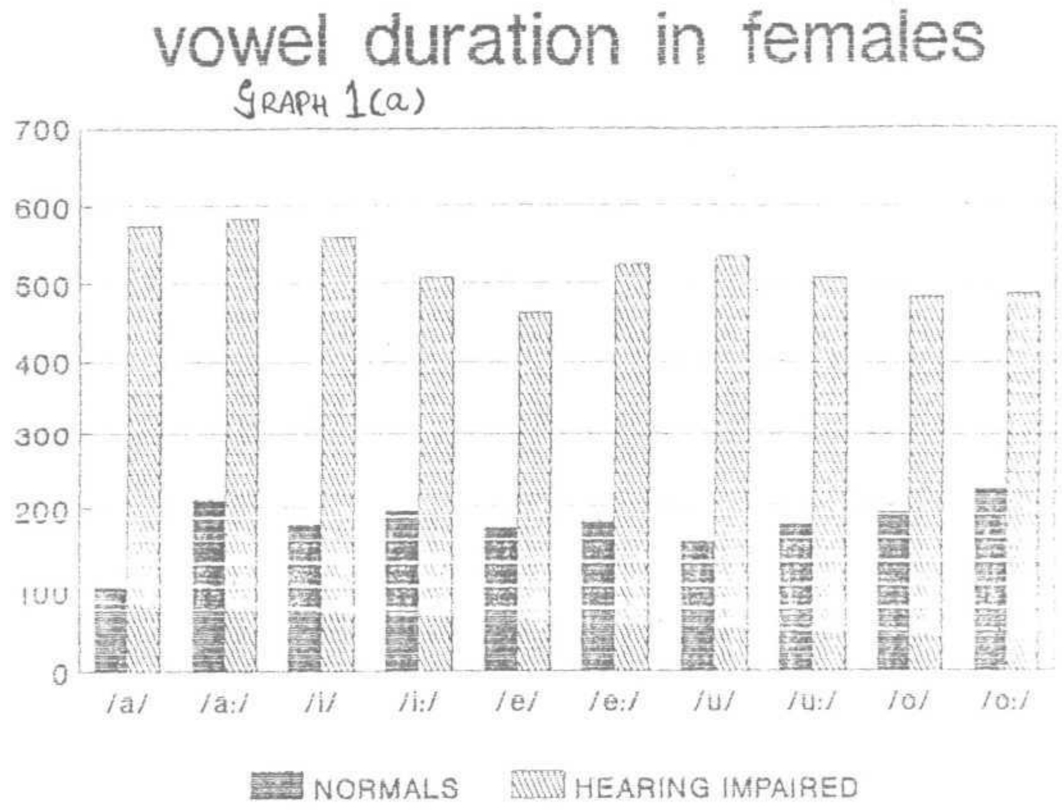
	NORMAL FEMALES		HEARING IMPAIRED FEMALES	
VOWEL	M(msec)	S.D	M(msec)	S.D
/a/	130	33.7	525.2	151.20
/a:/	205.2	36.77	552.2	231.07
/i/	203	32.12	612.6	111.05
/i:/	257.2	46.67	569.6	133.85
/e/	164.0	49.92	522.8	165.92
/e:/	214.8	43.83	502.6	264.00
/u/	193.0	33.22	565.8	210.83
/u:/	207.2	29.02	518.6	108.57
/o/	220.6	45.64	569.0	114.62
/o:/	239.6	47.0	665.4	76.78

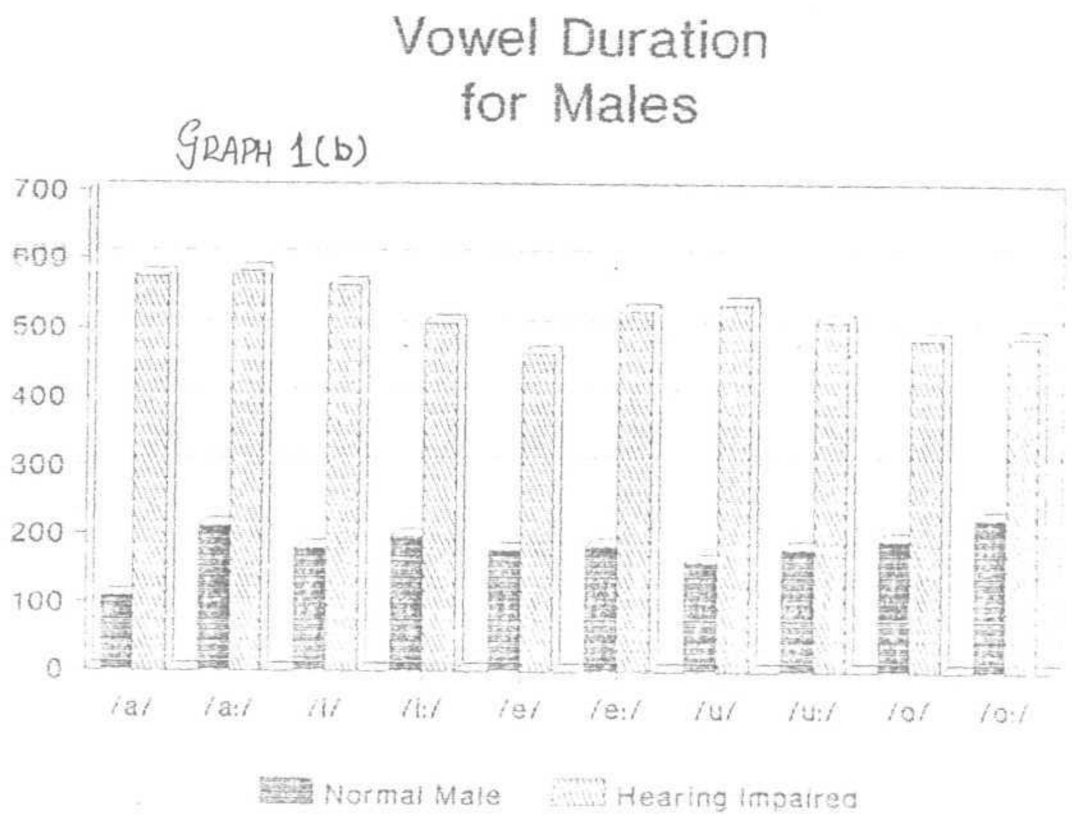
* Signifiant difference between means at p-0.05 level.

Table l(b) The mean, S.D values of vowel duration in hearing impaired and normal group male in (Msec)

	NORMAL MALES		HEARING IMPAIRED MALES	
VOWEL	M(msec)	S.D	M(msec)	S.D
/a/	108.0	48.2	574.0	162.30
/a:/	210.8	40.08	582.2	109.84
/i/	180.4	25.11	561.2	153.36
/i:/	195.4	17.19	507.4	84.27
/e/	176.0	25.08	463.6	63.30
/e:/	182.6	40.96	524.0	135.80
	158.6	22.9	534.0	147.00
/u:/	179.0	32.0	508.6	68.86
/o/	190.8	46.38	483.8	89.76
/o:/	223.4	61.99	488.2	105.42

* Signifiant difference betveen means at p-0.05 level.


vowel duration in females
Graph 1(a)
700
600
500
400
300
200
100
0
/a/
/a:/
/i/
/i:/
/e/
/e:/
/u/
/u:/
/o/
/o:/
NORMALS
HEARING IMPAIRED


Vowel Duration
for Males
Graph 1(b)
700
600
500
400
300
200
100
0
/a/
/a:/
/i/
/i:/
/e/
/e:/
/u/
/u:/
/o/
/o:/
Normal Male
Hearing Impaired

group did not show any significant differences in mean values of 3hort and long vowels.

Among hearing impaired females, vowel */o:/* had longest duration (665.4 msec) followed by /i/ (612.6 msec), /i:/ (569.6 msec), /o/ (569 msec) /u/ (565.8 msec), /a:/ (552.2 msec), /a/ (525.2 msec), /e/ (522.8 msec), /u:/ (518.6 msec) and /e:/ (502.6 msec). So females had the vowel duration as in the decreasing order: o:> i>i: >o> u>a:>a>e>u:>e: .

Among the hearing impaired males vowel /a:/ had longest duration (582.2 msec) followed by /a/ (574 msec), /i/ (561.2 msec), /u/ (534 msec), /e:/ (524 msec), /u:/ (508.6 msec), /i:/ (507.4 msec), /o:/ (488.2 msec), /o/ (483.8 msec) and, /e/ (463.6 msec). So male hearing impaired had vowel durations in the following decreasing order: a:> a:>i >u> e:> u:>i:>o:>o>e.

Wilcoxin signed rank test performed showed a significant-difference between the (i) hearing impaired males normal males (ii) hearing impaired females normal females at <0.05 level of significance, both males and females of hearing impaired group showing longer durations than the males and females of normal group.

Wilcoxin signed rank test performed showed no significant difference between the (i) Hearing impaired males and hearing impaired females and (ii) Normal males and normal females at >0.05 level of significance.

Thus the hypothesis (1b) stating that there is no significant difference between the vowel duration values of the hearing impaired and normal subjects is rejected, both in case of males and females.

The hypothesis (2) stating that there is no significant difference between males and females has been accepted in respect of hearing impaire dgroup, and it is also accepted in case of normal group.

2. WORD DURATION:

The words spoken by the hearing impaired subjects had longer durations in general when compared to the normal hearing group.

Table - 2(a) and 2(b) show the mean, S.D. and range of this parameter for both the groups.

Among normal hearing group, there were no significant differences in word duration of male and female subjects. Word /kal/ had shortest duration in both males and females.

As shown in table 2(b): In normal hearing males word /pe:r/ had longest duration (600.6 msec) followed by /bu:t/ (578.0 msec), /bi:d3/ (559.4 msec), /pa:p/ (546 msec), /ko:h/ (537.6 msec), /gol/ (531.8 msec), /tek/ (503 msec), /dul/ (446 msec) and, /kal/ (422.4 msec).

As shown in table 2(a): In normal hearing females word /bi:d_3/ had longest duration of 609.0 msec followed by /ko:n/

(543.8 msec), /gol/ (538.4 msec), /pe:r/ (527 msec), /bu:ṭ/ (523.6), /pa:p/ (523.4 msec), /dig/ (500 msec), /dul/ (480 msec), /tek/ (455.8 msec) and, /kal/ (434 msec).

As shown in table 2(b): Among hearing impaired males word /pe:r/ had longest duration of 1416.6 msec followed by /dig/ (1274.6 msec), /ko:n/ (1268.8 msec), /dul/ (1254 msec), /bu:ṭ/ (1247.8 msec), /tek/ (1247.2 msec), /pa:p/ (1244 msec), /gol/ (1192 msec), /bi:d_3/ (1124.4 msec), /kal/ (1036 msec).

As shown in table 2(a): Among hearing impaired females, word /gol/ had longest duration of 1316.8 msec followed by /bi:d.3/ (1252.8 msec), /dig/ (1219.4 msec) /ko:n/ (1207 msec), /dul/ (1206.2 msec), /pa:p/ (1143.4 msec), /bu:ṭ/ (1102.8 msec), /pe:r/ (1089.6 msec) and, /kal/ (1020 msec).

The hearing-impaired group had greater variations than that of the normal hearing group.

The minimum value labels for the words ranged from 331-485 msec and the maximum ranged from 620-715 msec for normal hearing group. In case of hearing-impaired the minimum values ranged from 415-825 msec and maximum value from 680-1980 msec.

Wilcoxin signed rank test performed showed significant differences between the

a) Normal hearing males and hearing impaired males

Table 2(a) The mean, S.D values of word duration in hearing impaired and normal group female in (Msec)

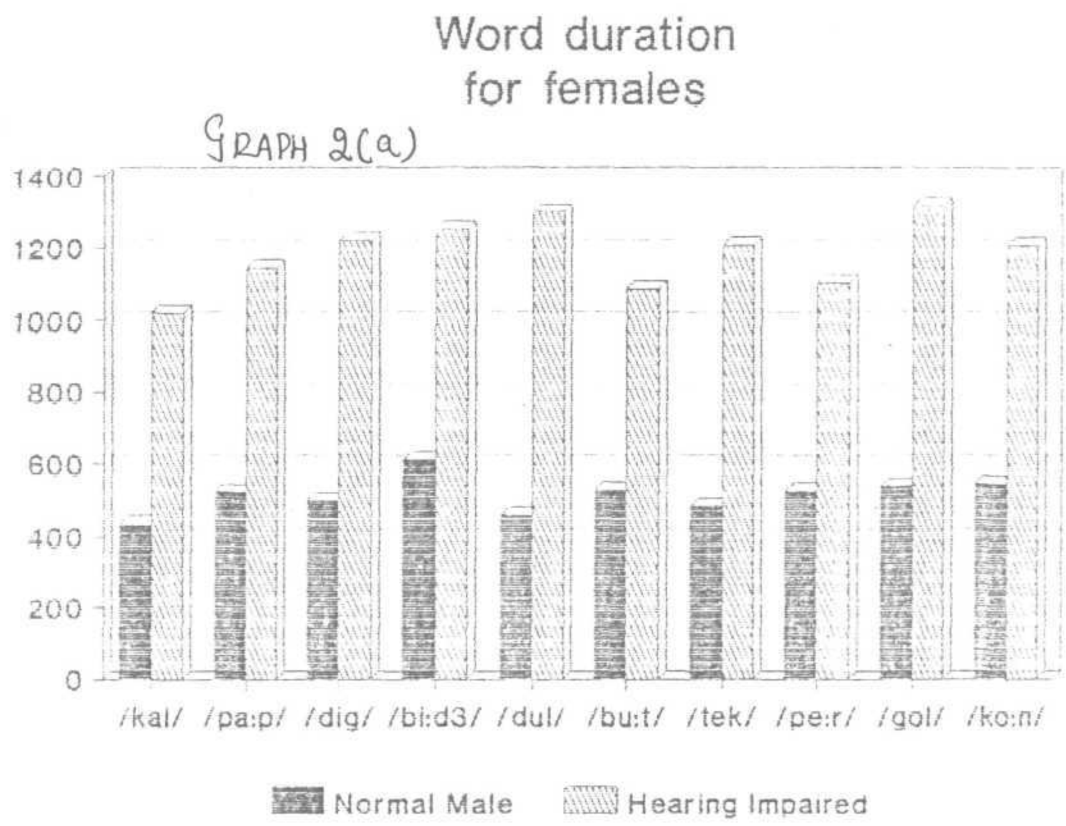
	NORMAL FEMALES		HEARING IMPAIRED FEMALES	
WORD	M(msec)	S.D	M(msec)	S.D
/kal/	434	88.08	1020.4	270.50
/pa:p/	523.4	103.17	1143.4	354.61
/dig/	500	54.49	1219.4	312.55
/bi:d3/	609.0	53.19	1252.8	334.04
/dul/	455.8	108.0	1301.6	393.59
/bu:t/	527	73.25	1089.40	411.19
/tek/	480.0	77.25	1206.2	180.014
/pe:r/	523.6	55.91	1102.8	238.5
/gol/	538.4	89.34	1316.8	267.95
/ko:n/	543.8	133.92	1207	286.49

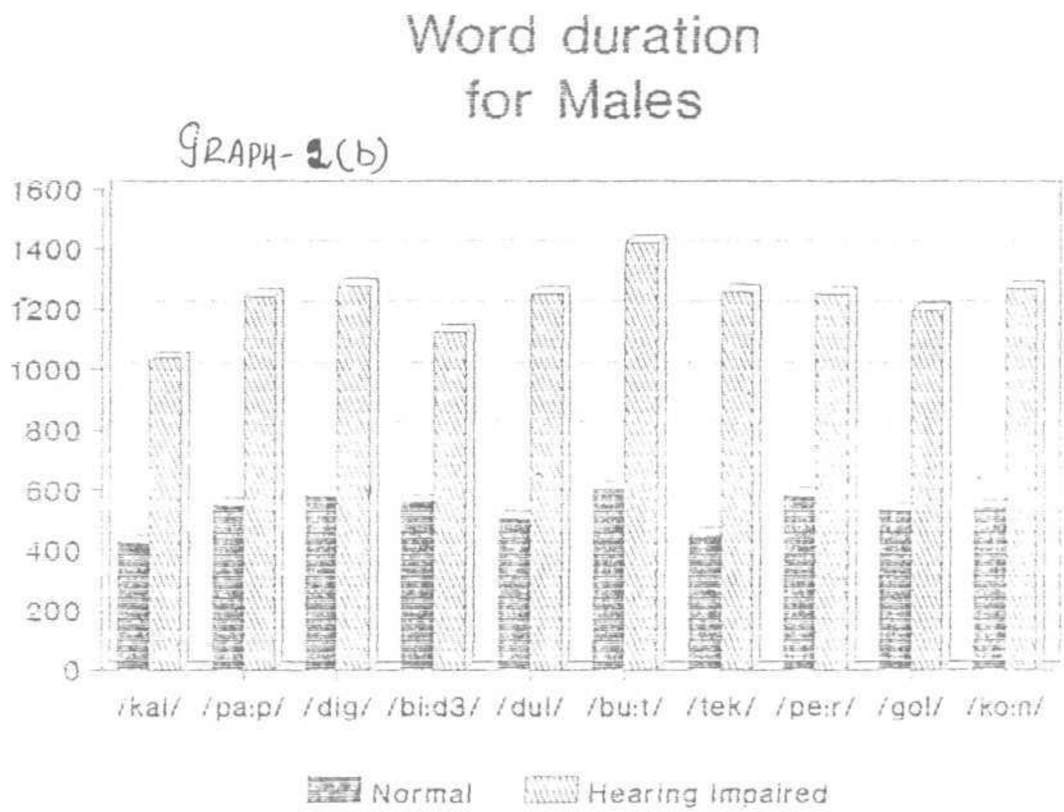
* Signifiant difference between means at p-0.05 level.

Table 2(b) The mean, S.D values of word duration in hearing impaired and normal group male in (Msec)

	NORMAL MALES		HEARING IMPAIRED MALES	
WORD	M(msec)	S.D	M(msec)	S.D
/kal/	422.4	56.11	1036.0	277.61
/pa:p/	546.0	52.84	1244.0	213.6
/dig/	578.0	73.95	1274.6	332.6
/bi:d3/	559.4	84.30	1124.4	226.0
/dul/	503.0	26.44	1247.2	242.2
/bu:t/	600.6	66.49	1416.6	107.8
/tek/	446.0	55.67	1254.0	243.1
/pe:r/	578.0	28.67	1247.8	122.9
/gol/	531.8	46.38	1192.0	275.92
/ko:n/	537.6	53.05	1268.8	223.0

* Signifiant difference between means at P-0.05 level.


Word duration
for females
GRAPH 2(a)
1400
1200
1000
800
600
400
200
0
/kal/ /pa:p/ /dig/ /bi:d3/ /dul/ /bu:t/ /tek/ /pe:r/ /gol/ /ko:n/
Normal Male
Hearing Impaired


Word duration
for Males
GRAPH- 2(b)
1600
1400
1200
1000
800
600
400
200
0
/kal/ /pa:p/ /dig/ /bi:d3/ /dul/ /bu:t/ /tek/ /pe:r/ /gol/ /ko:n/
Normal
Hearing Impaired

b) Normal hearing females and hearing impaired females, at $p < 0.05$ level of significance, the subjects of hearing impaired showing longer durations than subjects of normal group.

further Wilcoxin signed rank test showed no significant difference between.

1) Normal hearing males and normal hearing females
2) Hearing imapaired males and hearing impaired females.

Thus the hypothesis (la) stating that there is no significant difference in the utterances of subjects with normal hearing and hearing impaired subjects in terms of word duration is rejected and hypothesis (2) stating that there is no significant difference between males and females has been in respect of hearing impaired group, and it is also accepted in case of normal group.

MEAN FUNDAMENTAL FREQUENCY:

In general the hearing-impaired subjects had higher mean fundamental frequency (F0) than that of the normal hearing subjects.

Table 3(a) and 3(b): Show the mean, S.D. and range of fundamental frequency of normal and hearing impaired subjects.

Among normal hearing subjects, it was seen that females had higher mean FO than males in all their utterances.

A shown in Table 3(b), among normal males word /pa:p/ had highest mean FO of 252.80 hz followed by /tek/ (250.6 Hz), /pe:r/ (232.21 Hz), /bi:dz/ (230.80 Hz), /dig/ (299.4 Hz), /kal/ (221 Hz), /dul/ (210.75 Hz), /gol/ (204.06 Hz), /bu:t/ (198.24 Hz) and /ko:n/ (190.78 Hz).

As show in the Table 3(a): Among normal hearing females, highest mean F0 was also found in word /pa:p/ (264.8 hz) followed by /dul/ (262.11 Hz), /bi:dz/ (260.3 Hz), /pe:r/ (256.49 Hz), /tek/ (256.2 Hz), /kal/ (255.60 Hz), /dig/ (249.2 Hz), /ko:n/ (226.79 Hz) and /gol/ (214.68 Hz) and /bu:t/ (208.54 Hz).

In case of hearing impaired group, no significant difference in mean F0 was seen among females and males.

As shown in Table 3(b): Among hearing-impaired males, highest mean F0 was found in word /dul/ (404.61 Hz) followed by /gol/ (384.81 Hz), /ko:n/ (374.70 Hz), /pe:r/ (352.23 Hz), /birds/ (312.70 Hz), /dig/ (307.90 Hz), /kal/ (298.60 Hz), /bu:t/ (295.60 hz), /pa:p/ (293.8 hz) and /tek/ (281 Hz).

As shown in Table 3(a): In case of hearing impaired females word /gol/ had highest mean F0 of 409.16 Hz followed by /pa:p/ (399.8 Hz), /pe:r/ (377.69 Hz), /bu:t/ (337.74 Hz), /dul/ (335.90 Hz), /ko:n/ (319.95 Hz), /kal/ (306.30 Hz), /bi:dz) (292.5 Hz), /tek/ (290 Hz) and /dig/ (287.6 Hz).

Table 3(a) The mean, S.D values of FO in hearing impaired and normal group female group-(Hz).

	NORMAL FEMALES		HEARING IMPAIRED FEMALES	
WORD	M (S.D.)	RANGE	M (S.D.)	RANGE
/kal/	255.6(5.85)	10.00	306.3(184.42)	35.778
/pa:p/	264.8(5.54)	12.01	399.8(178.10)	40.18
/dig/	249.2(6.07)	8.89	287.6(145.0)	38.08
/bi:d3/	260.3(11.86)	15.78	292.5(123.41)	42.78
/dul/	256.21(7.55)	14.06	290.0(98.0)	28.78
/bu:t/	256.49(18.78)	15.08	377.69(145.1)	34.08
/tek/	262.11(25.1)	20.14	335.90(241.31)	31.46
/pe:r/	208.54(31.6)	21.78	337.74(218.74)	50.78
/gol/	214.68(21.78)	11.80	409.16(148.78)	49.16
/ko:n/	226.79(20.78)	10.81	319.95(178.71)	50.18

* Signifiant difference between means at p-0.05 level.

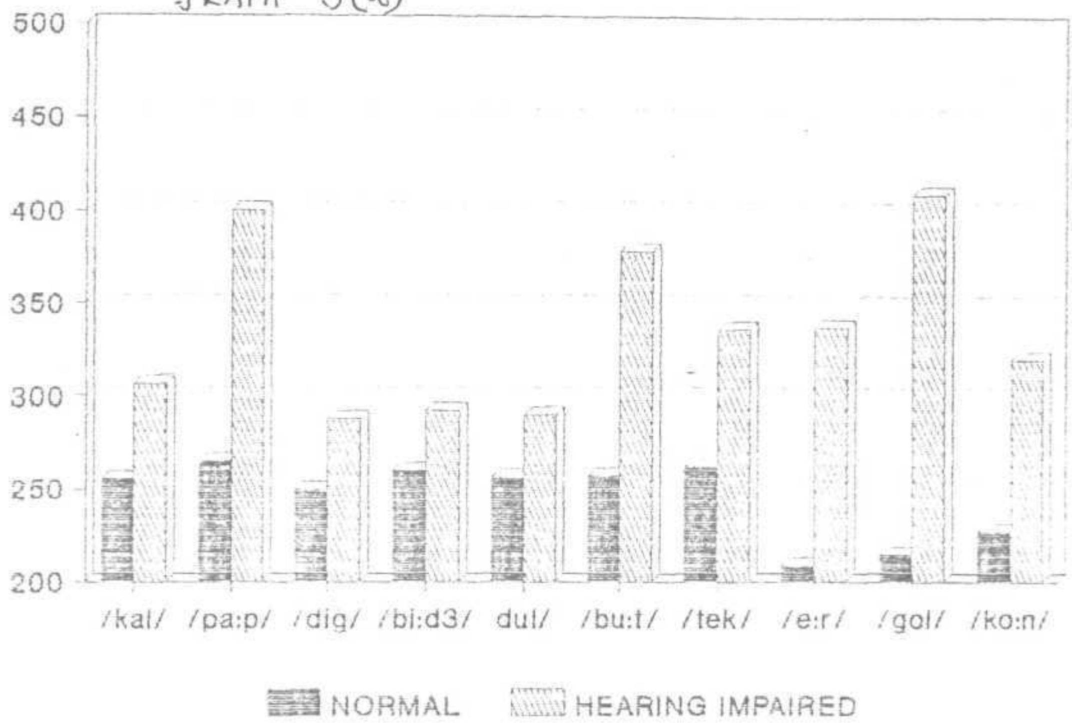
Table 3(b) The mean, S.D and range values of F0 in hearing impaired and normal hearing male group (Hz).

	NORMAL MALES		HEARING IMPAIRED MALES	
WORD	M (S.D.)	RANGE	M (S.D.)	RANGE
/kal/	221.0(11.53)	8.78	298.6(167.43)	34.78
/pa:p/	252.80(16.82)	10.80	293.8(189.08)	30.48
/dig/	229.4(12.94)	12.45	307.90(118.7.8)	28.56
/bi:d3/	230.8(13.77)	9.08	312.7(156.79)	25.64
/dul/	250.6(6.51)	7.15	281.0(185.70)	40.15
/bu:t/	232.21(20.80)	15.78	352.23(130.82)	34.08
/tek/	210.75(16.98)	21.01	404.61(139.81)	38.78
/pe:r/	198.24(15.74)	13.45	295.6(74.81)	39.68
/gol/	204.24(15.74)	10.40	384.81(231.93)	41.78
/ko:n/	190.78(18.75)	12.46	374.70(218.28)	45.08

* Signifiant difference between means at p-0.05 level.

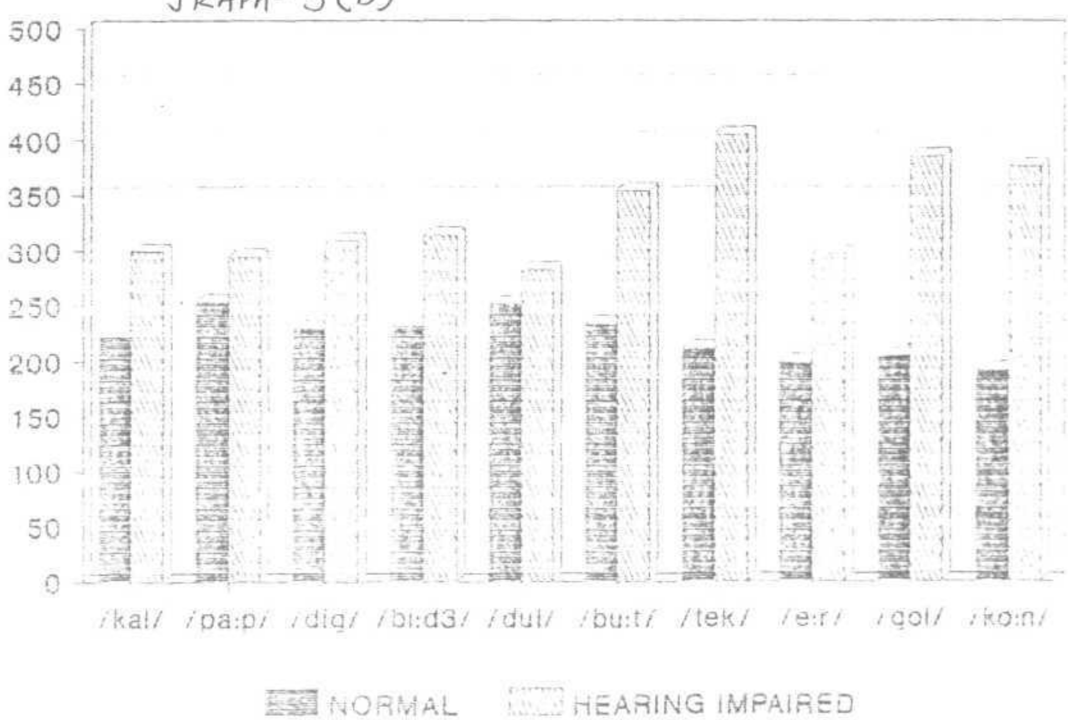
F0 for females

GRAPH- 3(a)



F0 in males

GRAPH- 3(b)



The minimum value among normals ranged from 170.80 Hz - 215 Hz and maximum from 259 - 290 Hz. The minimum values among hearing impairedd ranged from 186.78 - 380 Hz and the maximum values ranged from 398 -589 Hz. So variations in range as reflected the standard deviation were seen more in hearing impaired group than in normal hearing group.

Wilcoxin signed rank test indicated significant difference between the groups: i.e.,

1) Hearing impaired males were significantly different from normal hearing males.

2) Hearing impaired females were significantly different from normal hearing females.

at $p < 0.05$ level of significance.

Wilcoxin signed rank test showed no significant difference between the males and females of both the groups. i.e.;

1) Hearing impaired males did not differ from hearing impaired females.

2) Normal hearing males did not differ from normal hearing females.

at $p > 0.05$ level of significance.

The hypothesis (lc) stating that there is no significant difference in hearing impaired subjects and normal hearing subjects in terms of mean F0 is rejected. Where as hypothesis

(2) stating that there is no significant difference between males and females has been in respect of hearing impaired group, and it is also accepted in case of normal group.

VOICE ONSET TIME:

Mean VOT values for normally hearing and hearing-impaired speakers were obtained for /p/, /t/, /k/ and /b/, /d/, /g/ stop consonants in the prevocalic contexts.

The means and standard deviations are presented in tables 4(a) and 4(b).

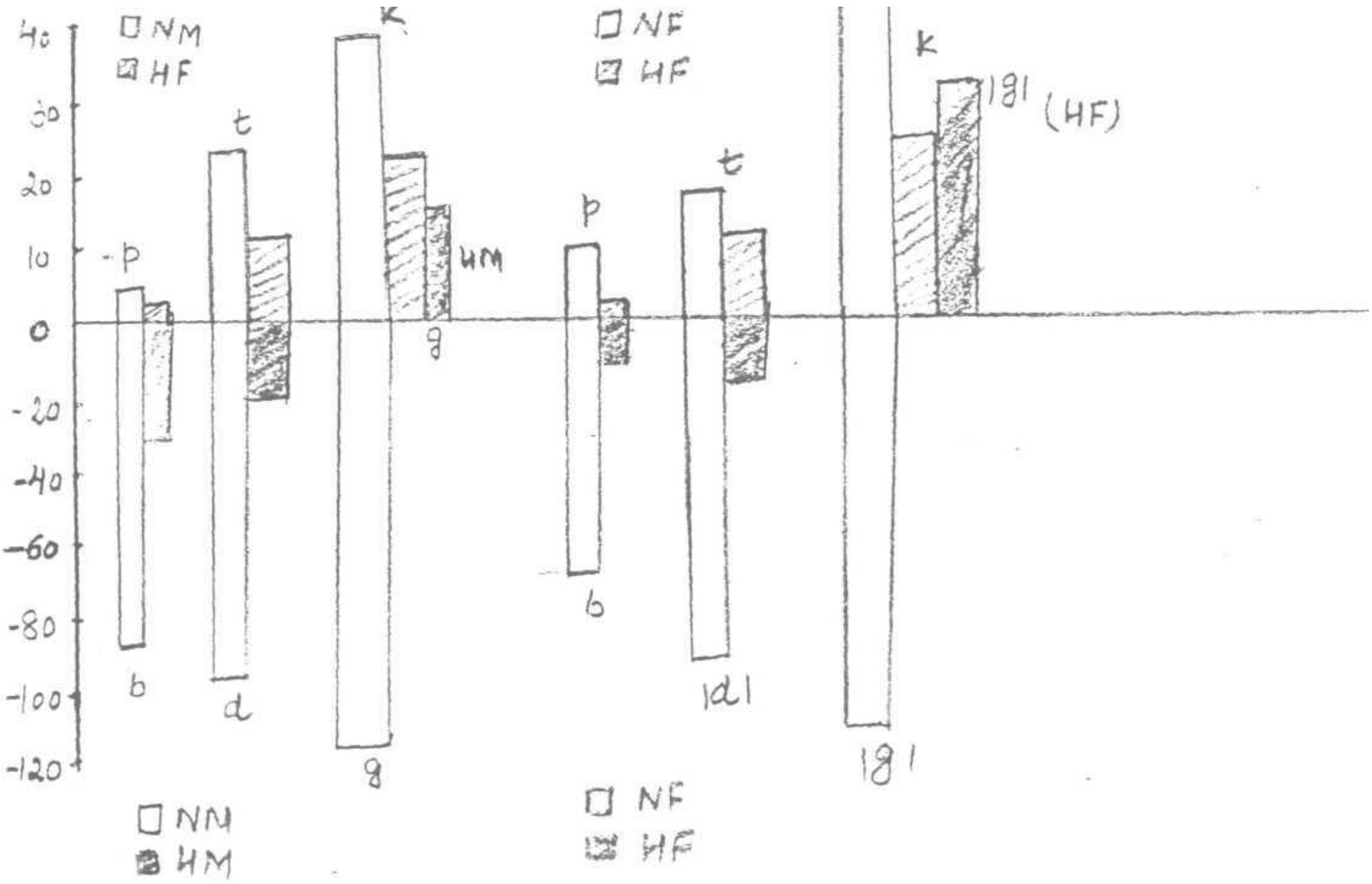
The mean VOT values are also displayed graphically in Fig: In the figure the vertical line represents the VOT values in msec. The center point of the vertical line at which the horizontal line joins represents the moment of articulatory release. This point was assigned a zero value. When the onset of voicing occurred after the articulatory release, the VOT was assigned a positive value (that is, above the horizontal line). When the onset of voicing occurred before the articulatory release the VOT was assigned a negative value (that is, below the horizontal line).

VOICELESS STOP CONSONANTS

In case of Normal hearing subjects all voice-less stop consonants had positive VOT values (voicing lag) indicating that voicing started after the release of the articulators. The mean VOT increased in duration as the place of articulation moved backward in the oral cavity. That is, the voicing lag increased in duration from /p/ to /t/ and to /k/. No individual was an exception to this rule.

In case of male normal hearing subjects /k/ and longest VOT (38.78 msec) followed by /t/ (20.89 msec) and /p/ (5.79 msec). Similarly females also followed the same pattern with /k/ sound having longest VOT of (45.78 msec) followed by /t/ (25.76 msec) and, least VOT of sound /p/ (8.79 msec).

The hearing-impaired subjects (both males and females) also had positive VOT values for all voiceless stop consonants. It can be observed from the Table 4(a) and Fig. 4 that VOT values for the hearing-impaired subjects were smaller than those obtained for normally hearing subjects. These differences were found to be statistically significant.



GRAPH-4 MEAN VOT VALUES OF VOICED & VOICELESS STOPS IN NORMAL & HG IMPAIRED

Hearing-impaired speakers also showed an increase in VOT values for voiceless stops as place of articulation moved backward in the oral cavity except in 2 subjects, one in male group and one in female hearing impaired group.

Table - 4(a): The mean and S.D. values of VOT of voiceless stops in hearing impaired and normal groups.

NORMAL		/P/	/t/	/k/
Male	M	5.79 msec	20.89 msec	38.78 msec
	SD	3.78	15.10	19.00
Female	M	8.79 msec	25.02 msec	45.78 msec
	SD	2.48	20.76	21.97
HEARING IMPAIRED				
Males	M	2.98 msec	10.70 msec	18.78 msec
	SD	3.48	3.89	4.96
Females	M	1.78 msec	11.06 msec	20.78 msec
	SD	5.82	7.57	8.78

The significant difference between means at $p < 0.05$ level.

VOICED STOP CONSONANTS:

Among normal subjects all showed negative VOT values (voicing lead) for /b/, /d/, /g/ stop consonants. Negative VOT values, indicate that the voicing occurred before the articualtory release. Mean negative VOT values produced by the subjects increased in duration as the place of articulation moved backwards in the oral cavity.

Table 4(b): The mean and S.D. values of VOT of voiced stops in normal and hearing impaired groups.

NORMAL		**/b/**	**/a/**	**/g/**
Males	M	-89.28 msec	-98.99 msec	-120.18 msec
	SD	10.89	20.78	30.81
Females	M	-76.92 msec	-88.08 msec	-115.84 msec
	SD	7.81	21.89	25.10
HEARING IMPAIRED				
Males	M	-30.78 msec	-20.78 msec	15.78 msec
	SD	7.81	8.09	4.81
Females	M	-15.78 msec	-19.78 msec	27.89 msec
	SD	3.78	4.59	8.76

The significant difference between means at P < 0.05 level.

In case of Hearing-impaired subjects factor of voiced atop consonants was severely reduced or absent. A majority of the hearing impaired speakers did not had negative VOT values for voiced stops /d/ and /g/. Among hearing impaired males /g/ sound did not reveal any negative VOT values. VOT was significantly reduced for sounds /b/ and /d/ as compared to normal males. Similarly hearing impaired females also varied significantly in VOT values when compared with normal females. No negative VOT values were seen for sounds /g/ and /d/.

Wilcoxin singed rank test indicated significant differences between the

1) hearing impaired males and normal hearing males.
2) hearing impaired and normal hearing females.

at < 0.05 level of significance.

The hypothesis (1d) stating that there is no significant difference between hearing impaired and normal hearing subjects in terms of VOT is rejected.

The hypothesis (2) stating that there is no significant difference between males and females has been accepted in respect of hearing impaire dgroup, and it is also accepted in case of normal group.

FORMANT FREQUENCY CHARACTERISTICS OF VOWELS:

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

Previous researchers (Potter et al. , 1947, Angelocci et al. , 1964) have indicated that the first three formants contribute the greatest part of vowel information. Consequently, the frequencies of ten vowels were the a concern of this study.

FIRST FORMANT FREQUENCY:

Table 5(a) depicts the mean standard deviation and ranges of formant frequency one of ten vowels for normal hearing and hearing impaired male subjects.

The means of first formant frequency (F_1) for the hearing impaired male subjects were higher than for the normal hearing subjects for the vowels /i/, /i:/, /u/, /u:/ and /o/. T he mean difference of F_1 values for these vowels varied from 40.6 - 208.4 Hz. For /i/ the difference between the means of hearing impaired and that of normal was 196.6 Hz; for /i:/ 125.2 Hz; /u/ 40.6 Hz; /u:/ 47.0 Hz and for /o/ 208.4 Hz. For vowels /a/, /a:/, /e/, /e:/ and /o:/ mean Fl values for hearing impaired male subjects were found to be lower than that of the normal male speakers. The mean difference of Fl for these vowels ranged from -171.8 to -30.8 Hz.

For /a/ vowel, the difference between the means of hearing impaired to that of normals was -30.8 hz; for /a:/ -171.8 Hz; /e/ -49.0 Hz; /e:/ -97.2 Hz, and /o:/ -111.6 Hz.

However, a significant mean difference between the hearing impaired males and normal males was found only for the vowels /a:/, /i/, /i:/, /o/, /o:/.

Table 5(b) Graph 5(b) show the mean F_1 values of female groups for the ten vowels. It was found that nearly all vowels produced by hearing impaired females had higher F_1

Table 5(a) The mean, S.D range and mean difference values of Fl in hearing impaired and normal hearing male group norma male group (Hz).

	NORMAL MALES		HEARING IMPAIRED MALES		
VOWEL	M (S.D.)	RANGE	M (S.D.)	RANGE	Mean diff Hearing & Normals
a	638.2(77.53)	255	607.4(156.05)	447	-30.8
*a:	902.2(21.85)	87	730.4(136.6)	453	-171.8
*i	305.4(46.96)	118	502.0(145.26)	360	196.6
*i:	362.4(96.01)	240	487.6(131.12)	388	125.2
e	669.8(103.96)	272	620.0(130.46)	624	-49.0
e:	533.0(53.33)	214	435.8(136.96)	450	-97.2
u	400.0(67.19)	202	440.6(92.17)	495	40.6
u:	403.6(27.51)	117	450.6(72.17)	298	47.0
*o	489.4(97.70)	278	697.8(128.0)	418	208.4
*o:	715.0(96.31)	229	603.4(122.77)	406	-111.6

* Signifiant difference between means at p-0.05 level.

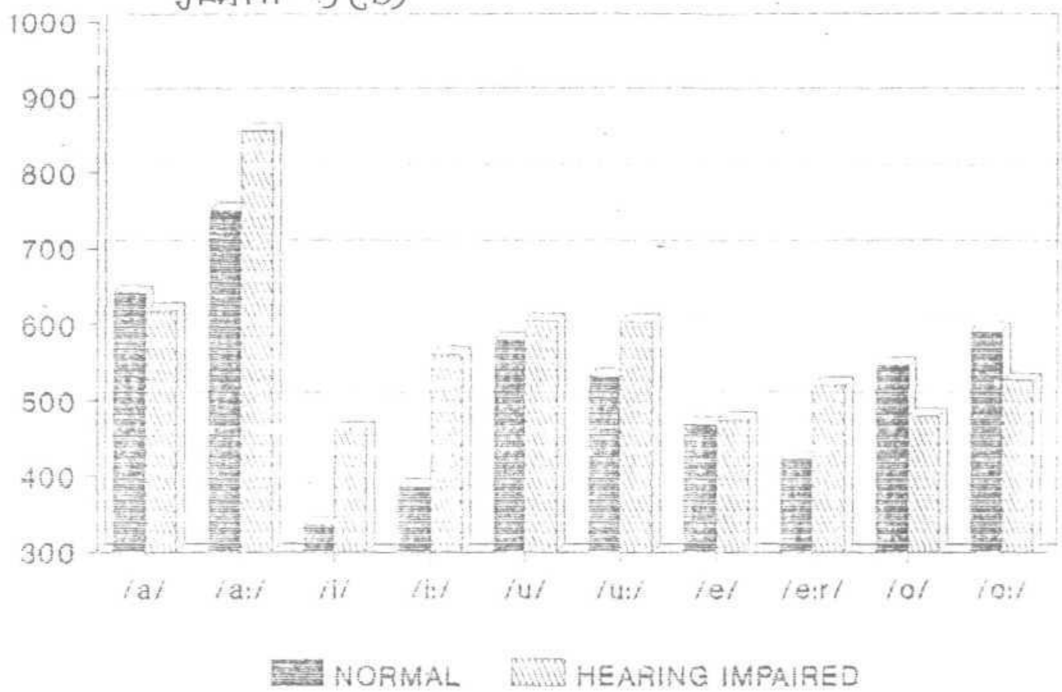
Table 5(b) The mean, S.D range and mean difference values of F2 in hearing impaired and normal hearing male group (in Hz).

	NORMAL FEMALES		HEARING IMPAIRED FEMALES		
VOWEL	M (S.D.)	RANGE	M (S.D.)	RANGE	Mean diff Hearing & Normals
a	641.6(94.36)	115	616.8(143.94)	480	-24.8
*a:	750.6(46.6)	98	855.40(94.91)	395	104.8
*i	334.8(30.86)	125	462.4(86.74)	415	127.6
*i:	385.8(51.48)	215	559.8(140.12)	315	174.0
e	579.8(91.42)	219	605.8(153.02)	368	26.0
e:	533.0(91.42)	208	603.60(136.86)	348	69.8
u	469.2(118.8)	210	474.0(50.7)	450	4.8
*u:	422.4(45.62)	115	520.6(84.38)	525	98.2
o	546.2(42.41)	218	478.2(55.5)	680	-68.0
o:	591.6(69.17)	105	526.8(82.84)	515	-64.8

* Signifiant difference between means at p-0.05 level.

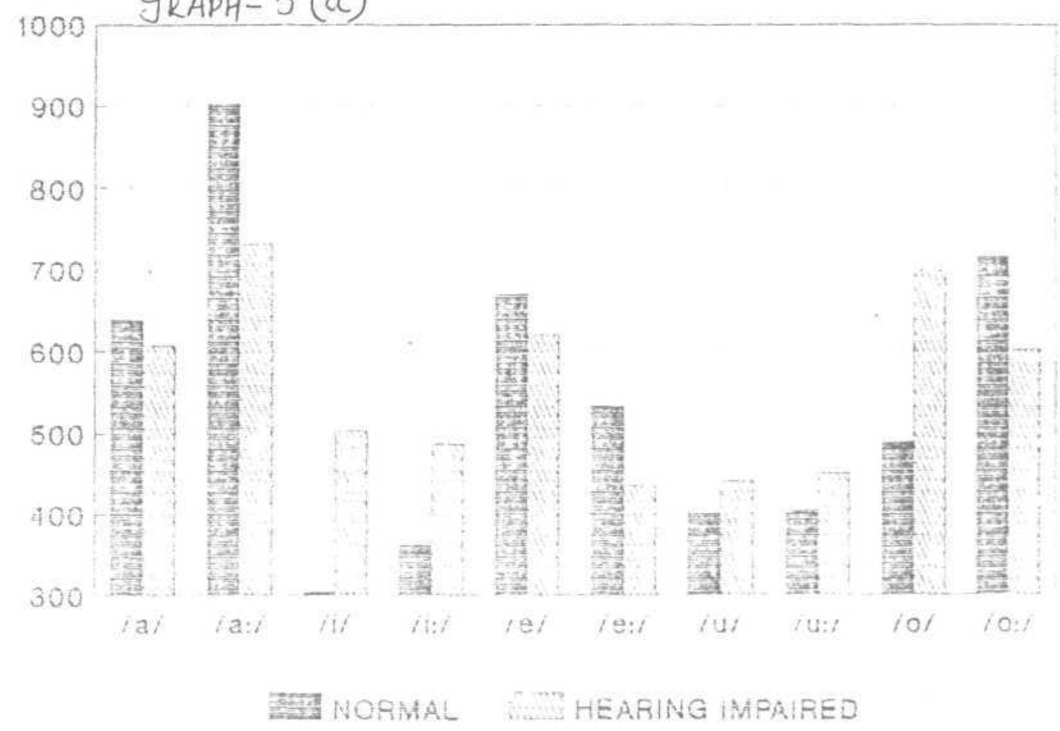
F1 in males

GRAPH- 5(b)



F1in females

GRAPH- 5(a)



values than that of normal female subjects. However the mean difference of Fl for these vowels varied from 4.8 to -174.0 Hz.

For /a:/ the difference between the means of hearing impaired females and that of normal females was 104.8 Hz; for /i/ 127.6 Hz; /i:/ 174.0 Hz; /e/ 26.0 Hz; /e:/ 69.8 Hz; /u/ 4.8 Hz; and /u:/ 98.2 Hz. For vowels /a/, /o/, and /o:/ the mean F1 values of hearing impaired females group were found to be lower than that of the normal female group. Mean difference between hearing impaired group and normal group for vowel /a/ was found -24.8 Hz; */of* -68.0 hz; and /o:/ -64.8 Hz. However, a significant mean different between the hearing impaired female and normal females was found only for the vowels /a:/, /i/, /i:/ and /u:/.

Comparison of Male and Female:

On comparing between males and females it was found that vowels /a:/, /i/ and /i:/ in both the groups showed significant mean difference between hearing impaired and normal hearing groups.

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

The hypothesis that there is no significant difference between the means of F_1 values of vowels of the hearing impaired females and normal hearing females was rejected for /a:/, /i/, /i:/ and /u:/ and accepted for /a/, /e/, /e:/, /u/, /o/ and /o:/.

The hypothesis (2) stating that there is no significant difference between males and females has been accepted in respect of hearing impaire dgroup, and it is also accepted in case of normal group.

SECOND FORMANT FREQUENCY:

Table - 6(a) and graph 6(a) show the mean F2 values of vowels for normal hearing males and hearing impaired males.

The mean F_2 values of vowels /a/, /u/, /u:/, /o/, and /o:/ were found to be higher i.e., the mean difference between normals and hearing impaired were 313.4 Hz, 450 Hz, 229 Hz, 62 Hz and 296.4 Hz. Mean difference for these vowels ranged from 62-450 Hz. The mean F_2 values for vowels /a:/, /i/, /i:/, /e/ and /e:/ were found to be lower for hearing impaired male group than that of normal hearing male group. The mean differences of these vowels for both groups were found to be /a:/ -171.0 Hz, /i/ -631.0 Hz, /i:/ -749.2 Hz, /e/ -690.6 Hz and /e/ -751.6 Hz. These mean difference values ranged from -751.6 to -171.0 Hz.

However significant difference between means for hearing impaired and normal hearing males were found for vowels /a/, /i/, /i:/, /e/, /e:/, /u/, /u:/ and /o:/.

Table 6(b) and Graph 6(b) depict the mean F_2 values of vowels for normal hearing and hearing impaired females.

The mean F_2 values for vowels /a/, /a:/, /u/, /u:/, /o/ and /o:/ were higher for hearing impaired female group than that of normal hearing females. The mean differences of these vowels for both females groups were found to be /a/ 337 Hz, /a:/ 347.2 Hz, /u/ 466.4 Hz, /u:/ 272.8 hz, /o/ 116.8 Hz and /o:/ 197.2 Hz. The mean difference values ranged from 116.8 - 466.4 Hz.

Where as mean F_2 values for vowels /i/, /i:/, /e/, and /e:/ were found to be lower for hearing impaired female group than that of normal hearing female group. The mean differences of these vowels for both groups were seen to be -497.4 Hz for vowel /i/, -691.4 Hz for /i:/, -325 hz for /e/, and -696.4 Hz. The mean difference values ranged from -691.4 to -325 Hz.

However significant difference between means for hearing impaired and normal hearing females were found for vowels /a/, /a:/, /i/, /i:/ /e/, /e:/, /u/, and /u:/.

Table 6(a) The mean, S.D range and mean difference values of F2 of hearing impaired males and normal hearing males group (in Hz).

	NORMAL MALES		HEARING IMPAIRED MALES		
VOWEL	M (S.D.)	RANGE	M (S.D.)	RANGE	Mean diff Hearing & Normals
*a	1170.6(144.59)	385	1484(370.21)	831	313.4
a:	1435.2(115.9)	298	1264.0(265.0)	800	-171.0
*i	2643.2(182.44)	372	2012.2(150.52)	1102	631.0
*i:	3404.0(173.68)	245	2654.8(390.25)	1272	-749.2
*e	2054.4(282.6)	265	1363.8(344.2)	842	-690.6
*e:	2096.0(75.43)	123	1344.4(334.0)	899	-751.6
*u	1121.0(125.56)	250	1571.0(180.1)	1823	450.0
*u:	1181.0(125.0)	228	1480.6(244.14)	665	299.0
o	1360.6(227.67)	318	1422.6(207.69)	766	62.0
*o:	1085.6(56.13)	310	1382.0(191.25)	890	296.4

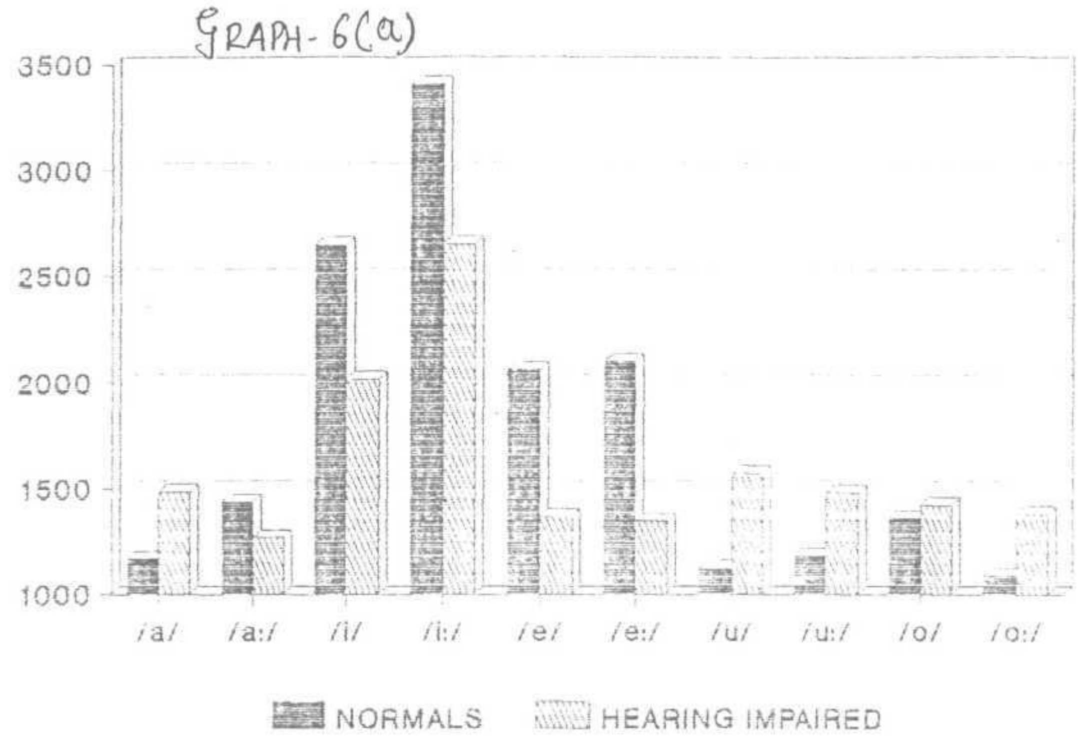
* Signifiant difference between means at p-0.05 level.

Table 6(b) The mean, S.D range and mean difference values of F3 in hearing impaired and normal hearing female group (in Hz).

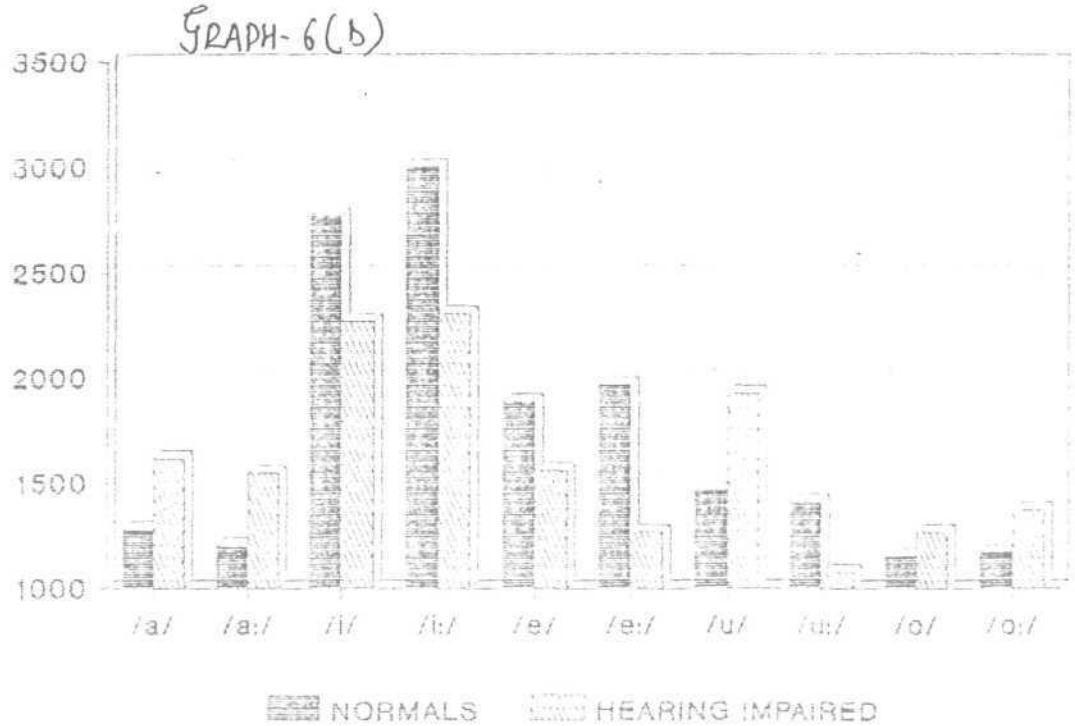
	NORMAL FEMALES		HEARING IMPAIRED FEMALES		
VOWEL	M (S.D.)	RANGE	M (S.D.)	RANGE	Mean diff Hearing & Normals
*a	1273.0(185.23)	370	1610.0(223.30)	758	337.0
*a:	1197.6(133.17)	223	1544.8(68.0)	962	347.2
*i .	2766.4(179.87)	434	2269.0(426.95)	851	-497.4
*i:	2999.4(130.12)	315	2308.0(342.06)	796	-691.4
*e	1880.0(137.63)	475	1555.0(185.24)	555	-3.25.0
*e:	1961.2(105.83)	280	1264.8(241.89)	769	-696.4
*u	1458.6(297.16)	295	1925.0(185.6)	572	466.4
*u:	1402.2(116.84)	105	1075.0(267.31)	996	272.8
o	1146.8(144.89)	195	1263.6(326.09)	894	116.8
o:	1170.4(107.50)	286	1367.6(437.0)	892	197.2

* Signifiant difference between means at p-0.05 level

F2 in Males



F2 in females



Comparison of Hales and Females:

Of both the groups showed that Overall similar pattern for mean F_2 among males and females of hearing impaired group. Both hearing impaired males and females showed higher mean F_2 for back vowels /a/, /a:/, /u/, /u:/, /o/, /o:/, than normal hearing group. Both hearing impaired males and females had lower mean F_2 than normal hearing group for front vowels (/i/, /e/, /i:/, /e:/).

Hearing impaired females had higher F_2 values for nearly all vowels than normal hearing females. But hearing impaired males showed more neutralized like schwa vowel when compared to males of normal group.

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

The hypothesis (2) stating that there is no significant difference between males and females has been rejected in respect of hearing impaire dgroup, and it is also accepted in case of normal group.

Thus it can be concluded that the mean F2 is significantly different in the vowels produced by hearing impaired to that of normal group.

FORMANT FREQUENCY THREE:

Table 7(a) and Graph 7(a) depict mean, standard deviation, and ranges of Formant three (F_3) of ten vowels for the normal and hearing impaired male subjects.

It was found that formant three (F_3) for the hearing impaired males was higher than that of normal male subjects for all the vowels except /i/ and /i:/. The mean difference of F3 values for vowels varied from 136.6 to 916 Hz. By far the greatest group difference in the mean of F_3 was for the vowel /a/ in which there normal hearing males had F_3 of 2222 Hz and the hearing impaired male 3138 Hz.

The normal hearing had a high F_3 than hearing impaired males for vowels /i/ and /i:/.

However, a significant mean difference between the hearing impaired normal hearing males was found for nearly all vowels i.e. /a/, /a:/, /i:/, /e/, /e:/, /u/, /u:/, /o/ and /o:/.

Table 7(b) and Graph 7(b) show the mean F3 values of ten vowels for hearing impaired and normal hearing female groups.

It is seen clearly from the table and graph that F3 for the hearing impaired females was higher than for the normal

Table 7(a) The mean, S.D range and mean difference values in hearing impaired and normal hearing males.

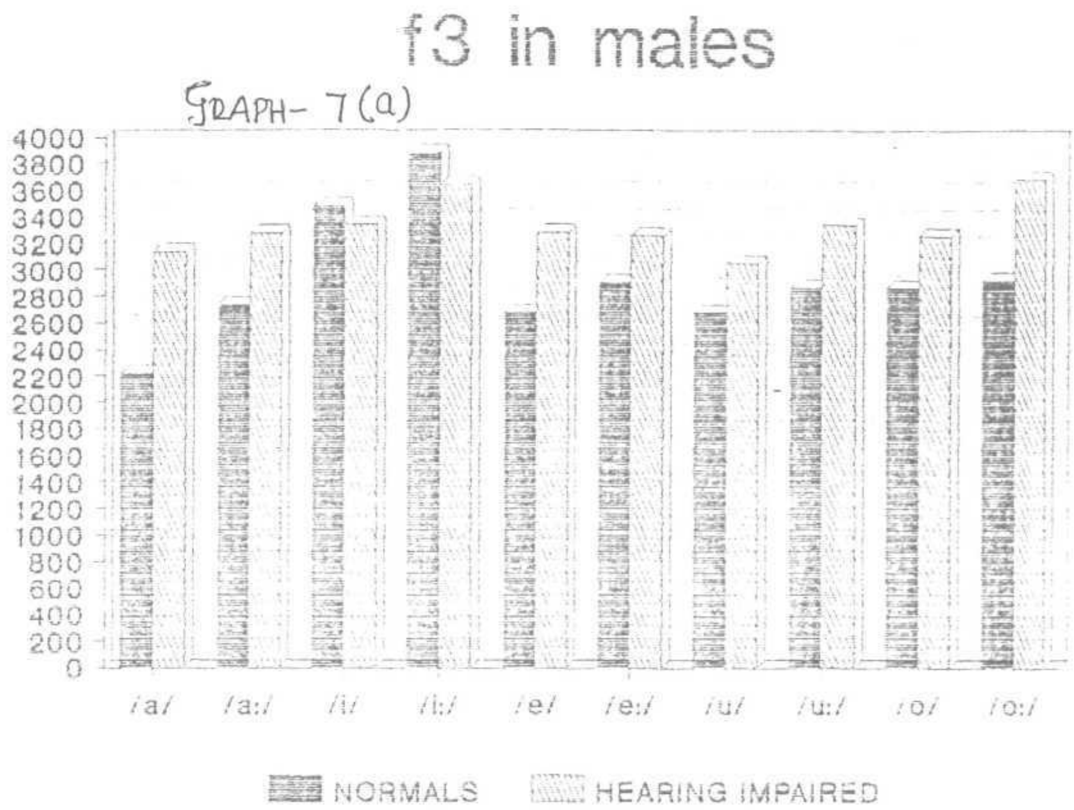
	NORMAL MALES		HEARING IMPAIRED MALES		
VOWEL	M (S.D.)	RANGE	M (S.D.)	RANGE	Mean diff Hearing & Normals
*a	2222 (182.98)	320	3138.0(115.11)	780	916.0
*a:	2749.0(194.12)	285	3276.0(299.43)	830	527.0
i	3476.6(189.19)	215	3340.0(221.47)	980	-136.6
*i:	3884.6(113.81)	268	3635.0(268.4)	751	-249.6
*e	26818.8(374.87)	185	3274.0(236.5)	769	592.2
*e:	2902.6(252.83)	278	3254.8(149.07)	654	352.2
*u	2687.4(166.6)	.198	3053.4(96.87)	796	366.0
*u:	2861.0(100.72)	210	3342.0(120.80)	752	481.0
*o	.2867.0(259.2)	310	32612.2(113.61)	699	394.2
*o:	2925.8(111.85)	280	3678.8(135.94)	898	753.0

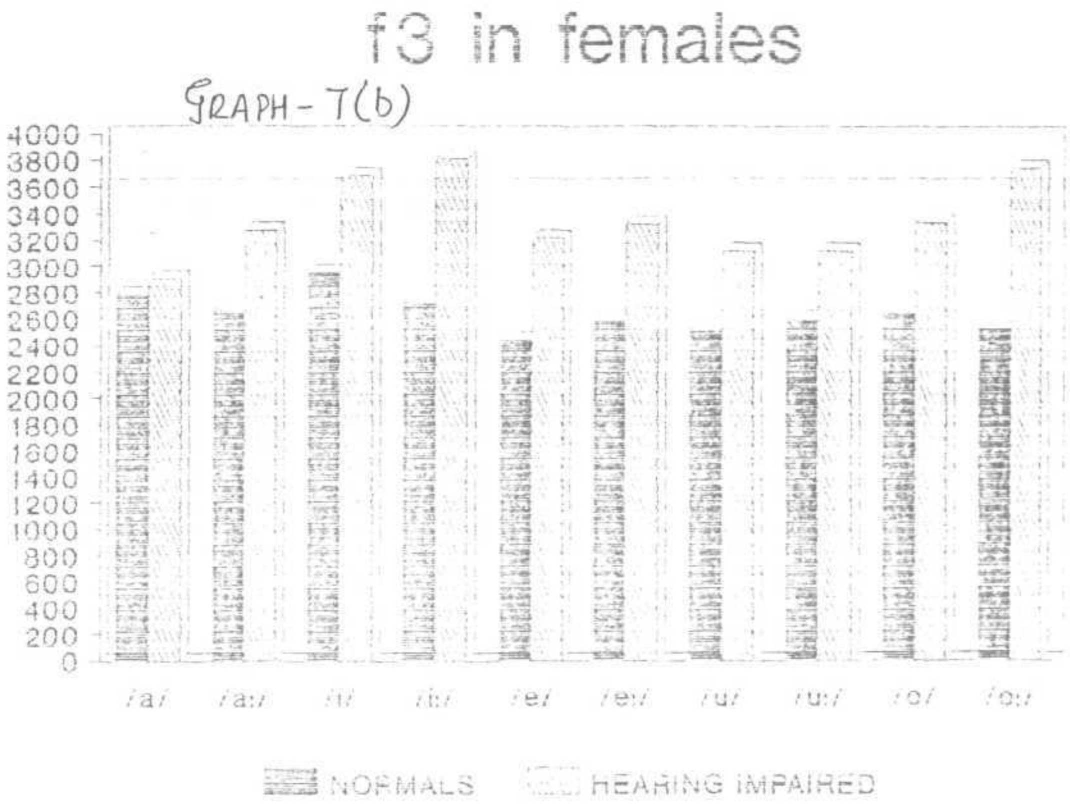
* Signifiant difference between means at p-0.05 level.

Table 7(b) The mean, S.D range and mean difference values of F3 in hearing impaired and normal hearing female group (in Hz).

	NORMAL FEMALES		HEARING IMPAIRED FEMALES		
VOWEL	M (S.D.)	RANGE	M (S.D.)	RANGE	Mean diff Hearing & Normals
a	2779.4(168.0)	315	2911.4(210.27)	892	132.0
*a:	2659.8(340.51)	221	3282.6(198.19)	688	622.8
*i	2952.0(237.23)	184	3675.4(139.75)	745	723.4
*i:	2720.4(255.4)	258	3804.0(173.68)	694	1084.0
*e	2433.6(220.71)	218	3220.2(237.19)	758	786.6
*e:	2582.2(251.68)	278	3319.6(307.17)	990	737.4
*u	2511.6(262.9)	218	3107.4(211.03)	1012	595.8
*u:	2593.0(198.57)	194	3119.0(387.9)	910	526.0
*o	2637.0(237.18)	230	3327.2(337.53)	928	690.2
*o:	2525.2(112.5)	320	3737.6(102.9)	810	1212.4

Signifiant difference between means at p-0.05 level.


f3 in males
GRAPH- 7(a)
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
/a/ /a:/ /i/ /i:/ /e/ /e:/ /u/ /u:/ /o/ /o:/
NORMALS
HEARING IMPAIRED


f3 in females
GRAPH- 7(b)
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
/a/ /a:/ /i/ /i:/ /e/ /e:/ /u/ /u:/ /o/ /o:/
NORMALS
HEARING IMPAIRED

hearing females for all the vowels. The mean difference among two groups of these vowels varied 132-1212.4 Hz. Longest group difference in the mean of F3 was 1212.4 Hz for the vowel /o:/. So it is clear that females also followed nearly the same trend as that of males i.e. both hearing impaired males and females had higher F3 values for nearly all vowels than normal hearing subjects. However, a significant mean difference between the hearing impaired and normal hearing females was seen for /a:/, /i/, /i:/, /e/, */e:/,* /u/, /u:/, /o/, and /o:/.

The hypothesis stating thai: there is no significant difference between the means of F3 values of vowels of the hearing impaired males and normal hearing males is rejected for /a/, /a:/, /i:/, /e/, /e:/, /u/, /u:/, */o/,* /o:/ and accepted for /i/ vowel.

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

The hypothesis (2) stating that there is no significant difference between males and females has been accepted in respect of hearing impaire dgroup, and it is also accepted in case of normal group.

Based on the analyses of vowels produced by the hearing impaired group, the following conclusions can be drawn:

1) F_1 is similar to normals.
2) F_2 is neutralized as schema vowel for male hearing impaired subjects.
3) F_3 is higher than normals.

PAUSES:

The analysis of intraword (or inter syllabic) pauses revealed that normal subjects did not show any pauses, where as pauses were observed in the utterances of five hearing impaired subjects (4 hearing impaired males and 1 hearing impaired females).

Generally it was found that male hearing impaired had more intraword pauses as compared to female hearing-impaired subjects.

Table-8 depicts the mean duration, standard deviation, ranges and no. of words paused among male and female hearing impaired subjects.

HEARING IMPAIRED MALES			HEARING IMPAIRED FEMALES		
P.D.(S.D.) msec.	PAUSED WORDS	RANGE	P.D.(S.D.) msec.	PAUSED WORDS	RANGE
380.2 (98.7)	8	270-502	481.5 (87.56)	4	450-540
492 (59.78)	7	210-768			
315 (74.09)	5	280-350			
297.3 (105.89)	3	258-336			

Among males, pauses were observed in the utterances of four hearing impaired subjects and one subject did not show any pauses.

The mean pause duration ranged from 297.3 - 492 msec.

One subject showed pauses in eight words with mean duration of 492 msec, followed by seven words with 380.2 msec, five words with 315 msec, and three words with mean pause duration of 297.3 msec.

Among female hearing impaired only one subject showed intraword pauses with mean duration of 481.5 msec. This subject revealed that in only four words.

So in present study, results revealed that hearing impaired males had intraword pauses and intelligibility of male hearing impaired speakers was found better than female hearing impaired subjects.

No pauses were found either in males or females of normal group.

So hypothesis stating that there is no significant difference in hearing impaired and normal hearing subjects in terms of pauses is rejected for males and accepted for female group.

The hypothesis (2) stating that there is no significant difference between males and females has been rejected in respect of hearing impairs dgroup, and it is also accepted in case of normal group.

BAND WIDTH:

First three band widths, B_1, B_2, B_3 were calculated for ten vowels. The hearing impaired subjects had smaller values of band widths as compared to normal hearing subjects. The standard deviation values did not show any consistent pattern. Similar findings were seen in males and vemales.

Thus, the hypothesis stating that there is no significant difference in the utterances of hearing impaired and normal hearing Punjabi speaking children in terms of

1.

a) Vowels duration is REJECTED.

b) Total duration of words is REJECTED.

c) Average fundamental frequency (FO) is REJECTED.

d) Voice onset time (VOT) of top consonants is REJECTED.

e) Intersyllabic pauses is REJECTED.

f) FORMANT FREQUENCIES (Fl, F2, F3)

i) First formant frequency (Fl) is ACCEPTED.

ii) Second formant frequency (F2) is REJECTED.

iii) Third formant frequency (F3) is REJECTED.

g) BANDWIDTHS (Bl, B2, B3)

i) Bl, B2 and B3 - REJECTED.

2.

The hypothesis (2) stating that there is no significant difference between males and females has been accepted in respect of hearing impaired group, and it is also accepted in case of normal group.

DISCUSSION

From the results of the study it is clear that the hearing impaired children tend to have significantly longer vowel duration than normal hearing children of same age and sex. This study indicates that the hearing impaired subjects had vowel duration nearly 2 to 3 times greater than that of the normal hearing subjects. Thus the Punjabi speaking hearing impaired children had longer vowel duration than normal children. Due to shortage of time relationship between vowel duration and word duration was not investigated so in future, this aspect can be evaluated. These findings are similar to the results reported by several other investigators (Angelocci, 1964; Calvert, 1962; John and Howarth, 1965; Boone, 1966; Levitt et al., 1974; Monsen, 1974; Parkburst an Levitt, 1979; Rasitha, 1994; Sheela, 1988; Leeper et al., 1987; Shukla, 1987; Vasantha, 1995; Rahul, 1997). Therefore the vowel prolongation seem to be a universal phenomenon in hearing impaired subjects.

The hearing impaired were also found to have a greater variability in terms of vowel duration. In Monsen's (1974) study the deaf subjects produced vowels which were longer by one and a half times when compared to the normally hearing speakers. Osberger and Levitt (1979) observed that the syllabic prolongation in the speech of the hearing-impaired was the prolongation of the vowels.

Similar findings have been reported by physiological studies as well (Rothman, 1977; Zimmerman and Reltaliata, 1981), Rothman (1971) who measured EMG activity associated with the vowel // followed by /t/, /k/, and /s/ and reported that the deaf group extended the duration of the vowel / / . Zimmerman and Reltaliata (1981) in their cineflourographic study demonstrated that the deaf subjects had longer utterance durations. They concluded that "the deaf, as a group, are more variable in their articulatory behaviour than are normal speakers'.

"It is not clear why the deaf should have particular problems with the timing of speech events like prolonging them and producing a high variability of timing. One possibility is that they depend heavily on vision and that vision simply does not operate in as rapid time frame as audition" (Carlson, 1977; Gannong, 1979). Another possibility is "that the 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 several, requiring a general showing of the mechanism of production and imposing high instability upon timing.

Lyberg (1981) reported a strong relationship between vowel duration and the fundamental frequency. Nataraja and Jagdish (1984) found that vowel duration of /i/ and /u/ were longer at higher and lower fundamental frequencies than at normal fundamental frequency. Since the hearing impaired tended to have a greater fundamental frequency than the normal hearing, the increased vowel duration may be an effect on this.

In the present study, it is found that the hearing impaired children had relatively higher fundamental frequency (FO) than their age and sex matched normal hearing control groups. This is in agreement with the findings of Angelocci, (1962); Calvert, (1962); Engelberg, (1962); Angelocci et al., (1964); Boone, (1966); Martony, (1977); Rajnikanth, Jagadish, (1989); Sheela, (1988), Rasitha, (1994); Rahul, (1997).

Pitch is difficult aspect of speech for deaf children to learn to control (Boothroyd, 1970). One possible reason for the difficulty is that deaf children may lack a conceptual appreciation of pitch (Martony, 1977).

Several explanations have been proposed to explain the higher FO in the hearing impaired. Pickett (1968) suggested that the increase in fundamental frequency may be 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 mechanisms for kinesthetic feedback and thus leading to increase in fundamental frequency.

Angelocci, (1964) further suggested that the hearing impaired attempted to differentiate vowels by excessive laryngeal variation rather than with articulatory variations as in the normal hearing subjects. This has led to an increased Fo. Whitehead and Makki (1977) hypothesised that the deaf speaker uses extra vocal effort to give him an awareness of the onset and progress of voicing and this leads to a higher fundamental frequency. Martony (1977) and Homma (1981) suggested that the laryngeal tension is a side effect of the extra effort put in using the articulatros. Since the tongue muscles are attached to the hyoid bone and the cricoid and thyroid cartilage, an extra effort on the articulators would result in tension and change of the vocal cords, leading to an increased Fo.

None of the above suggested reactions would be able to explain the higher fundamental frequency found in hearing impaired. It is likely that several of these reasons interact to cause an increased Fo. However, it is evident that a higher FO in the hearing impaired indicates a lack of laryngeal control due to absence of auditory feedback.

In the present study it is found that hearing impaired male subjects inserted more pauses than the hearing impaired females subjects. Four male subjects out of five, and only one females subject out of five inserted intraword pauses.

Several studies have reported the similar findings that the profoundly hearing impaired speakers insert more pauses and pauses of longer durations than do speakers with normal hearing (Boone, 1966; Boothroyd, 1974; Heidinger, 1972;

Stevens, 1971; Osberger and McGarr, 1982; Sheela, 1988; Jagadish, 1989; Rasitha, 1994).

The frequent pauses observed in the speech of the hearing impaired may be the result of poor respiratory control (Lee, 1971). Hixon and Forner (1977) found that the muscle activity to be normal for deaf individuals during quite breathing but noted that they do not take enough air while breathing for speech.

In the present study, it was seen that the total duration of words were longer in the hearing impaired group than the age and sex matched control groups.

Similar findings have been reported by Leepers, (1987); Sheela, (1988); Rasitha, (1994). Total duration of words would be more in hearing impaired children as they prolong the speech segments and insert several intersyllabic pauses. Osberger and Mcgarr (1982) also reported that prolongation of speech segment is present in the production of phonemes, syllables and words in the speech of hearing impaired.

These researchers suggested that the confusion of the voiced and voiceless distinction is the commonest problem encountered by the hearing impaired speakers. However, the direction of this error has sometimes been reported as occurring to the voiced member of the pair and at the other times to the voiceless cognate (Millin, 1971; Smith, 1975). These studies indicated that coordination of the articulators necessary for voicing contrast is an exceedingly difficult task for the hearing impaired speakers. This aspect has been reflected at the acoustic level as well (Monsen, 1975; 1976 a-b, 1978).

Physiological researches (Hutchinson and Smith, 1976; Whitehead and Barefoot, 1980; and Whitehead, 1982) have shown that the hearing impaired speakers have difficulty in coordinating the events of respiration and laryngeal valving. These observations provide the physiological reason for the failure to correctly produce voiced and voiceless distinction by the hearing impaired speakers.

Mahshie (1980) and Mcgarr and Lofquist (1982) showed that during pauses between vowels the hearing impaired speakers inappropriately opened the present study, hearing impaired speakers exhibited positive VOT values for the voiceless stop consonants like the normally hearing subjects. However, VOT values obtained from the hearing impaired speakers, were shorter than those of the normal hearing subjects. This finding is in agreement with the study reported by Gilbert and Campbell (1978). This reduced positive VOT values in the speech of the hearing impaired may be attributed to the reduced oral breath pressure (Gilbert, 1975; Hutchinson and Smith, 1976).

It was found in the present study that hearing impaired speakers frequently produce errors in voiced consonants. Hearing impaired subjects showed reduced negative VOT values for /b/ and /d/. Absence of negative VOT values was seen in males and females of hearing impaired group.

Present findings correlate with the previous research studies which reported similar results (Mangun, 1961; Nober, 1967; Markides, 1970). Glottis, a pattern never observed in the production of the normally hearing speakers. The authors opined that hearing impaired speakers have difficulty in coordinating the temporal and spatial demands of different articulators resulting in voiced and voiceless confusion.

However, Hutchinson and Smith (1976), Whitehead (1982) have shown that some hearing impaired speakers do produce plosives with normal air flow patterns, that is, voiceless plosives would be produced with greater airflow than their voiced cognates, suggesting that atleast some hearing impaired speakers are relatively successful in coordinating respiration and laryngeal valving. In the present study also some hearing impaired male speakers demonstrated successful acoustical distinction between voiced and voiceless "plosives.

Implications for Therapy:

Absence or inadequate negative VOT values is obviously an important underlying acoustic cause for voiced-voiceless confusion in the speech of the hearing impaired. Therefore the therapeutic procedure should be aimed at eliciting voicing lead for voiced sounds.

Gulian et al., (1983) have demonstrated the usefulness of the Fricative and timing Aid (FTA) in teaching the temporal nature of the voiced and voiceless sounds, to profoundly deaf children and they concluded that "while the voicing distinction may not be acquired spontaneously it is a skill within the reach of profoundly deaf children when they are adequately trained".

Similarly, the real time visual display, spectrography and other similar techniques in teaching the distinction of voiceless and voiced sounds should prove beneficial. Clinical experience also suggests that, tactile cues for pre-voicing, initiated by closed mouth voicing will also help in teaching the distinction.

In the present study it was found that formant frequencies (Fl, F2, F3) of hearing impaired varied from that of normal hearing subjects. Overall it was seen that F_1 is similar to normal hearing subjects. F_2 is neutralized like schwa vowel and F3 is significantly higher than normal hearing subjects. The hearing impaired group showed higher variability than normal group.

The range of the mean frequencies of the three formants were greater for the hearing impaired than for the normal hearing. The extensive overlapping of the vowel areas of the hearing impaired children of this study indicated that they were missing the acoustical vowel targets. It is reasonable to assume, that they were not placing their articulators accurately enough to meet this criterion.

F_2 is higher in female hearing impaired subjects than normal hearing female subjects and vowels do not have articulatory reference points that can be easily described.

Similar findings have been reported by various investigators (Angelocci et al., 1964; Potter et al. , 1947; Fairbands et al., 1961; Levitt, (1976); Sheela, 1988; Rasitha, 1994; Rahul, 1997).

Levitt (1976) from a study of the acoustic and perceptual characteristics of speech of the deaf children concluded that the formant frequency values were typical of the schwa vowel. Similar findings are reported in the present study where F2 is neutralized appears like a schwa vowel. Rahul (1997) further reported similar findings. Angelocci et al. , (1964) reported that F3 was generally higher for vowels produced by hearing-impaired than that of normally hearing children. Similar findings are seen in the present study.

Angelocci et al. , (1967) further suggested that deaf children attempted to achieve vowel differentiation by varying fundamental frequency of voice relatively more than the frequency of the formants. In physiological terms, deaf achieves vowel differentiation by excessive laryngeal variation with only minimal articulatory variations.

This study, therefore shows that:

1. The vowel duration was greater in the speech of hearing impaired, as compared to the normal hearing subjects, for all vowels.

2. The word duration also was longer significantly in hearing impaired subjects than that of normal hearing subjects.

3. Average FO was higher in both male and female hearing impaired speakers as compared to normal hearing speakers.

4. VOT for voiceless stops was reduced in valve than normals and absence of decrease in negative value for voiced stops than normals was found in hearing impaired speakers.

5. Intraword pauses were present in males but not in female hearing impaired speakers whereas complete absence of pauses in normal hearing speakers.

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

   a) The first formant frequency (Fl) was either similar or higher or lesser to normal hearing speakers.

   b) i) F2 for females hearing impaired speakers was higher than normal hearing females subjects.

ii) F2 for male hearing impaired was lesser for front vowels and higher than normals for back vowels. It is more neutralized like schwa vowel.

iii) F3 for both male and female hearing impaired subjects was higher than normal hearing speakers.

7) Bandwidths were lower in hearing impaired subjects than normal hearing subjects.

Thus the speech of the Punjabi speaking hearing impaired children has been described and compared with normal hearing subjects, achieving the objective of the study.

SUMMARY AND CONCLUSIONS

> "Although speech reading can compensate to a large extent for the loss of hearing in sofar as speech reception is concerned, no comparable skill exists in the hearing world to compensate for an inability to produce ordinary intelligible speech".

MONSEN (1978)

Neumeros studies (Voelker, 1938; Hudgins and Numbers, 1942, Angelocci et al., 1964; Boone, 1966; Nober, 1967; Markides, 1970; Smith, 1975, Geffner, 1980; Ravishankar, 1985; Shukla, 1987; Sheela, 1988; Rasitha, 1994; Vasantha, 1995; and Rahul, 1997) have shown that, the speech of individuals with severe to profound hearing loss that dates either from birth or shortly thereafter tends to differ from that of normals. The typical speech characteristics of hearing impaired individuals include misarticulations, nasality, high pitch, slow rate, faulty rhythm and faulty intonation patterns.

Several researchers Calvert, 1962; Angelocci et al., 1964; Monsen, 1974; 1976a, 1976b, 1976c, 1978, 1979; Gilbert and Campbell, 1978; Rothman, 1976; Whitehead and Jones, 1976, 1978; and Leeper et al., 1980) have recognized the need for describing the speech of the hearing impaired individuals using objective measures like voice onset time, vowel duration, formant frequencies, consonant duration, fundamental frequency, transitional patterns, oral and nasal airflow, shimmer and jitter.

Describing the speech of the hearing impaired objectively not only has the advantage of an objective measurement but also sheds some light on the probable reasons for the poor intelligibility which in turn may help in developing effective therapeutic procedures.

"Speech training must be efficient in order to get intelligible speech. An efficient speech training program requires that there are methods to assess the child's speech errors as well as methods to estimate the impact of these errors on the intellibility" (Oster, 1985).

Results of such objective analysis of hearing impaired speech will help in determining, the error type and kinds of errors that should be considered first while planning a training program for the improvement of speech of the hearing impaired child.

Many of speech parameters which are related to speech intelligibility are language specific.

The present study, the first of its kind in Punjabi language was undertaken with an aim of analyzing the segmental aspects of the speech of the hearing impaired children.

Ten congenital hearing - impaired subjects, 5 males and 5 females in the age range of 8-12 yrs. were selected from the vatibu special school Chandigarh, for the study.

Ten normal

subjects including 5 males and 5 females, were matched for age and sex for the controls.

Ten simple *(CYC)* Punjabi meaningful words were used as speech samples. These words contained the vowels /a/, /a:/, /i/, /i:/, /e/, /e:/, /u/, /u:/, */o/,* and /o:/ in medial position.

All the subjects were asked to read words and their utterances were recorded in a portable speech recorder (Panasonic, model RQ-A170).

The recorded speech samples were analysed using computer software to determine the following parameters:

1. Vowel duration
2. Word duration
3. Average fundamental frequency (FO)
4. Voice onset time (VOT)
5. Pause duration
6. Formant frequency (Fl,-F2, F3)
7. Band width (Bl, B2, B3).

Statistical analysis was done to determine significant differences exist between normal hearing and the hearing impaired groups.

Results of the present study showed that:

1. The vowel duration was significantly higher in hearing subjects. The hearing impaired males and females both

subjects including 5 males and 5 females, were matched for age and sex for the controls.

Ten simple (CVC) Punjabi meaningful words were used as speech samples. These words contained the vowels /a/, /a:/, /i/, /i:/, /e/, /e:/, /u/, /u:/, /o/, and /o:/ in medial position.

All the subjects were asked to read words and their utterances were recorded in a portable speech recorder (Panasonic, model RQ-A170).

The recorded speech samples were analysed using computer software to determine the following parameters:

1. Vowel duration
2. Word duration
3. Average fundamental frequency (FO)
4. Voice onset time (VOT)
5. Pause duration
6. Formant frequency (Fl,- F2, F3)
7. Band width (Bl, B2, B3).

Statistical analysis was done to determine significant differences exist between normal hearing and the hearing impaired groups.

Results of the present study showed that:

1. The vowel duration was significantly higher in hearing subjects. The hearing impaired males and females both

produced nearly 2 to 3 times longer vowel durations indicating significant prolongations of the vowels.

2. The hearing impaired subjects produced significantly longer word durations than the normal subjects. Both the hearing impaired groups (males and females) had nearly 1.5 to 2 times longer word durations than normal hearing subjects.

3. Significantly higher average FO was exhibited by the hearing-impaired subjects than that of the normal hearing group. Larger variations were seen in hearing impaired group.

4. Both normally hearing and hearing impaired speakers had positive VOT values for voiceless stops. However, VOT values for the hearing impaired speakers were shorter. Normally hearing speakers showed negative VOT values for voiced stops, while in a number of hearing impaired speakers negative VOTs were absent. Mean VOT values produced by both the groups increased as the place of articulation moved backward in the oral cavity.

5. Intrasyllabic pauses (intraword) were not found in normal hearing speakers. Among hearing impaired speakers nearly all male subjects revealed significant intrasyllabic pauses and only one female subject exhibited pauses.

6. The hearing impaired males and females did not had significant differences in their F_1 as compared to normal hearing controls.

7. For female hearing impaired group F_2 was found to be higher than normal hearing females group. But male hearing impaired tend to have a "neutralized" F_2, i.e. they tend to keep the F2 similar to that of the neutral schwa vowel when compared with normal male subjects.

8. All the hearing impaired subjects including males and females revealed a significantly higher F3 than that of the normal hearing control subjects.

9. Bandwidths (Bl, B2, B3) of hearing impaired subjects were reduced than that of normal hearing subjects. But not any specific pattern was observed.

CONCLUSIONS:

The data from the normally hearing subjects showed that the speech parameters were language specific, that is, parameters are different in quality and quantity in different languages. For example, in the English language voiced stops have shorter positive valves and voiceless stops have longer positive values. Whereas in the Punjabi language voiced stops have positive VOT values, Shukla (1987) also reported the similar findings in Kannada language.

However, it is seen that certain speech parameters to behave similarly in different languages. For example, vowel lengthening phenomenon which is seen in the English language is also seen in Punjabi language.

These observations emphasis the need for studying the different parameters of speech is different languages.

The present study provides normative data for the parameters studies for Punjabis language.

The results of this study indicates that the hearing impaired individual differed from normals in certain temporal and frequency characteristics of speech. Further a greater variance was seen in the hearing impaired individual's than in the normally hearing group, that is, the hearing impaired speakers not only behaved differently from normals but also were different from each other.

RECOMENDATIONS:

1. Similar kind of research may be taken up with a large sample of subjects.
2. As in the present study, hearing impaired subjects varied in certain aspects, so a more homogenous group of subjects may be further studied.
3. Various spectral parameters and their relations to the factors affecting the speech intelligibility in the hearing impaired children may be studied.

Such information will be useful in planning therapy with hearing impaired children.

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APPENDIX - I

Following ten words (CVC) were selected as speech samples for the study.

/kal/

/pa:p/

/dig/

/bi:d$_3$/

/dul/

/bu:t/

/tek/

/pe:r/

/gol/

/ko:n/