TEMPORAL AND ACOUSTtC ANALYSIS OF SPEECH IN TELUGU IN HEARING IMPAIRED CHtLDREN

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CERTIFICATE

This is to certify that this Dissertation entitted TEMPORAL AND ACOUSTtC ANALYSIS OF SPEECH IN TELUGU - IN HEARING IMPAIRED CHILDREN is the bonafide work in part fulfiiment for the degree of Master of science (Speech and Hearing) of the student with Register No.M9614.

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CERTIFICATE

This is to certify that this Dissertation entitted TEMPORAL AND ACOUSTtC ANALYSIS OF SPEECH IN TELUGU - IN HEARING IMPAIRED CHtLDREN has been prepared under my supervision and guidance.

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DECLARATION

This Dissertation entitled TEMPORAL AND ACOUSTtC ANALYStS OF SPEECH IN TELUGU - IN HEARING IMPAIRED CHILDREN is the result of my own study under the guidance of Dr. N.P.Nataraja Prof, and HOD-Speech Sciences, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any University for any other diploma or degree.

Mysore
May, 1998

Reg. No.M9614

Dedicated to

All My Teachers
whose blessings
has made me stand
on my own platform

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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 Warshofsky, 1971).

Communication, as it is in today's world, makes the human race different from animals. The bulk of communication, around the world uses speech. Speech is the most efficient medium of communication known to man; so much so, that efforts are on to make speech as a medium of communication even between men and machines.

'Normal speech is a complex, highly skilled motor act. The refinement and stabilization of speech motor patterns probably continues well into teenage years' (Kent, 1976).

Speech is an integrated function involving the reception non-invasive, needs relatively simple instrumentation, may be used routinely to depict changes in the physical characteristics of frequency, intensity and the duration of speech segments (Leeper, et al. 1977). Acoustic analysis of speech of hearing impaired permits a finer grained consideration of some aspects of both correct and in correct production than would be possible using methods applied in 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 the facilitating the oral production skills of the hearing impaired.

In order to develop more effective speech training procedures for deaf children, it is necessary to know how their speech deviates from that of normally hearing children and the effect of various errors and abnormal speech patterns on the intelligibility (Levitt, 1978).

Speech characteristics as described by various investigators typical to that of hearing impaired individuals include misarticulations, nasality, high pitch, slow rate, rhythm and faulty intonation patterns. This review deals with the characteristics of speech segments (vowels and consonantal individually in terms of their production, normal as well deviant. This review also includes the relationship of intelligibility to that of the acoustic characteristics.

AIM OF THE STUDY

This study was undertaken to study the speech characteristics of Telugu speaking hearing-impaired children spectrographically in terms of word duration, vowel duration, pause duration, formant frequencies (F1,F2 and F3), average fundamental frequency and bandwidth characteristics (B1, B3 and B4).

HYPOTHESIS

The following hypotheses were proposed for the study:

1. There is no significant difference in terms of the speech of the male hearing-impaired chidlren to that of the normal male hearing children in terms of - word duration, vowel duration, pause duration, formant frequencies (F1.F2 and F3), average fundamental frequency and bandwidth characteristics (B1, B3 and B4).
2. There is no significant difference in terms of the speech of the female hearing-impaired chidlren to that of the normal female hearing children in terms of - word

duration, vowel duration, pause duration, formant frequencies (F1,F2 and F3), average fundamental frequency and bandwidth characteristics (B1, B3 and B4).

3. There is no significant difference in terms of the speech of the mate hearing-impaired chidlren to that of the normal female hearing-impaired children in terms of - word duration, vowel duration, pause duration, formant frequencies (F1,F2 and F3), average fundamental frequency and bandwidth characteristics (B1, B3 and B4).

4. There is no significant difference in terms of the speech of the normal male hearing chidlren to that of the normal female hearing children in terms of - word duration, vowel duration, pause duration, formant frequencies (F1,F2 and F3), average fundamental frequency and bandwidth characteristics (B1, B3 and B4).

METHODOLOGY

The speech samp is were coletcted fromthe thirty norma) and thirty hearing-impaired children (age range 7-11 yers). Speech sample invovied the elicitation of ten VCV words written on the flash card. One out of three trails were analysed using a PC/AT computer with the necessary software to obtain spectral parameters. The data was been subjected to statistical analysis and results have been discussed.

1.5

IMPLICATIONS OF THIS STUDY

The results of this study would help in better understanding of the speech of the hearing-impaired children in an Indian language. The results of the study would provide data regarding the spectrographic characteristics of speechof the hearing-impaired children. This information would help in planning and developing therapy programmes for the hearing-impaired.

REVIEW OF LITERATURE

It is language, more than anything else, that distinguishes man from the rest of the animal world. Language affects and indeed structures virtually all aspects of human behaviour. It is impossible to think of any aspect of human culture or human behaviour that would be unchanged if language did not exist.

Communication, as it is in today's world, makes the human race different from animals. The bulk of communication, around the world uses speech. Speech is the most efficient medium of communication known to man; so much so, that efforts are on to make speech as a medium of communication even between men and machines. "Normal speech is a complex, highly skilled motor act. The refinement and stabilization of speech motor patterns probably continues well into teenage years' (Kent, 1976).

Speech is an integrated function involving the reception of words by the ears or the eyes, their interpretation and synthesis as language within the brain and the expression of this langauge response as further spoken or written words. It includes the whole of this receptive, formation and expressive activity. Words are composed of sequences of sounds. They are symbolic and have a consistent range of meaning (Morley, 1972). "Speech and language are normally and usually effortlessly developed through the auditory mode" (Ross and Giolas, 1978). "The ability to communicate through speech is of enormous value. It provides a range of opportunities, and options in personal, educational and social level, as well as in employment that cannot exist through any other form of interchange' (Ling, 1976).

"The auditory pathway is the natural and most effective way to learn speech and languages in addition to providing all the other auditory information from our environment such as music, door bell, bird song and soon" (Pollack, 1981). Further, hearing helps in monitoring one's own speech by providing sensory information through feedback. Hearing-impairment has a marked effect on a chiIds ability to acquire speech. The orderly and seemingly development of speech, language communication is interfered with by the presence of hearing loss (Stack, 1979).

The normal hearing child is continuously exposed to sounds from birth or even before birth. It is through this continuous auditory stimulation that a normal child attains speech. The task is however very difficult for a child born deaf. Thus hearing controls speech, and without hearing speech fails to develop. Hearing-impairment has a marked effect on the child's ability to acquire speech (Whetnall and Fry, 1964). Hearing is essential for the seemingly natural development of speech and language, and communication is interfered with by the presence of a hearing loss (Stark, 1979). The oral communication skills of the hearing-impaired children have long been of concern to educators of the hearing-impaired, speech pathologist and audiologists, because the adequacy of such skills can influence the social, educational and career opportunities available to these individuals (Osberger and McGarr, 1982).

Research has shown that speech reception threshold at 2000 Hz has a high correlation to that of speech production performance affecting both the quantity and quality of speech output. Thus the hearing-impaired children exhibit a delay and or deviancy in their speech and language development.
"Although no speech can compensate to a large extent for the loss of hearing in so far 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). The oral communication skills of hearing-impaired children have long been of concern to educators of the hearing-impaired, speech pathologists and audiologists,

because the inadequacy of such skills can influence the social, educational and career opportunities available (Osberger and McGarr, 1982).

The ultimate goal in aural rehabilitation for the hearing-impaired individual, is to attain, as far as possible, the same communication skills as those of the normal hearing individuals. The poor oral communication skills of the hearing-impaired are evident to anybody who may have heard their speech. However, those can be overcome. But a very few deaf individuals achieve good speech quality. Many more deaf children could be trained to speak proficiently if we had greater insight into the essential problems (Levitt, 1974). This concern has lead to a number of experiments on speech of the hearing-impaired. The variety of techniques physiological (Metz, et al. 1985), acoustic (Monsen, 1976 a, b; Angelocci et al. 1964; Calvert, 1962; Shukla. 1985; Sheela, 1988; Rajanikantha, 1986) perceptual methods (Levitt, et al. 1976; Stevens et al. 1983; Hudgins and Numbers, 1942; Markides, 1970; Smith, 1975; McGars, 1978; Geffner, 1980 have been used.

Within the last decade advances have been made in studying the speech. This is largely due to the development of sophisticated processing and analysis techniques in speech science, electrical engineering and computer science. These technological advances have also been applied to the analysis of speech of the hearing-impaired and to the development of clinical assessment and training procedure (Osberger and McGarr, 1982).

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 routineely to depict changes in the physical characteristics of frequency, intensity and the duration of speech segments (Leeper, et al. 1977). Acoustic analysis of speech of hearing-impaired permits a finer grained consideration of some aspects of both correct and incorrect production than would be possible using methods applied in the subjective procedures (Osberger and McGarr, 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 the facilitating the oral production skills of the hearing-impaired.

In order to develop more effective speech training procedures for deaf children, it is necessary to know how their speech deviates from that of normally hearing children and the effect of various errors and abnormal speech patterns on the intelligibility (Levitt, 1978).

Speech characteristics as described by various investigators typical to that of hearing-impaired individuals include misarticuIations, nasality, high pitch, slow rate, rhythm and faulty intonation patterns.

Speech sounds of a given language are classified as vowels and consonant basically.

Vowel

"Vowel is a conventional vocal sound produced by certain positions of the speech organs which offer little obstruction to the airstream and which forms a series of resonators above the level of the larynx in the vocal tracts'" (Wood, 1971).

For the production of any sound, a vibrating medium has to be set into motion by some kind of energy. In the case of vowel production vocal folds act as the vibrator and produce the "tone" which has a regular pattern. And the vocal tract approximates a tube closed at one end and open at the other. The quality of a vowel depends on the shape of the activities of the pharynx, the mouth and the nose, which in turn depend on the positions of the soft palate, the tongue and the lips. The range of movement, the velocity of movement and the direction of movement of these articulators depend upon synergised neural commands given to them by the nervous system. Enunciation of vowels help in identifying the consonants in speech and to relay prosodic information. Intelligible hearing-impaired speakers do enunciate vowels more precisely than unintelligible speakers.

Phonetic inventories from the spontaneous speech samples of hearing-impaired children were obtained by various researchers such as Carr (1953), Sykes (1940), Geffner (1980). The vowels most commonly used by young hearing-impaired children include the central vowels /ʌ,ə/ and the low front vowels /æ, ɛ /. The extreme high vowels /i, u/ occurred relatively infrequently in the speech of children. However, Carr (1953) found that these children used a wide range of vowels than noted above. The vowel usage of these children were similar to that of the hearing infants of 11 to 12 months.

Geffner (1980) analyzed the spontaneous speech of sixty five six year old deaf children and found that low vowels were correctly produced than those with mid or high tongue positions. This study agrees with that of the findings of Nober (1967) and Smith (1975). Sykes (1940) found that four to seven year old hearing-impaired children produced almost half of the number of vowel sounds in isolation but not in combination with consonants. Hudgins and Numbers (1942), one of the first investigators, in study of production of vowels and diphthongs in the speech of the hearing-impaired classified the errors according to five major types :

1. Substitution of one vowel for another
2. Neutralization of vowels
3. Diphthongization of vowels
4. Nasalization of vowels
5. Errors involving dipthongs :

either the diphthong was split into two distinctive components or the final member of the diphthong was dropped.

Vowel modifications such as substitution and neutralization of vowels were the common errors. This also included the production of diphthongs. In addition Markides (1970) study has added prolongation of vowels apart from the categories such as vowel substitution. neutralization and diphthonizatien.

According to Boone's (1966) study, the hearing-impaired speakers tend :o keep their tongue retracted in a low back position. On contrary, Stein (1980) in a cineflIuorographic study of vowe is showed fronting of back vowels. Studies (Monsen, 1974 and Osberger, et al. 1982) have used sentence context for vowels and have interpreted that the hearing-impaired speakers use a restricted amount of tongue movement to produce vowels. In terms of errors of substitution, the hearing-impaired speakers tend to have difficulty in discriminating/producing tense-lax vowels according to Smith (1975). This difficulty was contradicted by the findings of Hudgins and Numbers (1942) and Markides (1970).

There are studies which have reported inappropriate nasalization of vowels (Martony, 1966: Stevens. et al., 1976). Stevens et al., found that 76% of the profoundly hearing-impaired children studied had excessive nasalization, in at least half of the vowels produced in monosylIabic words. Thus the major problem in the speech of the hearing impaired has been the production analysis. To understand this problem and suggest therapeutic solution it because necessary to analyse the vowel production. Hence study of formant frequencies responsible for perception of vowels was considered.

FORMANT FREQUENCY CHARACTERISTICS OF VOWELS

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 (F1) and second (F2) formants are traditionally used to provide an acoustic description of vowels. The higher formants other than F1 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. F1 represents the tongue height. F1 decreases as the vowels go from /'{/ to /u/. F2 decreases from / i / o/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/	/ɪ/	/ɛ/	/æ/	/a/	/ɔ/	/ʊ/	/u/	/ʌ/	/ɜ/
Fo	272	269	260	251	256	263	276	274	261	261
F1	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

Eguchi and Hirsh (1969) studied formant frequencies of vowels of chi Idren 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 below:

	/i/		/ɛ/		/æ/		/ɔ/		/u/	
Age	F1	F2	F1	F2	F1	F2	F1	F2	F1	F2
5	408	3235	642	2418	643	2423	901	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) while studying 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 F1 and

F2 and low F3 value than those of normal group. The hearing-impaired group showed higher variability than normals.

From the literature it is seen that very few studies have been done on the spectrographic analysis of speech of hearing-impaired children. Since the information about the formant frequencies of the hearing-impaired is important in understanding speech the formant frequencies F1, F2, F3 were considered for the present study.

DURATION CHARACTERISTICS OF VOWELS

The duration of a phoneme 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. This need not be learnt. Even prior to the age of three, chi Idren can recognize important temporal parameters of the language.

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. Lonefal et al., (1982) reported that the prepausal lengthening effect identified for adults were also found in young children's spontaneous utterance. Durational changes in vowels serve to differentiate not only between vowels themselves but also between similar consonants adjacent to those vowels (Raphael, 1972; Gold. 1980). 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 varied systematically from shorter to longer in the following order : a stressed vowel preceding a voiceless stop < voiceless fricative < Nasal < Voiced stop < Voiced Fricative.

DiSimoni (1974) after 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 durational values compared for both voiced and voiceless consonant environments were found to be significantly different in six and nine year old subjects, but not in 3 year old subjects.

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

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

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

Both males and females showed a consistent decreases 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.

The duration of the speech segment is altered in hearing-impaired speakers. There is a general tendency towards lengthening of vowels and consonants (Calvert, 1962; Levitt, et al. 1974). "The prolongation of speechsegments such as phonemes, syllables and words are often, present in the speech of the hearing-impaired (Osberger and McGarr, 1982). Calvert (1961) was among the first to do objective measurement of phonemic duration in speech of the hearing-impaired by spectrographic analysis of bisyllabic words. The result of this study showed that hearing-impaired speakers extended the duration of vowels. Studies done by Rajanikanth (1986), Shukla (1987) and Sheela (1988) and Jagadish (1989) on Indian hearing-impaired population showed a longer vowel duration. Rajanikanth (1986) who used and compared male and female hearing-impaired (n=53) found significant difference like other researchers. Shukla investigated on hearing-impaired individuals. Sheela (1988) and Jagadish (1989) studied speech of the hearing-impaired children and they found hearing-impaired showed greater variation in their vowel production. Osberger and Levitt (1979) observed that syllable prolongation in the speech of the hearing-impaired was due to prolongation of vowels.

Leeper et al. (1987) studied VOT, total syllable duration for VCV syllables, initial and final vowel duration in five hearing-impaired children and nine normal hearing chi Idren who served as controls. They were matched for age and sex with hearing-impaired children. The speech stimul i employed were bisyllabic (VCV) utterances with a symmetrical vowel /a/ - obstruent /p/ vowel /a/ formant. The stimuli were in three utterance contexts of increasing length; i.e. /apa/. saw apa or apa saw apa with /apa/ the results showed that hearing-impaired children took significantly longer time than their controls to produce syllables. In addition, there was a numerical trend for the first word like utterance in the phrase to be shorter than their controls to produce syllables. In addition, there was a numerical trend for the first word like utterance in the phrase to be shorter than the next word for both groups of children. Again variability was almost twice as large for the hearing-impaired children than normals. Analysis of the temporal characteristics of initial & final vowels in the /apa/ utterance showed that the hearing-impaired children had significantly larger durations on both positions of the syllable than did their controls. For the normal hearing children the initial vowel in the VCV utterance was significantly shorter in the first word than in subsequent initial vowels in the sentence like frames of increasing length that is, the first vowel in the three word like /apa/ saw /apa/ task was significantly shorter than the 2nd initial vowel. The findings were the same for the initial vowel in the five word like length utterance for the normal hearing children. The hearing-impaired children did not show a significant systematic shortening of the initial vowel in the syllabic productions for either three or five word like utterance length. The only trend that wa3

Hence in the present study, vowel duration has also been considered as a parameter characteristics of the hearing-impaired speech production.

CONSONANTS

Consonant is "a conventional speech sound produced, with or without laryngeal vibration by certain successive contractions of the articulatory muscle which modify, interrupt, or obstruct the expired airstream to the extent that its pressure is raised" (Wood, 1971).

As stated earlier in vowel production, consonants too can be studied in their normal production patterns as well in terms of their deviant productions in the speech of the hearing-impaired. Sykes (1940) found that, hearing-impaired children produced front consonants /b, p, m, w/ more often than back consonants. Nober (1967) analyzed correctly articulated consonants according to place of articulation and found that bilabials had highest score (59%) followed by labio-dentals (48%), glottals (34%), lingua dentals (32%), lingua-alveolars (23%), lingua palatals (18%) and lingua velars (12%). Smith (1975) and Gold (1978) did a cross-population comparison study by using same test materials and procedures. Smith (1975) examined the segmental errors in the speech of profoundly hearing-impaired children in an oral day school for the deaf. Gold (1978) examined the segmental errors in mainstreamed hard-of-hearing and profoundly hearing-impaired children. They also found that the scores produced in the front of the mouth most often correct, followed by the back consonants. Sounds produced in the middle of the mouth were prone to errors than were sounds produced in the back of the mouth.

Study on analysis of consonant errors by Huntington et al. (1968) and Levitt et al. (1976) showed that the hearing-impaired speakers tend to position their articulators fairly accurately, especially for those places of articulation that were highly visible, but failed to coordinate the movement of the articulators properly. Stoel-Gammon (1982) in his study on phonological acquisition by hearing children 1.5 to 3.10 years of age and hearing-impaired children 2.4 to 7.3 years of age revealed the following : The speech of older hearing-impaired children showed many similarities to that of the younger hearing-impaired children. Noticeable differences existed between the production patterns of the two groups of children at a very early age, and the speech of some hearing-impaired children never progressed beyond the very early stages of development.

The longitudinal data obtained by Stoel-Gammon (1982) revealed that the hearing-impaired children progressed toward the correct production of the target phonemes at a much lower rate than the normal hearing children. And the hearing-impaired children passed through three developmental stages. In the first stage the child produced a wide variety of substitutions for the target phoneme. In the second stage, there was a narrow range of substitution. In the third stage, the phoneme was produced correctly and not all hearing-impaired children passed through the third stage (as it is easily reflected through the segmental errors) even throughout their adult life.

The cross sectional data of Stoel-Gammon (1982) study revealed the following : Though the rate of development was found to be slower in hearing-impaired children the pattern of development was found to be similar to that of the hearing children. Similar patterns of correct production and error types were present in both the groups of children. The set of substitution pattern common to both the groups included voicing of initial stops, devoicing of final stops, fricatives and affricates and substitution of homorganic stops for fricatives. However the errors were more frequent in hearing-impaired children and they showed a large range of substitution types eg :/k, g/ for /tʃ/ than those made by hearing children. Errors that present only in the hearing-impaired children's speech were : substitution of a glottal stop for the target phoneme, substitution of palatal fricative /ʃ/ for the affricates /tʃ /' and /dz/ and substitution of back consonants /h, k, g/ for other nonlabial consonants. Gammon (1982) found that the normal children's production had depalatization of /tʃ , ʃ , dz/ resulting in a substitution of /s/ for /ʃ/ or /tʃ/ for /tʃ , dz/ which were not present in hearing-impaired children.

Any comprehensive analysis of the articulatory skills of hearing-impaired children should not forget to appreciate the work of Hudgins and Numbers (1942) who studied 192 subjects between the ages of 8 and 20 years whose hearing losses ranged from moderate to profound. The test material included reading simple sentences. The vowels. consonants and diphthongs errors were related to speech intelligibility.

The articulatory errors were divided into substitutions, omission, distortions and addition of phonemes. Among the more common type of consonantal errors included confusion of the voiced-voiceless distinction, substitution of one consonant for another, added nasality, misarticulation of consonants blends, misarticulation of abutting consonants, and omission initial or final consonants of word. This over all pattern has been replicated in various studied such as studies by Geffner, 1980: Gold, 1978; Nober, 1970; Smith, 1975.

Voicing Errors : One of the most frequent errors found by Hudgins and Numbers was confusion of the voiced-voiceless distinction. Smith (1975) determined that voicing errors were common for these children and most often involved substitutions of the voiced for voiceless pair. Markides (1970) who studied 110 British hard-of-hearing and deaf children found substitution of the voiceless cognate for the voiced as the common error. Nober (1967) by using Templ in-Darley Test of articulation analyzed the production of phonemes by 46 severely and profoundly hearing-impaired children and reported that voiceless phonemes were produced more correctly more often than voiced phonemes.

Substitution Errors : Based upon the place of articulation, the errors found had been described earlier (Sykes, 1940; Nober, 1967; Smith, 1975; Huntington, et al. 1968; Levitt et al. 1976). Based on the manner of articulation, nasal oral substitution has been reported as the common problem. Hudgins and Numbers (1942) have viewed it both as a problem affecting segmental attributes and voice quality.

Smith (1975) has reported that the hearing-impaired children had erroneous production of palatal plosives, fricatives, affricates, and nasal /ŋ/. Glottals were frequently substituted for stops and fricatives showed a high rate of substitution but not from plosives. Affricates were substituted not for other consonants, but by plosives. However, bilabial plosives, the glides and fricatives /f/ and /v/ were produced correctly. Results of study by Nover (1967) agreed with the findings of study by Smith (1975) and the general pattern reported was that the gl ides were most often correct, followed by stops, nasals and fricatives. Geffner and Smith (1980) who studied 67 six year old severely and profoundly hearing-impaired children and reported similar findings.

Omission Errors : Once again Hudgins and Numbers (1942) showed that the omission of consonants might occur in the initial and/or final position of the words, and also reported that as nonfunction of releasing or arresting of consonants respectively. The consonants which were frequently omitted from the initial position of words included /h, l, r, y, th, s/. There could be dropping of the final consonants completely, releasing the consonants into the following syllable, or incomplete production where by the phoneme by losing its dynamic properties turning into a passive gesture.

Markides (1970) reported that the deaf children misarticuIated nearly 72% of all consonants attempted, whilst the partially hearing children misarticulated a little over 26%. This study showed that in the deaf individuals, omissions were more than substitutions and distortions. Among the partially hearing-impaired children substitutions were found to be more than omissions and distortions. Geffner (1980) found that omissions were the most frequent (91%) followed by substitutions (7%), distortions (1%) and finally additions (01%). Velar consonants as they are not visible were omitted to a greater proportion than the more visible front consonants /s/, /p/ and /b/ and other bilabials and labiodentals.

In terms of consonants-cluster errors, Hudgins and Numbers (1942) found that the errors involved two forms : One or more components of the cluster were dropped or an adventitious phoneme, usually the /a/ as added between the elements.

Stop Consonants : The stops are unique among the sounds of speech in that they include a variable period of total blockage of airflow during which sound output may cease. During this interval, air pressure rises behind the point of closure to be released as a burst of acoustic energy. Plosives are stops in which the pressure is bui lt up pulmonically. Other types of stops such as clicks, ejectives and implosives can be formed by nonpulmonic pressures. The spectrographic events which are seen in the production of the stop consonants are many: silence, voice bar, burst, aspiration, voice onset time and formant transitions.

It hs been reported that it is difficult to extract the acoustic characteristics of consonants produced by the hearing-impaired either because of the mismatch between spectrograph filters and fundamental frequency (Huggins. 1980) or due to source function abnormalities (Monsen, et al. 1979). Moreover any sound due to the mis-articulation or modification either at the place of articulation or by the manner of articulation or both, the spectrographic pattern itself may be lost. There can be even additional spectral changes because of the insertion of tne unwanted segment into the target sound (s). The formant transitions may be exceedingly shorter in duration or missing altogether. The extent of frequency range of the formant transitions have been reported to be limited. Even it has been found that the slopes of transition remained fairly flat when either a rising or falling pattern was indicated. Moreover, the F2 transitions in the speech of the hearing-impaired has been found to be reduced both in time and frequency. Hearing-impaired children have been found to have are stricted range of movement or articulators in static position or with fronting or backing of the tongue or even with unwanted lowering of the velum affecting the spectral characteristics of the speech. It is to be noted that every production by the (whether correct or incorrectly produced) hearing-impaired will have their own unique pattern. Because of the inappropriate breath management for speech activities at the respiratory level, because of the increased level of laryngeal tension either due to habit or to enjoy ample amount of tactokinsthetic feedback and because of the unique production patterns of the utterances by the hearing-impaired, there will be a unique spectral change in the speech of the hearing-impaired.

There can be even inappropraite management of intensity. There can be even durational aspects altered which all will influence the speech of the hearing-impaired. Inappropraite nasalization will lead to the presence of additional unusuaI harmonics, reductions in intensity of the formants which will also be reflected in the spectrogram. Apart from that there can be unwanted noise source arising due to the aperiodic vibration of the vocal folds or through the in coordination existing between the respiratory-laryngeal-supra laryngeal systems and moreover the average duration of the speech segments may be either prolonged or may not be even released. All these features can be determined by using spectral analysis. These were no studies available on the formant frequencies of consonants to the investigator. Hence the study of formant frequencies of stop consonants were considered as necessary.

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 Abramson, 1964, 1967). The release of the oral occlusion relative to the onset of glottal pulsing 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). Voiceless plosives, on the other hand due to greater intraoral breath pressure resulting in the increase of airflow rate causing frication 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-ordinate laryngeal and oral articulatory movements, the accuracy of articuiatory movements the distinetiveness of phonemes, transition of articulatory postures, neuromuscuIar co-ordination (Till and Strivers. 1981). Increase in VOT is noted when the place of articulation moved backward in the oral cavity as in English (Lisker and Abramson. 1964); in French (0'Shaughnessy, 1981); in Japanese (Homma, 1981) and in Kannada (Basu, 1979) 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 produced as 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 centred on short VOT values but by age 6. a bimodal distribution of VOT values emerges. The variability of VOT values for voiced is 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 aduIt I ike minimum.

In Kannada. there have been studies done on VOT of normals by Ravishankar (1981.): Kushal Raj and Nataraja (1984). The values 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/	
	RS	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 VCT Lag
upa /p/	0	0	0	0	0	0	0	8
Ati /t/	0	10	0	0	0	0	0	0
like /k/	0	12	0	19	0	4***	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*	0	51	on	92*	0	63*	0
	(45)				(61)		(49)	

* Cessation of voicing;
*** Triple/Multiple burst

(1) Voicing Duration Within The Closure Period

Monsen (1976b) by measuring VOT spectrographicaily for 36 profoundly hearing-impaired children on word initial stops (/p/, /t/, /k/) and (/b/, /d/,/g/) revealed the following : Some of the children distinguished the cognates in the normal manner. VOT values were longer for the voiceless than voiced segments and VOT contrasts were longer for velars than for alveolars and bilabia is. However mo9t 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 differences in VOT for hearing-impaired normal hearing children as a prerequisitic strategy 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.

Closure Duration : Closure duration indicates the time for which the articulator is held in position for stop consonant. Lehiste (1970) and most other investigators agree that when other factors are constant, the closure duration of labials is longer than alveolars and velars. In English, stop closure duration is drastically reduced following nasals. Angelocci (1962) and Calvert (1962) reported that fricative consonants and closure periods of plosive consonants may have inordinately long duration.

Savithri and Sridei (1990) studied 5-8 year old children in words such as upa, ati, etc. And the closure duration values of their unpublished study have been tabulated here :

Words	I Child closure duration	II Child closure duration	III Child closure duration	IV Child closure duration
upa /p/	101	108	107	103
ati /t/	147	125	122	107
i ike /k/	77	104	90	121
aake /k/	118	123	124	89
uba /b/	91	109	89	83
eedi /d/	63	29	30	67
aga /g/	76	105	106	87
i iga /g/	64	51	51	63

Calvert (1961) found that the hearing-impaired extended the closure periods of plosives upto 5 time the average duration for normal speakers.

Angelocci et al. (1961) claimed that his deaf subjects took four to five times as long to produce fricatives as did his normal hearing subjects. The closure periods of plosives were also considerably prolonged. According to Hood (1986) training on duration of phonemes would improve intelligibility significantly if articulation was good. Leeper et al. (1980) who studied the effect of utterance length upon closure duration in hearing-impaired individuals, reported that the mean closure duration values are always higher and more variable for young deaf speakers than for normal hearing children. However, in general mean.values and variability decreased by both the groups as the utterance length increased. The higher mean closure duration as well functional articulation problem in the difficulty in assessing the relative distance of the articulators to achieve approximation.

Whitehead (1991) studied closure duration of hearing-impaired adults with Intelligible speech and semi-intelligible speech in compared to normals. The results indicated that for all three groups of speakers longer durations occurred in initial stops as compared with medial stops and in bilabial stops as compared with lingua-alveolar stops. And there was a non-significant trend for voiceless stops to have grater durations than voiced stops. Semi-intelligible hearing-impaired speakers had longer closure durations than the other two groups. The excessive closure duration was the result of increased intra-oral air pressure behind the stoppage with a subsequent greater peak flow upon release. thus the closure duration has been taken up as **a** parameter for study.

Intelligibility of Speech of the Hearing-impaired

One of the most recognized but least understood concomitants of deafness is a deficit of oral communication skills. The speech produced by many deaf persons is frequently unintelligible to even experienced listeners. Moreover it is frequently difficult to determine the exact nature of speech errors that reduce the speech ' intelligibility. Without a clear understanding of the underlying nature of unintelligible speech of deaf, the development of effective clinical statement is limited **(Metz,** 1982).

Speech intelligibility refers to how much of what a child says can be understood by a listener (Osberger and McGarr, 1982). In a study of intelligibility of 192 hearing-impaired subjects ranging 8-19 years of age, a group of experienced listeners were asked to listen to the speech samples of the hearing-impaired and write down whatever was understood by them. The means core for the group was found be only 29% (Hudgins and Numbers, 1942).

Brarson (1964) found that only 20-25% of the words in the speech of hearing-impaired subjects were intelligible to listeners unfamiliar with hearing-impaired children speech. The subjects had a hearing-impairment of greater than 75 dB Hl_, had normal intelligence and no other known handicap. Markides (1970) studied 58 hearing-impa i red children aged 7 to 9 years only about 31% of their words were intelligible to their teachers whereas 19% intelligible to naive listeners. Smith (1972) studied 40 hearing-impaired children in the age group 8-10 and 13-15 years and found the word intelligibility as assessed by 120 listeners unfamiIiar with the speech of hearing- impaired was 18.7%. Gold (1980) found that only about 20% of the speech output of the deaf is understood by the person on the street. This lack of intelligibility may be attributed to several frequently occurring segmental and suprasegmental errors. Mensen (1978) reported a relatively high mean intelligibility score of 76% however the attributes such high scores to the simpler test materials used to study the speech intelligibility.

According to Ling (1976), intelligibility ratings can vary not only with the type of judge employed but also with the materials used and with the methods of analysis applied. However, the results of various suggests that the overall level of speech intelligibility is grossly inadequate for oral communication. Intelligibility rating have been reported to be 10-15% higher when judged by teachers or experienced listeners than those by the naive listeners (Geffner et al. 1978; Mangan, 1961; Monsen, 1978).

Sentences, when used as test materials tend to be more intelligible than words and sentences which are spoken directly to listener in a face to face situation are more intelligible than sentences that are tape recorded (Hudgins, 1949; Thomas, 1964). This suggests that contextual cues also affect the intelligibility of speech. Poor speech intelligibility achievement in the hearing-impaired has been correlated to several variables related to reception and production of speech. Among the perceptual variables, residual hearing (Montgomery, 1967; Elliot, 1969; Boothroyd, 1969; Markides, 1970; Smith, 1975; Stoker and Lake, 1980; Ravishankar, 1985; Vasantha, 1995) and lip reading (Stoker and Lake, 1980; Vasantha, 1995) abilities have been studied. The results have indicated that both residual hearing as well as ones lip reading ability effect intelligibility. Children with lesser degree of hearing loss were found to have a better speech intelligibility. Also, hearing-impaired children tend to have a better speech intelligibility when their lip reading abilities were better.

On the production side speech intelligibility has been studied in relation to segmental and suprasegmentaI errors. Errors involving individual speech phonemes, i.e. segmental errors have been studied by Hudgins and Numbers, 1942; Nober, 1963; Markides, 1970; Smith, 1973; McGarr, 1980; Ravishankar, 1985; etc. These studies suggest a negative correlation between the frequency of segmental errors and intelligibility, i.e. the higher the incidence of segmental errors the poorer the intelligibility of speech (Parkburst and Levitt, 1980). However, most of these studies have been correlational studies, where the effect of correction of certain errors in speech, has been studied. In such studies, the researcher does not have full control over speech. It is likely that, parameters other than those under study also varied with therapy. and these contribute to the intelligibility of speech. These findings have been supported by several studies on acoustic features of speech of the hearing-impaired (Calvert, 1961; Monsen, 1974, 1976a, b, c; Rothman, 1976).

Both consonant and vowel errors have long been recognized in the speech of the hearing-impaired. Consonant errors include, voicing errors, substitution and omission, while vowel and diphthong errors include, substitution and omission, while vowel and diphthong errors include, substitution, neutralization of vowels, diphtongization of vowels, etc. Monsen (1978) examined the relationship between intelligibility, and (a) four acoustic variables of consonant production (b) three acoustic variables of vowel production, and (c) two measures of prosody to find the variables which were highly correlated with intelligibility. He found VOT and the second format frequency to be significant.

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 positions consonant substitution and unidentifiable or gross distortions of the intended phonemes (Levitt, et al., 1980).

TIMING

1. Rate : Physical measures of speaking rate have shown that profoundly hearing-impaired speakers on the average take 1.5 to 2.0 times longer to produce the same utterances as do

normal hearing speakers (Boone, 1966; Hood, 1966; Howorth, 1965; Voelker, 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 production have often differed by a factor of two or more (Hood, 1966). Nikerson, et al. (1974) studied 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/minute.

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

a. Increased duration of phonemes, and

b. Improper and often prolonged pause within utterances (Gold, 1980)

2. Increased Duration of Phonemes : The duration of a phonemes bears important information in the perception of a speech message. Duration changes in vowels serve to differentiate not only between vowels themselves but also between similar consonants adjacent to those vowels (Raphel, 1972; Gold, 1980). There is a general tendency towards lengthening of vowels and consonants in the deaf (Angelocci, 1962; Boone, 1966; Levitt, et al. 1974; Levitt and Parkburst, 1978; Sheela, 1988: Rasitha, 1994).

Calvert (1961) was among the first to obtain objective measurements of phonemic duration in the speech of hearing-impaired by spectrographic analysis of bisyllabic words. This study showed that hearing-impaired speakers extend the duration of vowels, fricatives and the closure period of plosives upto 5 times the average duration for normal speakers. Monsen (1946) studied 12 deaf and 6 normal hearing adolescents as they read 56 CVCs words containing the vowels /i/ or/ I/. He found that the deaf subjects tend to create mutually exclusive durational classes for the two vowels, such that, the duration of one vowel could not approximate that of the other, even when they occurred in the presence of different consonants. For the normal subjects, the duration of /i/ was always long 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 strategies to interpret the speech that was heard.

The vowel duration also varies with reference to the voice-voiceless distinction of the following consonant. The hearing-impaired fail to produce the 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 individuals matched for age and sex. The result 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 medical 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 weru around 200 msecs, 195 msecs. and 185 msecs. respectively. In the hearing-impaired speakers

/i/ /u/ tended to be longer than in normal speakers and the vowel /a/ tended to be either longer or shorter when compared to the length of the vowel/a/ in normal speaker.

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 hearing-impaired speakers, vowel /a/ was shorter than vowel /i/ and /u/.

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

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

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

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

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

I) 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 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 smaIler, in the deaf chi Id's speech.

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

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 suprasegmentaI 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 still observed.

3. Pauses : Pauses have been found to be inserted at syntactically inappropraite boundaries. Such as between two syllables in a bisyllabic word or within phrases by the hearing-impaired speakers (Osberger and McGarr, 1980; Sheela, 1988; Jagadish, 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. Boothroyd, et al. (1974) considered that within phrase pauses were more serious problem than between phrase pauses in deaf speakers.

The inappropraite 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. In spite of these deviencies, 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.

4. Voice Quality : There seems to be general agreement that the deaf speakers have a distinctive voice quality (Bodycomb, 1946; Calvert, 1962; Boone, 1966). However it is not easy to define this characteristic voice quality of the hearing-impaired. Hearing-impaired are often reported to have a breathy voice qual i ty. Hudgins (1937) and Peterson (1946) attributed this largely to inappropraite positioning of the vocal cords and poor control of breathing during speech. A large glottal opening in the hearing-impaired may be due to the failure of the vocal cords to close properly. This result in 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 deaf persons speech. A few of them include tense, flat, breathy, harsh, throaty, etc. he also attempted to determine if the speech of deaf persons is distinguishable on the basis of quality from that of people with normal hearing. He had teachers of the deaf attempt to determine by listening whether the recorded speech 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 breathy voice or by normal hearing speakers. Isolated vowels from which on set and termination characteristics had been clipped could not be distinguished as to source, but the sources of the sentences were identified with 70% accuracy. Calvert (1971) concluded that deaf voice quality is identified not only on the basis of relative intensity, fundamental frequency and the harmonics, but also by the dynamic factors of speech such as transition gestures that change from one articulatory position into another.

5. Pitch and Intonation

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 may be characterized by

   a) Little variation in Fo resulting in flat and monotonous speech
   b) Excessive or erratic pitch variation

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; Calvert, 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 (19660, Shukla (1987), etc.

These differences may vary as a function of the age or sex of the hearing-impaired speakers. While these were no significant differences in average Fo between young normal hearing and hearing-impaired children aged 6-12 years (Boone, 1966; Green, 1956; Monsen, 1979), differences have been reported between groups of older children (7-18 years old males). Osberer (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.

Meckfessel 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-pubertaI males. However, Greene (1956) found similar value for the two groups. Gi Ibert 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 I iterature 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 values for the hearing and hearing-impaired male speakers overlapped for the last half of the utterance" (Osberger, 1981).

Rajanikanth (1986) reported that when compared to normals the hearing-impaired, in general. showed a higher FFS. He also noted that there was a significant 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 articuIators. 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 intension 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.

Fo Variation :

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

a) Lack of variation of Fo, and
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; Carlvet, 1962; Martony, 1968; Nandyal. 1981). This would result in the monopitch observed in the speech of the hearing-impaired.

A particular problem is that of inappropraite 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 them 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 (Martone, 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 net simply normal variations that have been some what exaggerated but, rather, pitch breaks and erratic changes that do not serve the purpose of intonation. These speakers may raise or lower the Fo by 100 Hz or more, within the same utterance. These are reports that often, after a sharp rise in Fo tne hearing-impaired speaker loses all phonatory control and thereafter there is a complete cessation of phonation (Smit.i, 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 contours 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 onwords of short duration. The Fo change may be more than 210 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, fol lowed 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" (Rajanikanth, 1985).

6. 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 thee 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 nonliner 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 above studies it is clear that pitch deviation is present in the speech of the hearing-impaired. The abnormal pitch variation have been considered to be the major cause of faulty intonation in the hearing-impaired. There are also evidences which suggest that the hearing-impaired individuals know and use some of the rules as used by the normal speakers.

7. Velar Control : Improper control of velum has long 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. Hyponality, he suggests, may be more prevalent among people with conductive loss than those with sensori-neuraI loss because nasal sounds may appear excessively loud to the former due to the transmittabi I ity of nasal resonances via bone conduction. Individuals with sensory-neural loss on the other hand may welcome the additional cues provided by the nasal resonances and therefore tend to nasalize sounds that should not be nasalized.

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 nasal ity may be affected by factors in addition to the activity of the velum. Some researchers have suggested that such factors as misarticuI ation, pitch variation and speech tempo affect the proper judgement (Coil ton and Cooper, 1968).

For these reasons, objective measures that correlate with the velar activity are put forward. Acoustic properties of nasal sounds that have been investigated include shifted and split first formant (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 nostri Is Fletcher, 1970; Shelton, Knox, Arudt and Elbert, 1967) and measurement of the vibration on the surface of the nose

(Holbwook and Crawford, 1970: Stevens, Kalikow and Willemain, 1974).

Sheela (1981) studied the effect of computer correction of some of the temporal aspects in the speech of the hearing-impaired on speech intelligibility. She studied eight children, four normal and four hearing-impaired. The age group was 8-10 years. The hearing-impaired children were having bilateral hearing loss of 70 dB or greater. The test materials consisted of eight bisyllabic Kannada words. The recorded words were digitized and acoustic analysis was carried out to obtain the vowel duration, word duration. Fo, F1, F2, F3. BW1, BW2 and BW3. Later the correlation of vowel duration, pauses and Fo were made in the speech of the hearing-impaired.

Results revealed that on the average the hearing-impaired subjects had -

1) Longer vowel duration when compared to the normals.
2) Intersyllable pauses were present in three of the hearing-impaired children.
3) Total duration of words was longer.
4) Average fundamental frequency was higher.
5) F1 and F2 was higher than normals and F3 was smaller.

Jagadish (1989) studied the effect of computer correction of some of the temporal aspects in the speech of the hearing-impaired on speech intelligibility. He studied six children, three normal hearing and three hearing-impaired aged between 9-12 years. The hearing-impaired children were having bilateral hearing loss of 70 dB or greater and without only additional handicaps. The test material consisted of eight bisyllable words in Kannada. Speech samples were recorded and the acoustic analysis was done to find the vowel duration, word duration, Fo, formant frequencies and bandwidth. The corrections of those parameters where there were significant differences between the values of the normal hearing group and the hearing-impaired group were done. The parameters corrected were, vowel duration and pause and the combination of these two parameters.

The results of the study indicated that -

1) Vowel duration were longer in the speech of the hearing-impaired subjects than for the normal hearing subjects.

2) Intersyllabic pauses were present in hearing-impaired and were absent in the normals.

3) Total duration of words produced by the hearing-impaired subjects were longer.

Thus it is seen that the speech of the hearing-impaired is characterized by several errors, which make it highly unintelligible. Even thoughit is important to study the acoustic characteristics of speech of the hearing impaired, only very few attempts have been made to study this in hering impaired children speaking Indian languages. There are nostudies speech of Telugu speaking hearing impaired. Hence, the spectrographic parameters such as word duration, vowel duration, fundamental frequency. formant frequencies and bandwidths of Telugu speaking hearing-impaired children were taken up for study.

METHODOLOGY

The main objective of this study was to analyse the acoustic characteristics of speech of Telugu speaking hearing impaired children who are using hearing aid and attending special school for deaf. The acoustical analysis of speech was done to obtain values of word duration, vowel duration, formant frequencies (Fl, F2, F3) in vowels, bandwidth characteristics (Bl, B2 and B3) in vowels, fundamental frequency in vowels and interword pause duration.

Subjects and Test Material

Thirty normal and thirty hearing impaired children between 7-11 years were selected for the study. Each group consisted of fifteen males and fifteen females.

The hearing impaired children were selected from the special schools for the deaf at Secunderabad on the criteria that the child should

(1) be in the age range of 7-11 years.

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

c) be able to read simple (VCV) bisyliabic words in Teiugu

d) have no additional handicaps other than that are directly related to the hearing impairment.

It must be noted that all the hearing impaired children chosen had receive(d) special education at special schools for the deaf and were regular users of hearing aid. All the children used oral speech mode for communication.

Thirty normal children were selected as control group to match teach hearing impaired subject in terms of age and sex. These children of the control group had hearing within normal limits on audiological testing and they were choosen from the regular primary school at Secunderabad and they too did not have any additional handicaps.

Test Material

The test material consisted of 10 bisyllabic Telugu words having the short vowels /a/ /i/ /u/ /e/ and/o/ and long vowels /a:/ /i:/ /u:/ /e:/ and /o:/. These words were simple so that both normal and hearing impaired children without read them which were written on cards (size 6" x 4").

Recording Procedure

The speech samples of all the children were recorded in a quiet room of the school building using a tape record. All subjects were comfortably seated and microphone was kept at a distance of 10 cms. from the mouth of the subjects. They were instructed to read the words written on the card presented to them by the experimenter. The experimenter presented one card at a time to the child. Each child read the card at a comfortable loudness level. Three readings of each word by each child. Words written on this was recorded on a C-90 sony cassette. Thus all the words read by all the subjects were recorded. But out of three trials one which was considered to be most intelligible was selected for analysis purpose for each subject of both the groups. Subject was made to repeat after the experimenter, whenever the subject had difficulty in reading the target word.

Instrumentation
(*Block* diagram)

```
+---------+  +-----------+  +---------+  +-------------+
| SI Unit +--+ A/D-D/A   +--+Computer +--+Amplifier and|
+---------+  | converter |  +---------+  | speaker     |
             +-----------+               +-------------+
```

Analysis of Data

The computer software Speech Science Lab (SSL)" and Vaghmi (both from voice and speech systems) loaded on a PC with 100 MHz pentium processor with SIU and AD/DA converter were used for analysis of the data. For all analysis a block duration of 30 mecs and a block shift of 10 msec, was used. The speech samples were digitized using 12 bit ADC/DAC load at the sampling frequency of 16000 Hz and were stored on computer hard disk. The acoustic parameters were measured using wide band spectrogram (600 Hz). The words were, analysed to obtain the following parameters from each word.

- Total word duration
- Vowel duration of both short and long vowels
- Duration of intra word pauses if any
- Formant frequencies (Fl, F2 and F3) of short and long vowels
- Bandwidth characteristics Bl, B2 and B3) of short and long vowels.
- Fundamental frequency of all short and long vowels.

1. Total Word Duration

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

2. Vowel duration of both short and long vowels

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

3. Duration of intra word pauses

The DISPLAY programme of SSL was used from the waveform a gap between two periodic signals were highlighted using cursors. The highiighted portion was heard. If the silence was perceived, then it was taken as pause. Once, this was confirmed, the duration of the highiighted portion was rad from the display on the monitor directly.

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4. Extraction of Formant frequencies

To extract the vowel formant frequencies (Fl, F2 andF3), the spectrogram of each utterance using the "SPGM" programme of the software Speech science Lab was obtained. After identifying the target vowel, the cursor was placed in the middle of the vowel portion so as to avoid the formant transitions and the formant frequencies were determined by using sectioning method (the linear predictive coding LPC method). This was done with 18 LPC coefficients. By moving the horizontal cursor, on the display of sectioned portion of the signal, to the peaks the (lowest Fl, next F2 and the next peak F3) formants frequencies were read digitally from display on the monitor.

5. Determining Fundamental frequency

For measurement of fundamental frequency the INTON programme in Vaghmi was used. The utterances were first analysed and then displayed to obtain the Fo contour and also the mean value of Fo of the word analysed.

Thus all the utterances of all subjects of both the groups were analysed to obtain word duration, vowel duration pause duration, formant frequencies (Fl, F2 and F3) and fundamental frequency.

Problems Faced While Analysing

Some of the hearing impaired subjects tended to distort. Most of the vowels which affected the measurement of the formant frequencies.

Statistical analysis

Descriptive statistics consisting of mean, standard deviation, minimum and maximum values were obtained for ail the parameters. To check whether there were any significant differences between the values of the normal hearing group and hearing impaired group. Student ' t' test was applied.

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Statistical analysis

Descriptive statistics consisting of mean, standard deviation, minimum and maximum values were obtained for all the parameters. To check whether there were any significant differences between the values of the normal hearing group and hearing impaired group. Student 't' test was applied.

Photograph showing the instruments used for analysis of speech

RESULTS AND DISCUSSION

This investigation was aimed at studying the acoustic and temporal parameters of speech in Teiugu speaking hearing impaired subjects. To determine the deviations of the hearing-impaired speech from normal subjects matched in terms of age, sex and language were also analyzed and compared.

Ten VCV words uttered by thirty hearing impaired children and thirty normal children, one out of three trials were used for spectrographic analysis. The parameters noted were

1. Word duration
2. Vowel duration of short vowels /a/, /i/, /u/, /e/, /o/ and long vowels /a:/, /i:/, /u:/, /e:/, /o:/.
3. Pause duration within the words.
4. Formant frequency characteristics (Fl, F2 and F3) of above mentioned vowels.
5. Fundamental frequency of above mentioned vowels.
6. Band width characteristics (Bl, B2 and B3) of above mentioned vowels.

Descriptive and inferential statistical analysis were carried out. The results are presented below:

WORD DURATION

Table la and Table lb provide mean, standard deviation and range of word duration for male and female subjects of both the normal and hearing impaired groups respectively. Graph-la and Graph-Ib provide mean values of the same.

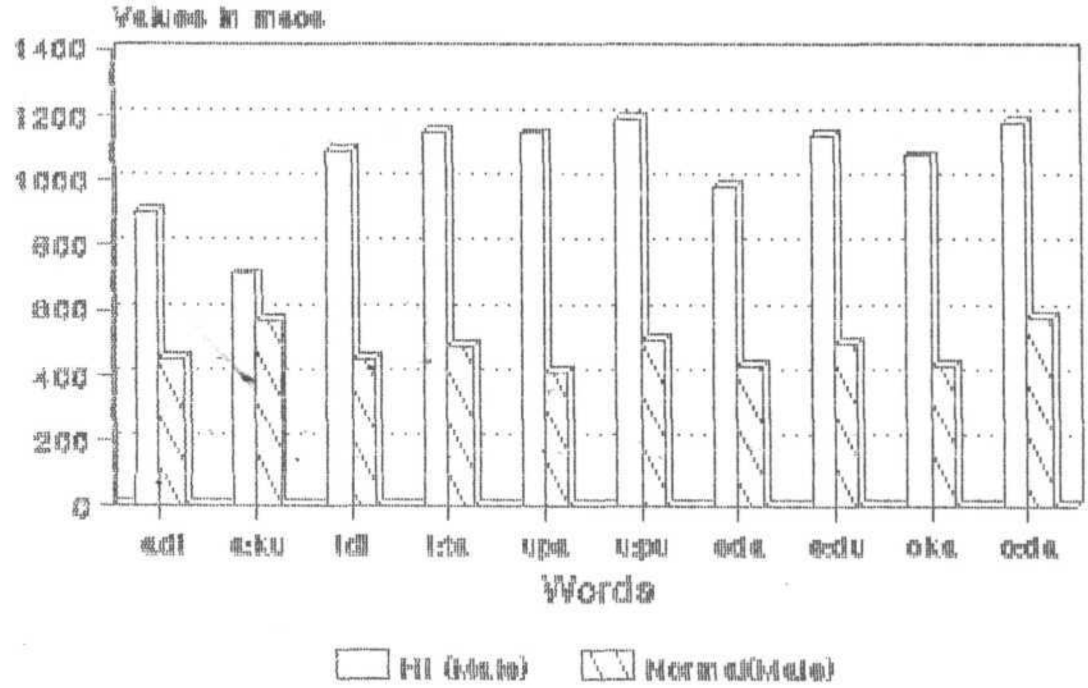
Table-la : The Mean, SD, Range and mean difference values of word duration in male hearing impaired and normal male group in msec.

Male words	Hearing Impaired			Normals			Mean diff HI & Nors
	Mean	SD	Range	Mean	SD	Range	
adi*	900	(436)	712-1096	450	(180)	358-612	+450
a:ku*	710	(338)	506-894	570	(226)	412-825	+140
idi*	1090	(464)	907-1224	446	(238)	258-726	+652
i:ta*	1150	(563)	976-1426	485	(242)	292-712	+665
upa*	1145	(574)	982-1348	410	(212)	316-682	+735
u:pu*	1190	(566)	1014-1392	505	(318)	395-795	+685
eda*	980	(436)	812-1196	425	(210)	390-715	+555
e:du*	1137	(574)	1018-1383	495	(195)	310-785	+642
oka*	1075	(583)	913-1228	432	(198)	288-728	+643
o:da*	1175	(485)	1012-1378	580	(225)	414-868	+595

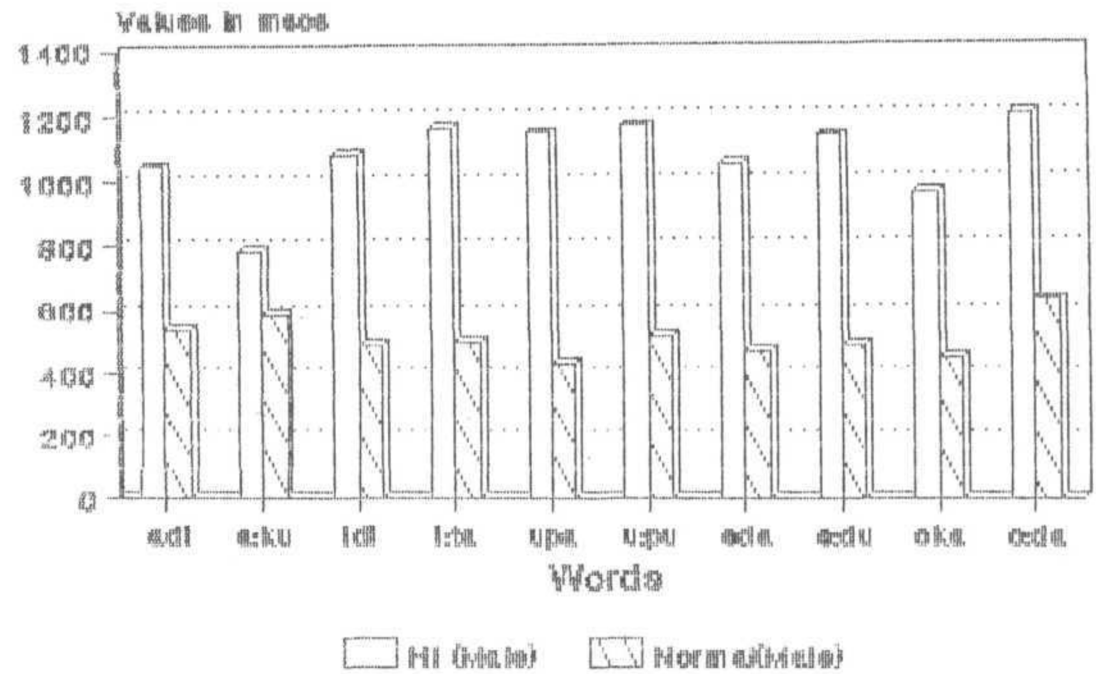
* Significant difference between the means at 0.05 level.

The mean word duration produced by the hearing impaired were found to be higher than that of normals. This was found

Gr.1a Mean word duration of HI and normal for (Male)



Gr.1b Mean word duration of HI and normal (Female)



to be statistically significant. This agrees well with results reported by Sheela (1988), Rajanikanth (1986), Jagadish (1989), Rasitha (1994) and Rahul (1997), even though they had studied different language i.e., Kannada and Malayalam.

The mean word duration produced by the male hearing impaired children had longest duration of 1190 msec. for /u:pu/ and followed by words /o:da/, /i:ta/, /upa/, /e:du/ /idi/, /oka/, /eda/, /a:ku/, /adi/, /a:ku/ with word durations of 1175 msecs, 1150 msecs., 1145 msec, 1137 msecs., 1090 msecs., 1075 msecs., 980 msecs, 900 msecs respectively. Whereas normal males had the word duration in the order of /o:da/, /a:ku/ /u:pu/, /e:du/ /i:ta/, /adi/, /idi/, /oka/, /eda/ and /upa/ with word durations of 580 msecs, 570 msecs., 505 msecs, 495 msec, 485 msecs., 450 msec. , 446 msec. , 432 msec. , 425 msecs. , and 410 msecs., respectively. Significant differences between normal and hearing impaired male subjects in the mean values of word duration were found for in all the words except for the word /a:ku/. The differences in mean values being 450 msecs., 140 msecs., 354 msec, 564 msecs., 733 msecs., 680 msecs., 650 msecs., 632 msecs., 588 msecs., and 645 msecs., for words

/adi/ /a:ku/, /idi/, /i:ta/, /upa/, /u:pu/, /eda/, /e:du/, /oka/ and /o:da/ respectively.

Table lb: The Mean, SD, Range and mean difference values of. word duration in female hearing impaired and normal female group in msecs.

Female words	Hearing Impaired			Normals			Mean diff HI & Nors
	Mean	SD	Range	Mean	SD	Range	
adi*	1045	(565)	736-1206	535	(226)	386-963	+510
a:ku	785	(536)	622-988	585	(258)	384-872	+150
idi*	1080	(620)	736-1305	488	(296)	298-763	+592
i:ta*	1160	(513)	712-1316	495	(185)	398-843	+665
upa*	1145	(543)	812-1218	425	(213)	354-768	+720
u:pu*	1165	(488)	763-1316	515	(316)	326-783	+650
eda*	1050	(496)	696-1406	465	(264)	318-813	+585
e:du*	1135	(525)	813-1383	485	(188)	309-808	+650
oka*	960	(425)	626-1206	445	(196)	316-764	+515
o:da*	1195	(622)	736-1409	630	(288)	396-914	+565

* Significant difference between the means at 0.05 level.

The mean word duration produced by female hearing impaired children had longest durtion of 1193 msecs. for /o:da/ and followed by 1165 msecs, 1160 msecs, 1145 msecs.,1135 msecs, 1080 msecs, 1050 msecs, 1045 msecs, 960 msecs, 720 msecs, for words /u:pu/, /i:ta/, /upa/, /e:du/ /idi/, /eda/, /adi/, /oka/, /a:ku/ respectively, whereas the normal females followed the order of /o:da/, /a:ku/, /adi/,

/u:pu/, /i:ta/, /idi/, /e:du/, /eda/, /oka/, /upa/ with word durations of 630 msecs, 495 msecs, 488 msecs, 485 msecs, 465 msecs, 445 msecs, 425 msecs, respectively.

The differences in mean values being 510 msecs., 150 msec. , 592 msecs. , 665 msecs. , 720 msecs. , 650 msecs. , 585 msecs. , 650 msecs. , 515 msecs and 565 mscs., for words /adi/, /a:ku/, /idi/ /i:ta/, /upa/, /u:pu/ /eda/ /e:du/ /oku/ and /o:da/ respectively.

Significant differences between the normal and hearing impaired female subjects in mean values of word duration were found for in all the words except for /a:ku/.

A comparison was also done within the groups for both normal and hearing impaired groups. It was found, that there was no statistically significant difference between males and females in both the groups.

The hypothesis stating that there is no significant difference between the mean word duration of the hearing impaired and normal children, both in case of males and females was rejected for all the words except /a:ku/ in both males and females.

The hypothesis stating that there is no significant difference between normal males and normal females, for all the words, was accepted.

The hypothesis stating that there is no significant difference within the hearing impaired group i.e. between males and females, was accepted.

Durational Characteristics of Vowels

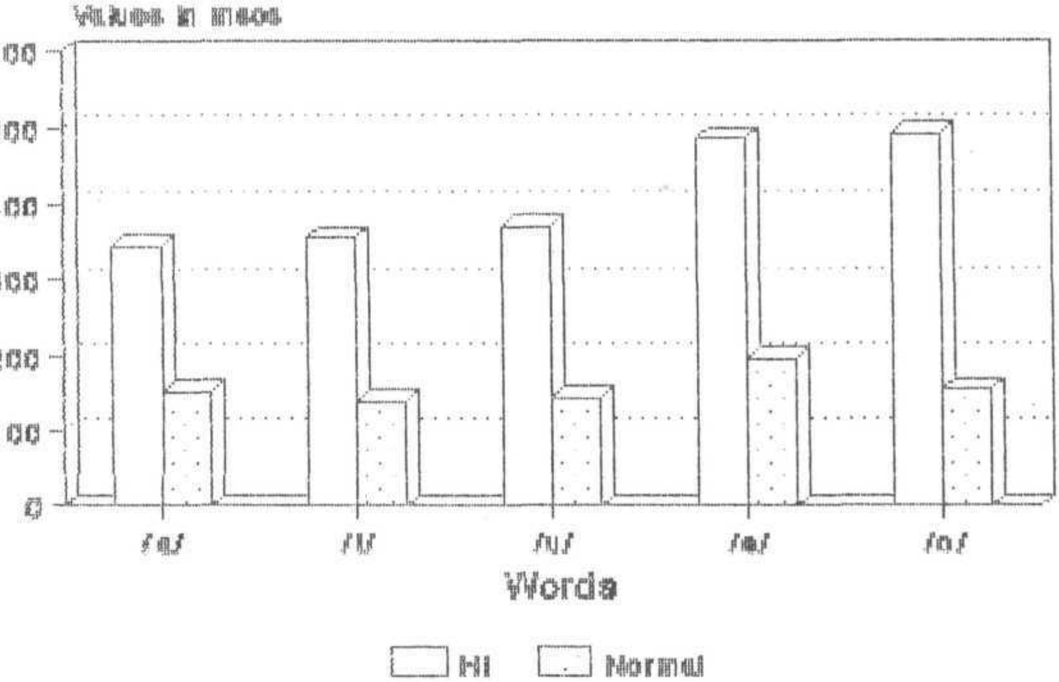
Table 2a and Table 2b provide mean, standard deviation and range of durations of short and long vowels produced by male hearing impaired and normal male groups respectively. Graph 2a and Graph 2b provided mean values of the same.

Table 2a: The Mean, SD, Range and mean difference values of short vowel duration in male hearing impaired and normal male group in msecs.

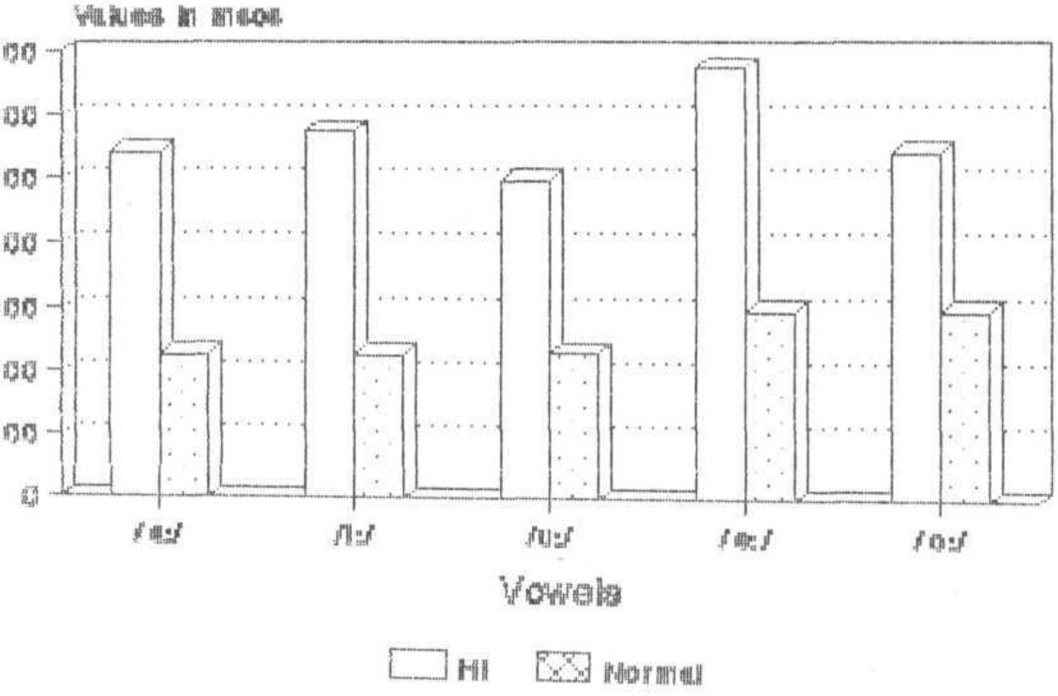
Male Vowels	Hearing Impaired			Normals			Mean diff HI & Nors
	Mean	SD	Range	Mean	SD	Range	
/a/*	345	(146)	244-432	152	(36)	98-208	+ 193
/i/*	356	(165)	203-449	138	(48)	95-284	+ 218
/u/*	372	(137)	221-485	143	(108)	72-205	+ 229
/e/*	485	(282)	160-530	194	(73)	112-275	+ 291
/o/*	490	(254)	276-560	154	(48)	93-251	+ 336

* Significant difference between the males at 0.05 level

Gr.2a Mean vowel duration of HI and normal for short vowel (Male)



Gr.2b Mean vowel duration of HI and normal for long vowels (Male)



The short vowel duration produced by the male hearing impaired. Children had longest duration of 490 msec, for /o/ followed by vowels /e/, /u/, /i/, and /a/ with values of 485 msec. 372 msec. 356 msec, and 345 msec., respectively. Whereas normal males had the durations in the order of /e/ > /o/ > /a/ > /u/ > /i/ with values of 194 msec. 154 msec. > 152 msec. 143 msec. and > 138 msec. Thus, the hearing impaired group followed more or less the same pattern as that of control group. Significant differences between normal males and males hearing impaired in group mean values of the duration of short vowels were found in ail the vowels with differences in mean values being 193 msec, 218 msec, 229 msec, 291 msec. and 338 msec. for vowels /a/, /i/, /u/, /e/ and /o/ respectively.

Table 2b: The Mean, SD, Range and Mean difference values of long vowel durations in male hearing impaired and normal male group in msecs.

Male Vowels	Hearing Impaired			Normals			Mean diff HI & Nors
	Mean	SD	Range	Mean	SD	Range	
/a:/*	543	(205)	336-1010	228	(76)	160-310	+ 315
/i:/*	575	(183)	260-930	229	(60)	162-365	+ 346
/u:/*	497	(169)	295-765	230	(69)	193-352	+261
/e:/*	675	(290)	386-785	298	(78)	210-480	+377
/o:/*	543	(189)	332-886	297	(67)	190-288	+ 246

* Significant difference between the males at 0.05 level

The duration of iong vowel duration produced by the males of hearing impaired group had longest duration of 675 msec. for /e:/ and followed by vowels /i:/ /u:/ /a:/ and /u:/ with values of 575 msec, 543 msec, 543 msec, 497 msec, respectively. Whereas the normal male subjects had the durations in the order of /e:/ > /o:/ > /u:/ > /i:/ > /a::/ with values of 298 msec. > 297 msec. > 236 msec. > 229 msec. > 228 msec. respectively. Significant differences between male hearing impaired and normal male subjects in mean values of duration of iong vowels were found for all the vowels with the differences in mean values being 315 msec, 346 msec, 261 msec, 377 msec, and 246 msec. for vowels /a:/, /i:/, /u:/, /e:/ and /o:/ respectiveiy.

Table 3a and Table 3b provide the durations of short and long vowels produced by female hearing impaired and normal female subjects. Graph 3a and Graph 3b provid mean values of the same.

The duration of short vowel produced by the female hearing impaired children had longest duration of 513 msec, for /o/ followed by vowels /e/, /i/, /u/ and /a/ with the values of 498 msec. 376 msec, 356 msec, and 354 respectiveiy. Whereas the normal females had the durations in the order of /e/ > /o/ > /u/ > /a/ /i/ with the values of 176 msec. 148

Tabie-3a : The Mean, SD, Range and mean difference values of. short vowel duration in female hearing impaired and normal female group in msec.

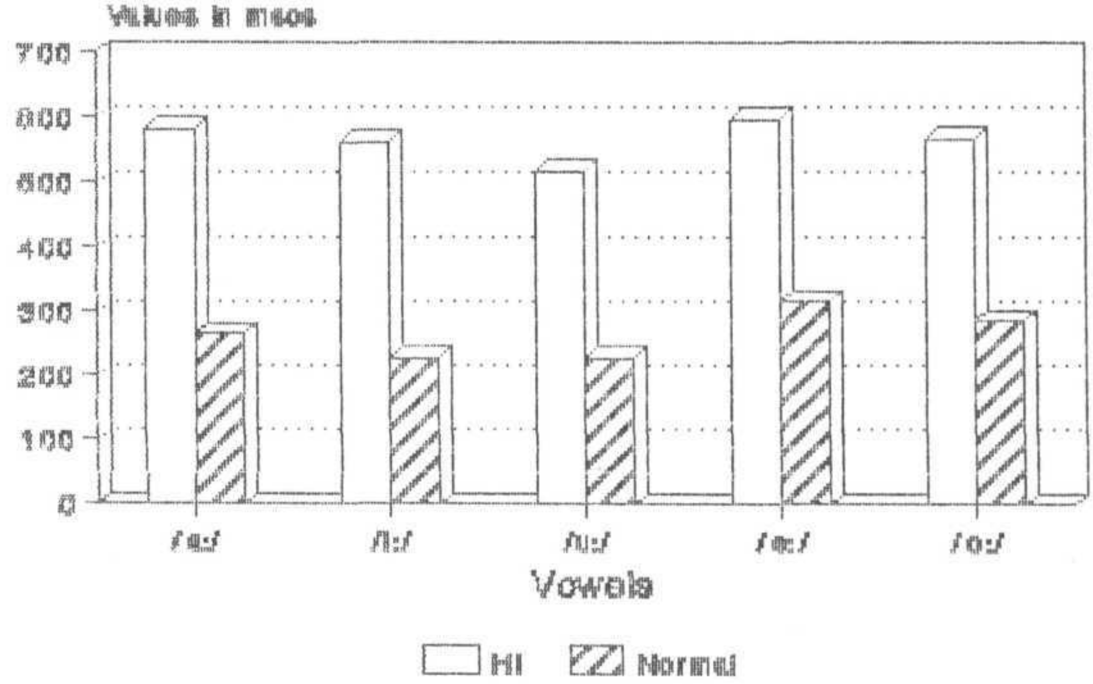
Female Vowels	Hearing Impaired Mean	SD	Range	formals Mean	SD	Range	Mean diff HI & Nors
/a/*	354	(218)	266-584	142	(36)	50-180	+212
/i/*	376	(168)	284-486	136	(29)	70-170	+240
/u/*	356	(139)	28-5121	145	(49)	50-220	+211
/e/*	498	(256)	28-5286	176	(58)	100-320	+322
/o/*	513	(288)	312-616	148	(92)	80-250	+365

* Significant difference between the males at 0.05 level

msec., 145 msec., 142 msec. and 136 msec. respectiveiy. Significant differences between female hearing impaired and normal female subjects in mean values of duration of short vowels were found for ail the vowels with the differences in mean values being 212 msec, 240 msec, 211 msec, 322 msec, and 365 msec. for the vowels /a/, /i/, /u/, /e/ and /o/ respectiveiy.

The duration of long vowel produced by the female hearing impaired subjects had longest duration of 596 msec, for /e:/ and followed by /a:/, /o:/ /i:/ and /u:/ with the values of 584 msec, 569 msec, 564 msc. and 517 msec, respectively.

Gr.3b Mean vowel duration of HI and normal for long vowels (Female)



Gr.3a Mean vowel duration of HI and normal for short vowels (Female)

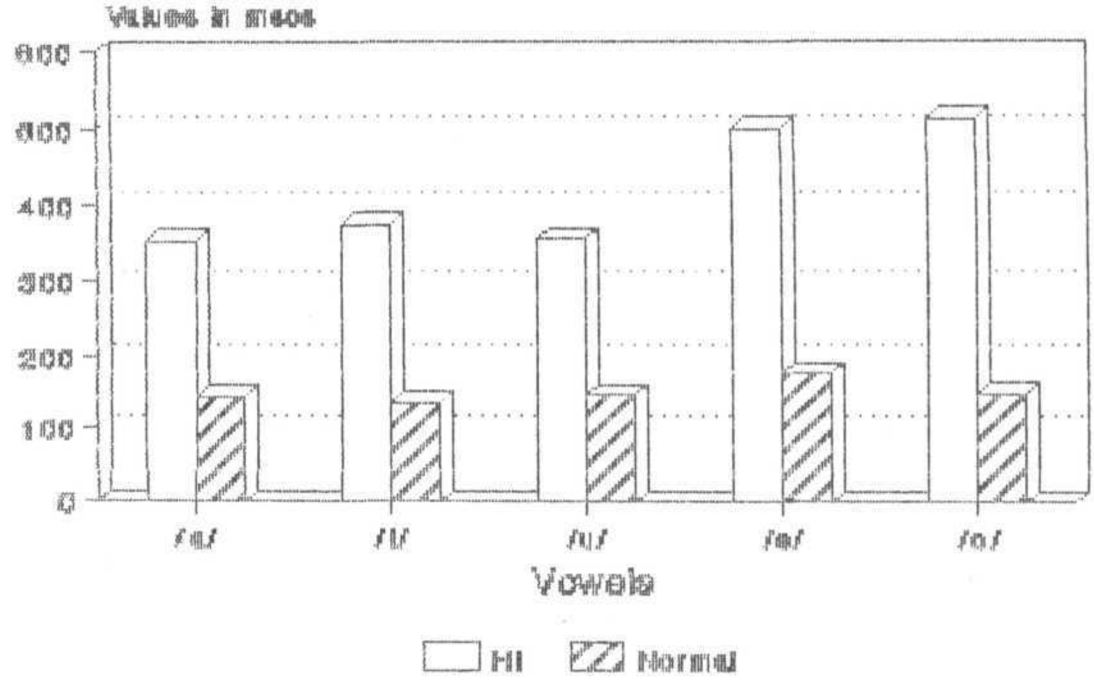


Table 3b: The Mean, SD, Range and mean difference values of long vowel duration in female hearing impaired and normal female group in msecs.

Female Vowels	Hearing Impaired			Normals			Mean diff HI & Nors
	Mean	SD	Range	Mean	SD	Range	
/a:/*	584	(260)	354-915	265	(69)	193-445	+319
/i:/*	564	(258)	265-865	228	(70)	140-386	+336
/u:/*	517	(353)	176-936	226	(79)	145-320	+291
/e:/*	596	(296)	178-945	315	(92)	154-480	+281
/o:/*	569	(295)	290-905	285	(53)	150-305	+284

* Significant difference between the males at 0.05 level

Whereas normal female subject had the durationai values in the order of /e:/ > /o:/ > /a:/ > /i:/ > /u:/ with the values of 315 msec., 285 msec. 265 msec. 228 msec, and 226 msec. Thus the hearing impaired group followed more or less the same pattern as that of control group. Significant differences between normal females and female hearing impaired subjects in mean values of long vowel duration were found for ail the vowels with the differences in mean values being 319 msec. 336 msec. , 291 msec., 281 msec., and 284 msec., for vowels /a:/, /i:/, /u:/, /e:/ and /o:/ respectively.

The results of durational characteristics of vowels of this study supported the results of the study of Rajanikanth (1986), Shukla (1987), Sheela (1988), Jagadish (1989), Sowmyanarayan (1992) i.e. the vowel duration produced by hearing impaired were higher than that of normals, even though they were of Kannada language.

A comparison was done within the groups for both males and females. In normals, it was found that there was a significant difference for /i/ between males and females. In hearing impaired there was no statisticaiiy significant difference, between males and females.

The hypothesis stating that there is no significant difference between the mean vowel, duration of the hearing impaired and normal children both males and females was rejected for all the vowels.

The hypothesis stating that there is no significant difference between normal males and normal females was accepted for all the vowels except for /i/.

The hypothesis stating that there is no significant difference between within the hearing impaired subjects both males and females was accepted with respect to all vowels.

Formant Frequency Characteristics of Vowels

Table 4a and Table 4b provide mean, standard deviations and range of Fl for short and long vowels in the speech of the male hearing impaired and normal male groups respectively. Graph 4a and Graph 4b provide mean values of the same.

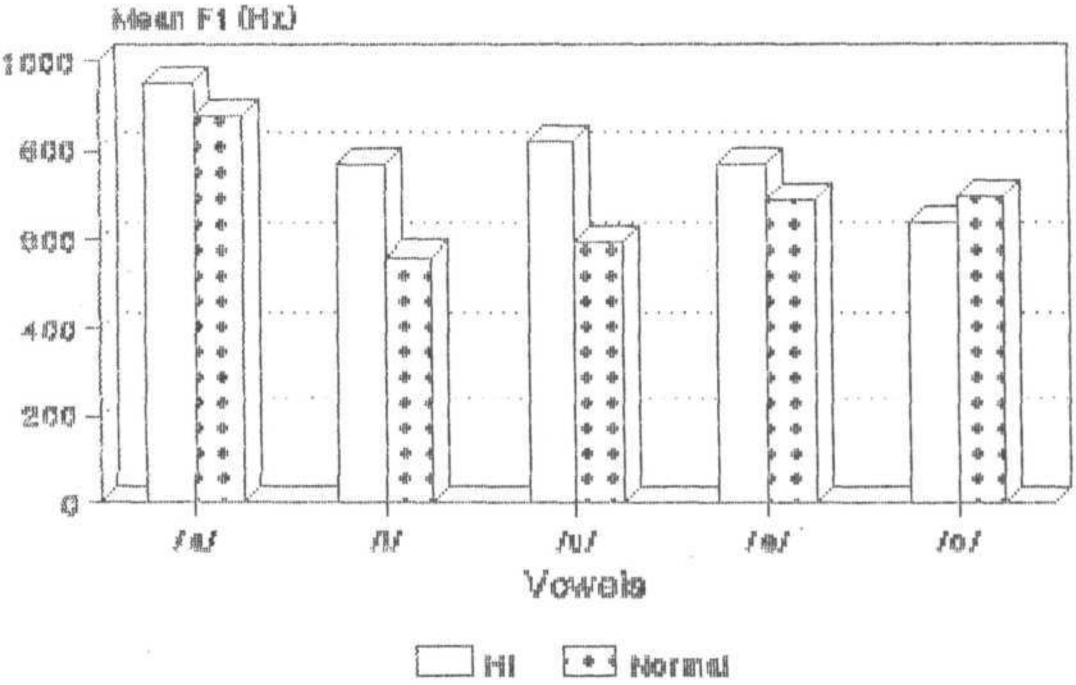
Table-4a: The mean, SD, Range and mean difference values of Fl of short vowels in male hearing impaired and normal male groups in (Hz).

Fl Male Vowels	Hearing Impaired			Normals			Mean diff
	Mean	SD	Range	Mean	SD	Range	HI & Nors
/a/	948	(176)	633-1216	878	(132)	645-1123	+70
/i/*	768	(210)	406-860	561	(123)	448-863	+207
/u/*	816	(180)	508-998	592	(168)	416-743	+224
/e/	766	(186)	492-947	688	(194)	516-918	+78
/o/	638	(168)	498-923	698	(189)	536-987	-60

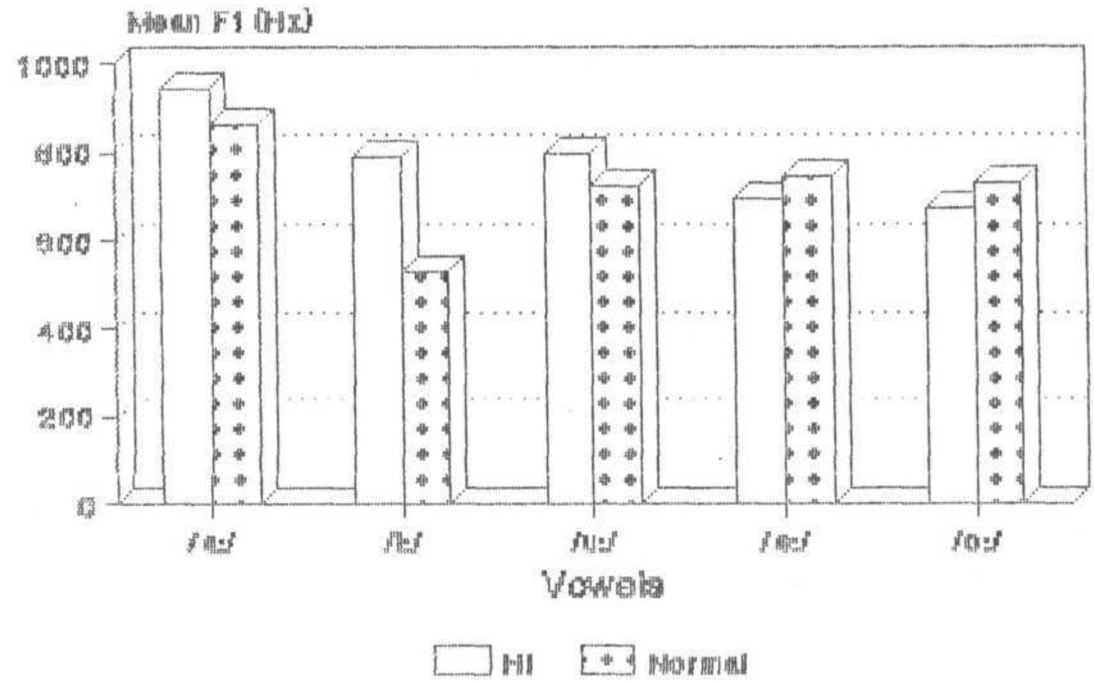
* Significant difference between the males at 0.05 level

The mean Fl values of all short vowels produced by the male hearing impaired subjects were found to be higher than that of the normal male group, (varying from 72 to 260 Hz) except for vowel /o/ (lower by 60 Hz). For */&/* the difference between the means of hearing impaired and that of normals was 70 Hz, for *lit* -207 Hz, for /u/ - 224 Hz and for /e/ 78

Gr.4a Mean F1 of HI and normal for short vowels (Male)



Gr.4b Mean F1 of HI and normal for long vowels (Male)



Hz. However significant mean difference between the groups was found only for the vowels /i/ and /u.

Table-4b: The mean, SD, Range and mean difference values of Fl of long vowels in male hearing impaired and normal male groups in (Hz).

Fl Male Vowels	Hearing Impaired			Normals			Mean diff HI & Nors
	Mean	SD	Range	Mean	SD	Range	
/a:/	938	(212)	650-1236	863	(223)	636-1198	+75
/i:/*	786	(118)	438-849	526	(138)	398-803	+260
/u:/	798	(196)	518-960	726	(116)	498-936	+72
/e:/	696	(186)	516-896	746	(113)	496-897	-50
/o:/	673	(213)	536-948	728	(119)	486-916	-55

* Significant difference between the males at 0.05 level

The mean Fl values of ail long vowels produced by the male hearing impaired were subjects found to be higher than that of normal male groups except for vowels /e:/ and /u:/ which were lower by 50 Hz and 55 Hz respectiveiy. The mean difference between the means of male hearing impaired to that of normal males for vowels /a:/, /i:/, and /u:/ were 75 Hz, 260 Hz and 72 Hz respectively. However significant mean difference was found for only vowel /i:/.

Table 5a and Table 5b provide mean, standard deviations and range of Fl for all short and long vowels in the speech of the female hearing impaired and normal female group respectively. Graph 5a and Graph 5b provide mean values of Fl for the same.

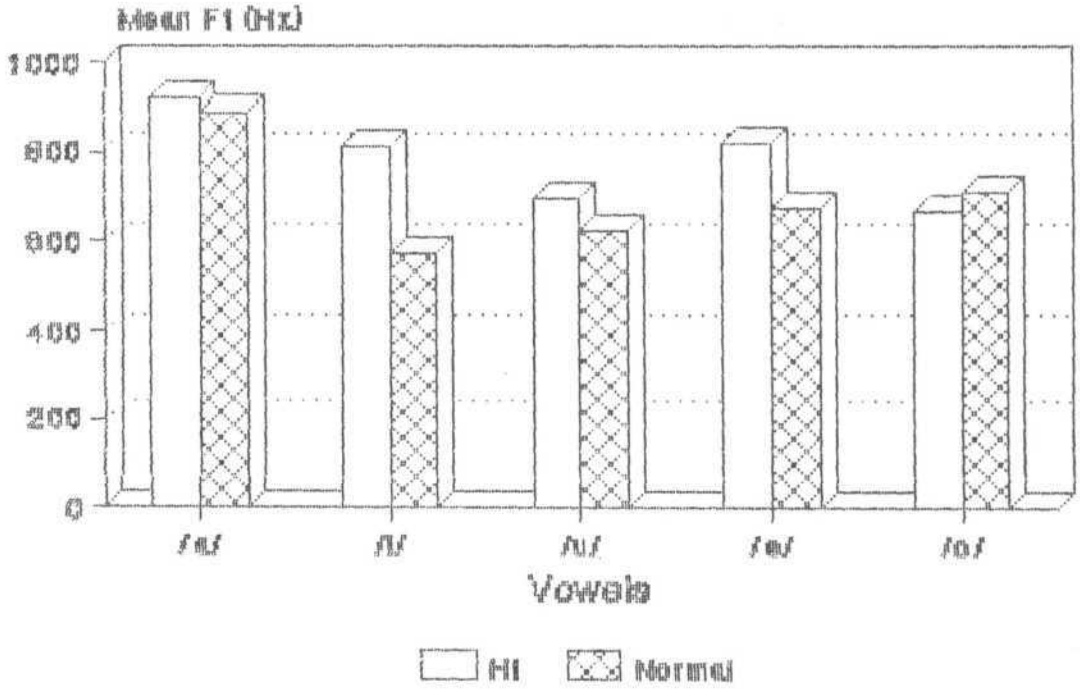
The mean Fl values of all short vowels produced by the hearing impaired female subjects were found to be higher than

Table 5a : The Mean, SD, Range and Mean difference values of Fl of short vowel in female hearing impaired and normal female groups in Hz

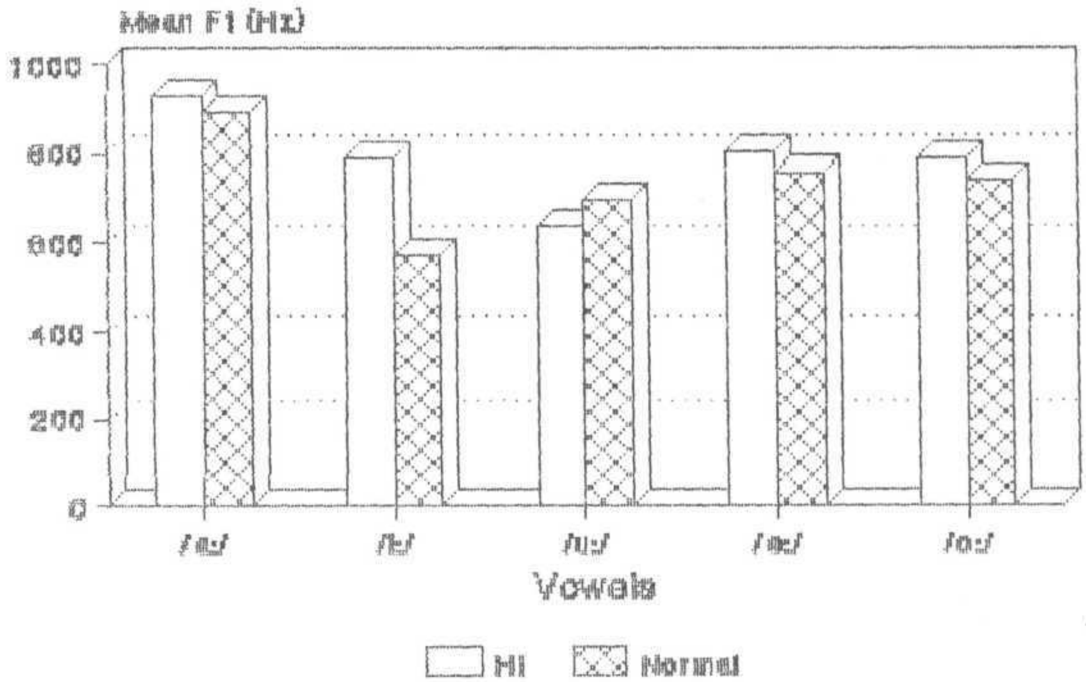
Fl Female Vowels	Hearing Impaired			Normals			Mean diff HI & Nors
	Mean	SD	Range	Mean	SD	Range	
/a/	916	(123)	638-1196	886	(138)	664-1264	+30
• /i/*	810	(216)	598-1096	569	(128)	449-911	+241
/u/	698	(136)	486-913	623	(138)	529-813	+75
/e/	816	(198)	593-1084	673	(116)	498-896	+143
/o/	668	(113)	515-898	710	(136)	598-969	-42

* Significant difference between the males at 0.05 level

that of the normal female subjects except for vowel /o/ which was lower by 42 Hz. The mean Fl differences between the hearing impaired females to that of normal females for vowels /a/ /i/ /u/ and /e/ were 30 Hz, 241 Hz., 75 Hz., and 143 Hz., Gr.5a Mean F1 of HI and normal for short vowels (Female)



Gr.5b Mean F1 of HI and normal for long vowels (Female)



respectiveiy. However significant mean differences were found for only /i/ and /e/.

The mean Fi values of long vowels /a:/, /i:/, /e:/, and /o:/ produced by the hearing impaired female were found to be higher than that of the normal females except for the vowel /u:/ which was lower by 60 Hz. The differences in mean Fl values between the hearing impaired female and normal females for long vowels /a:/,/u:/, /e:/, and /o:/ were 30 Hz, 220 Hz., 50 Hz., and 50 Hz., respectiveiy. However significant difference was found only for /i:/. The Fl results of this study supported the results of the study of Sheeia (1988) and Sowmyanarayana (1992) i.e. the Fl values in the vowels

Table 5b: The mean, SD, Range and Mean difference values of Fi of long vowel in female hearing impaired and normal female group in Hz.

Fl Female Vowels	Hearing Impaired			Normals			
	Mean	SD	Range	Mean	SD	Range	Mean diff HI & Nors
/a:/	923	(146)	612-1013	893	(210)	485-1186	+30
/i:/*	789	(227)	496-1010	569	(127)	416-812	+220
/u:/	638	(110)	413-843	698	(113)	463-869	-60
/e:/*	806	(113)	636-1198	756	(111)	498-916	+500
/o:/	786	(136)	516-936	736	(123)	496-936	+50

* Significant difference between the males at 0.05 level

produced by the hearing impaired were higher than that of normal subjects both in males and females.

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

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

The hypothesis stating that there is no significant difference between the mean values of Fl of hearing impaired males and females for all vowels was accepted.

The hypothesis stating that there is no significant difference between the mean values of Fl of normal subjects i.e., males and females for all vowels was accepted.

Second Formant Frequencies

Table 6a and Table 6b provide mean, standard deviation and range of F2 for short and long vowels in the speech of the hearing impaired male and normal male groups respectively. Graph 5a and Graph 5b provide mean values of the same.

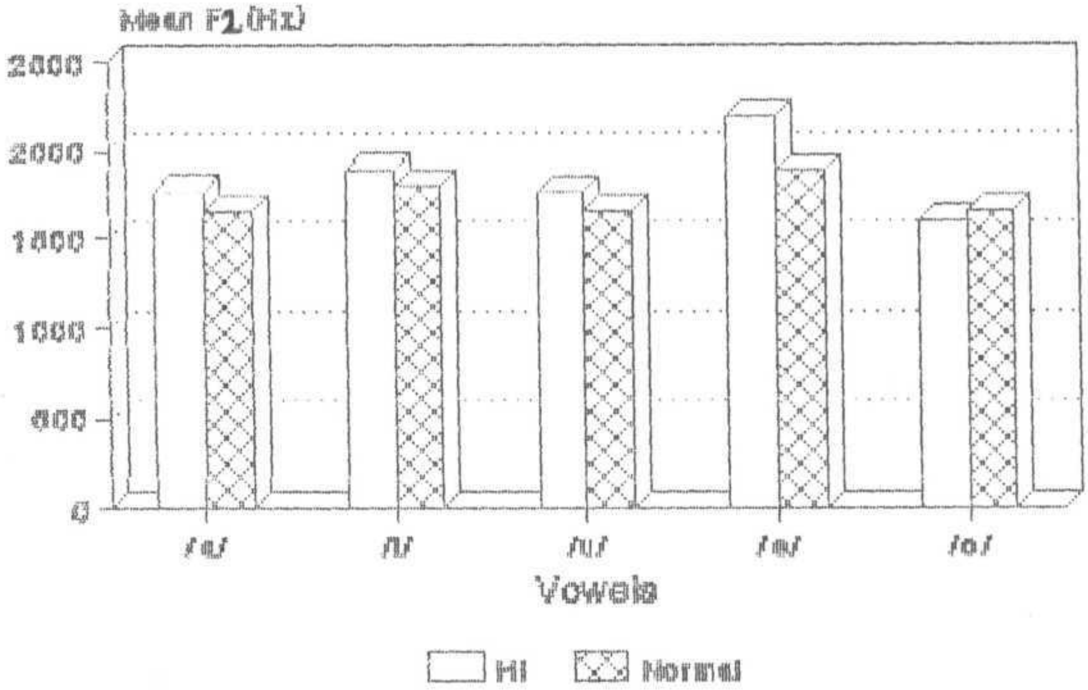
Tabie-6a : The man, SD, Range and mean difference values of F2 of short vowels in male hearing impaired and normal male groups (Hz).

F2 Males Vowels	Hearing Impaired			Normals			Mean diff HI & Nors
	Mean	SD	Range	Mean	SD	Range	
/a/	1765	(210)	1486-2109	1645	(138)	1187-2264	+ 120
/i/	1891	(268)	1346-2098	1785	(264)	1496-2089	+ 106
/u/	1760	(310)	1510-2196	1640	(276)	1396-1798	+ 120
/e/*	2185	(326)	1695-3446	1886	(253)	1535-2196	+299
/o/	1596	(264)	1286-1789	1645	(256)	1026-1968	-49

* Significant difference between the males at 0.05 level

The mean F2 values of all short vowels produced by the hearing impaired males were found to be higher than that of the normal male group except for vowel /o/ which was lower by 49 Hz. The difference in mean F2 between the hearing impaired and to that normal males for vowel /a/,/i/,. /u/,

Gr.6a Mean F2 of HI and normal
for short vowels (Male)



and /e/ were 120 Hz, 106 Hz, 120 Hz and 299 Hz respectively. However significant difference was found only for /e/.

Table 6b : The man, SD, Range and Mean difference values of F2 of long vowel in male hearing impaired and normal male groups (in Hz).

F2 Male Vowels	Hearing Impaired			Normals			Mean diff
	Mean	SD	Range	Mean	SD	Range	HI & Nors
/a:/	1683	(284)	1416-1898	1596	(210)	1364-1864	+87
/i:/	1853	(296)	1618-2113	1748	(269)	1505-2119	+105
/u:/*	1848	(310)	1498-1996	1576	(264)	1396-1948	+272
/e:/	1806	(287)	1438-2158	1896	(310)	1568-2029	-90
/o:/	1846	(315)	1563-2245	1735	(316)	1098-1976	+111

* Significant difference between the males at 0.05 level

The values of mean F2 of all long vowels produced by the hearing impaired male were found to be higher than that of the normal males except for vowel /e:/ which was lower by 90 Hz. The difference in mean F2 between the hearing impaired and normal males for vowels /a:/, /i:/, /u:/, and /o:/ were 81 Hz, 105 Hz, 272 Hz and 111 Hz respectively. However, significant difference was found only for vowel /u:/.

Table 7a and Table 7b provide mean standard deviation and range of F2 for short and long vowels in the speech of

Table-7a : The Mean, SD, Range and mean difference values of F2 of short vowel in female hearing impaired and normal female group in (Hz).

F2 Female Vowels	Hearing Impaired			Normals			Mean diff HI & Nors
	Mean	SD	Range	Mean	SD	Range	
/a/	1830	(185)	1490-2105	1650	(126)	1180-2310	+ 180
/i/*	1555	(370)	1090-2285	1855	(254)	1530-2060	-300
/u/*	1846	(260)	1610-1920	1620	(270)	1425-1830	+226
/e/*	2230	(285)	1685-3445	1950	(253)	1630-2090	+ 280
/o/	1525	(125)	1016-1895	1669	(154)	1010-1940	-135

* Significant difference between the males at 0.05 level

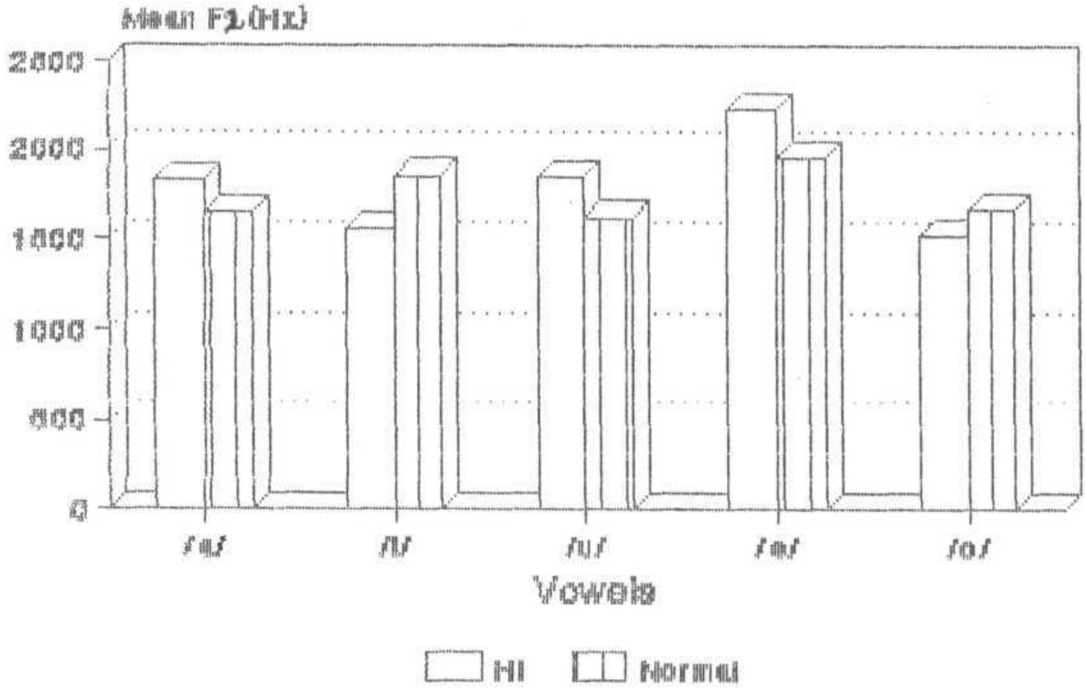
Table-7b : The Mean, SD, Range and mean difference values of F2 of long vowel in female hearing impaired and normal female group in (Hz).

F2 Female Vowels	Hearing Impaired			Normals			Mean diff HI & Nors
	Mean	SD	Range	Mean	SD	Range	
/a:/	1785	(185)	1316-2385	1610	(145)	1210-2380	+ 175
/i:/'	*1968	(268)	1814-2216	1765	(284)	1605-2110	+203
/u:/	1825	(342)	1564-2010	1580	(256)	1385-1815	+245
/e:/	1630	(248)	1390-1964	1980	(283)	1636-2098	-350
/o:/	1680	(265)	1006-1886	1725	(210)	1054-1948	-45

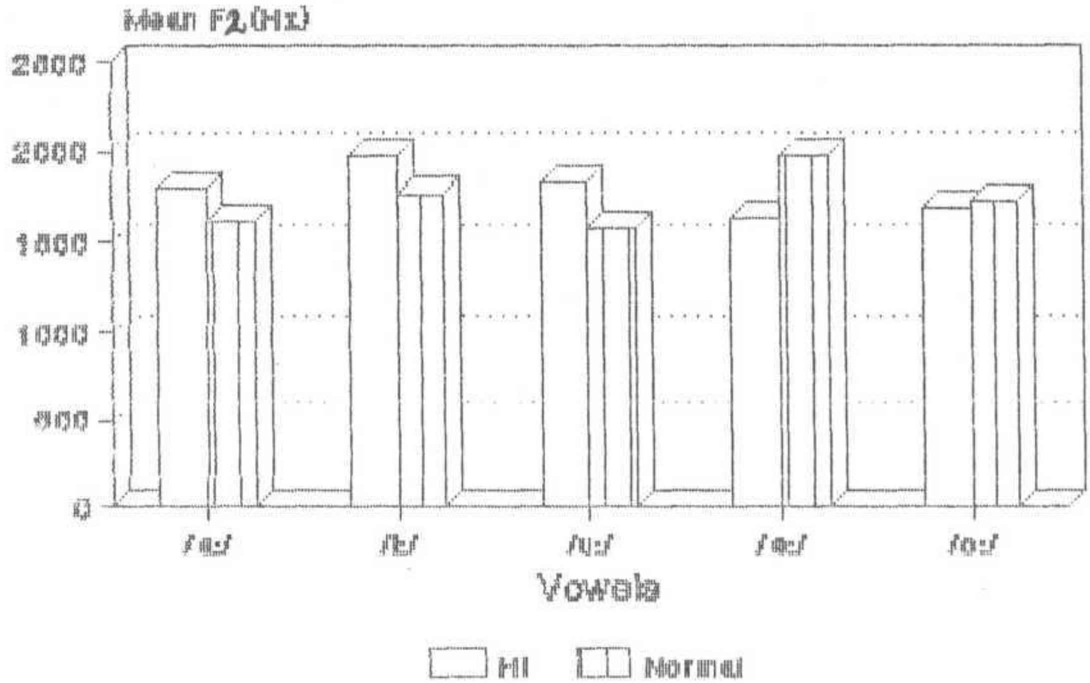
* Significant difference between the males at 0.05 level

the hearing impaired female and normal female groups respectively. Graph 7a and Graph 7b provide mean values of the same. The mean F2 of all short vowels produced by the

Gr.7a Mean F2 of HI and normal
for short vowels (Female)



Gr.7b Mean F2 of HI and normal
for long vowels (Female)



hearing impaired female were found to be higher than that of the normal female group except for vowels /i/ and /o/ which were lower by 300 Hz and 135 Hz respectively. However significant differences were found for voweis /i/, /u/ and /e/ only.

The values of mean F2 of all long voweis produced by the hearing impaired females were found to be higher than that of the normal females except for voweis /e:/ and /o:/ which were lower by 350 Hz and 45 Hz respectively. The mean Fl difference between the means of hearing impaired female and normal females for vowels /a:/, /i:/, and/u:/ were 175 Hz, 203 Hz and 245 Hz respectively. However significant differences were found for voweis /i:/, /u:/ and /e:/.

The F2 results of this study supported the results of the study by Sheela (1988) and Sowmyanarayana (1992) i.e. the F2 values in the vowels produced by the hearing impaired subjects were higher than that of normals both in males and females.

The hypothesis stating that there is no significant difference between the means of F2 values of males of hearing impaired groups and normal groups was accepted for voweis

/a/, /i/, /u/, /o/ /a:/, /i:/, /e:/ and /o/ and was rejected with respect to vowels /e/ and /u:/.

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

The hypothesis stating that there is no significant difference between the means of F2 values of two groups hearing impaired subjects i.e., males and females for ail vowels was accepted.

The hypothesis stating that there is no significant difference between the means of F2 values of normal subjects males and females for all vowels was accepted.

Third Formant Frequencies

Table 8a and Table 8b provide the mean F3 values of short and long vowels for male hearing impaired and normal male children respectiveiy. Graph 8a and Graph 8b provide mean value of the same.

The results of t-test did not show any significant, difference in F3 values produced male hearing impaired and normal male children, even though the mean F3 values for both

Table 8a: Mean, SD, Range and Mean difference values of F3 of short vowel in male hearing impaired and normal male group in Hz.

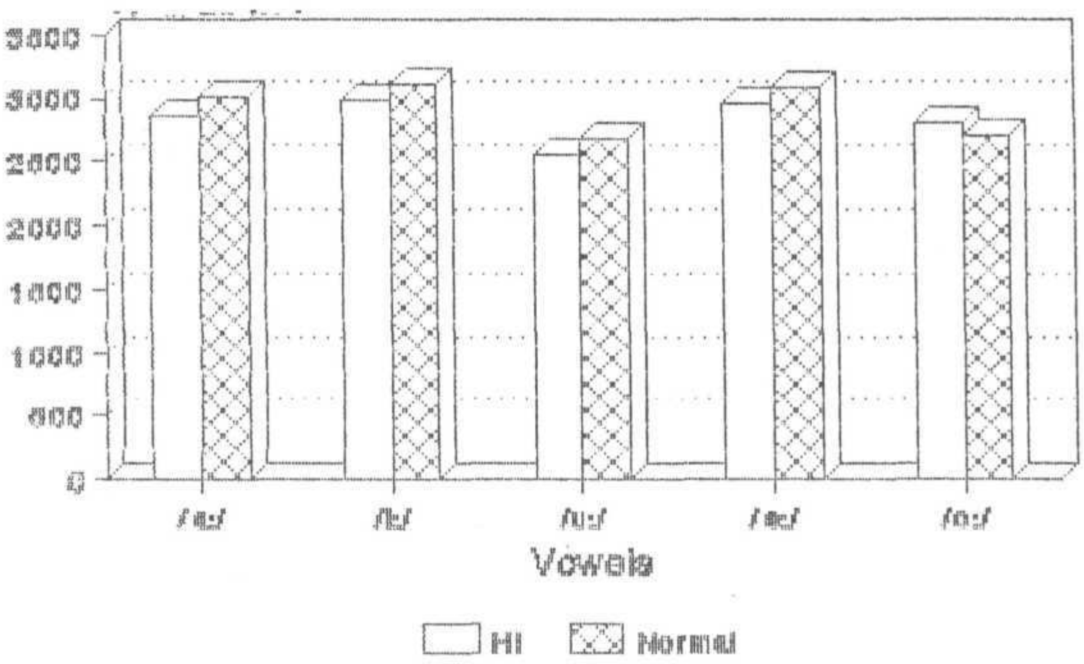
F3 Male Vowels	Normal			Hearing Impaired			Mean diff
	Mean	SD	Range	Mean	SD	Range	HI & Nors
/a/	2845	(340)	2022-3010	2695	(340)	2015-2985	-150
/i/	2965	(355)	2028-3505	2845	(357)	2030-3210	-120
/u/	2456	(390)	1750-3150	2525	(292)	1680-3315	+69
/e/	2985	(385)	2210-3660	2798	(270)	2150-3560	-187
/o/	2480	(280)	2085-2820	2460	(335)	1985-2850	-120

Table 8b: Mean, SD, Range and Mean difference value of F3 of long vowels in male hearing impaired normal male group in Hz.

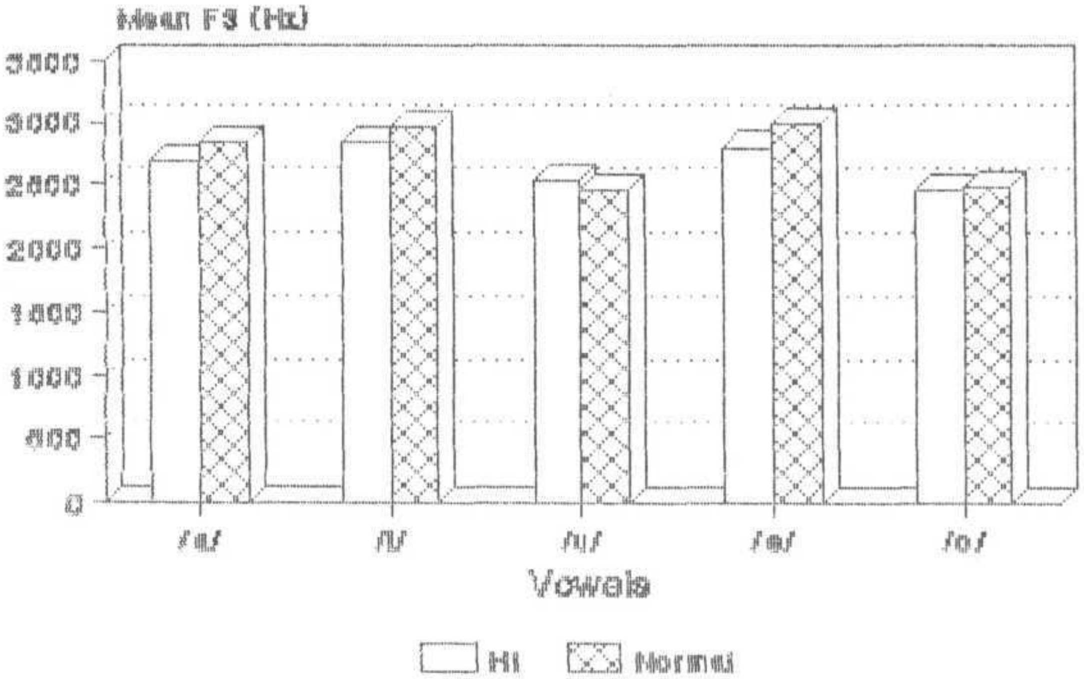
F3 Male Vowels	Normal			Hearing Impaired			Mean diff
	Mean	SD	Range	Mean	SD	Range	HI & Nors
/a:/	3005	(395)	2105-3621	2865	(380)	2005-3115	-140
/i:/	3125	(335)	2235-3526	2985	(365)	2135-3456	-140
/u:/	2686	(380)	2010-3256	2568	(376)	1690-3265	-118
/e:/	3095	(335)	2545-3760	2965	(345)	2165-3460	-130
/o:/	2715	(260)	2365-3561	2810	(386)	2096-2910	+105

short and long vowels produced by hearing impaired male were found to be lower than that of normal male chiidren except for /u/ and /o:/ which were higher than normals. The

Gr.8b Mean F3 of HI and normal
for long vowels (Male)



Gr.8a Mean F3 of HI and normal
for short vowels (Male)



difference in mean values of F3 between the hearing impaired males and normal males for short vowels /a/ /i/ /u/ /e/ and /o/ were 150 Hz, 120 Hz, 69 Hz, 187 Hz and 120 Hz respectiveiy. The differences in mean values of F3 between the hearing impaired male and normal male subjects for long vowels /a:/, /i:/, /u:/, /e:/, and /o:/ were 140 Hz, 140 Hz, 118 Hz, 130 Hz, and 105 Hz respectively.

The result of this study supported the results of the study by Sheela (1988) and Sowmyanarayana (1992) i.e. the F3 of the hearing impaired group is lower than that of the normals.

Table 9a and Table 9b provide the mean F3 values of short and long vowels for female hearing impaired and normal females children respectiveiy. Graph 9a and Graph 9b provide mean value of the same.

The results of t-test did not show any significant difference in F3 values produced male hearing impaired and normal male children, even though the mean F3 values for both short and long vowels produced by hearing impaired male were found to be lower than that of normal male children except for /a/ and /i/ which were higher than normals. The

Table 9a: Mean, SD, Range and Mean differences of F3 of short vowels in female hearing impaired and normal female group in Hz.

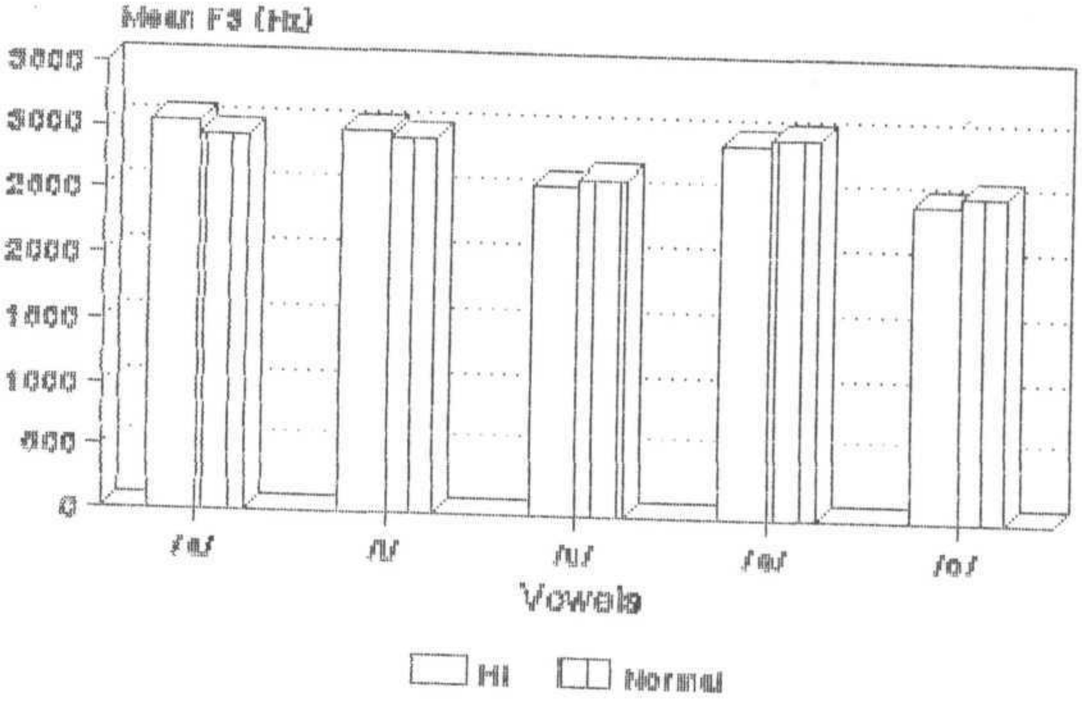
F3 Female Vowels	Hearing Impaired			Normals			Mean diff
	Mean	SD	Range	Mean	SD	Range	HI & Nors
/a/	3028	(368)	2116-3625	2946	(346)	2086-3036	-82
/i/	2998	(396)	2098-3598	2935	(364)	2043-3416	-63
/u/	2593	(346)	1683-3198	2646	(340)	1763-3210	+53
/e/	2938	(376)	1997-3543	2998	(396)	2236-3589	+100
/o/	2487	(416)	1594-3148	2563	(383)	2186-2898	+77

Table 9b: Mean, SD, Range and Mean differences of F3 of long vowels in female hearing impaired and normal female group in Hz.

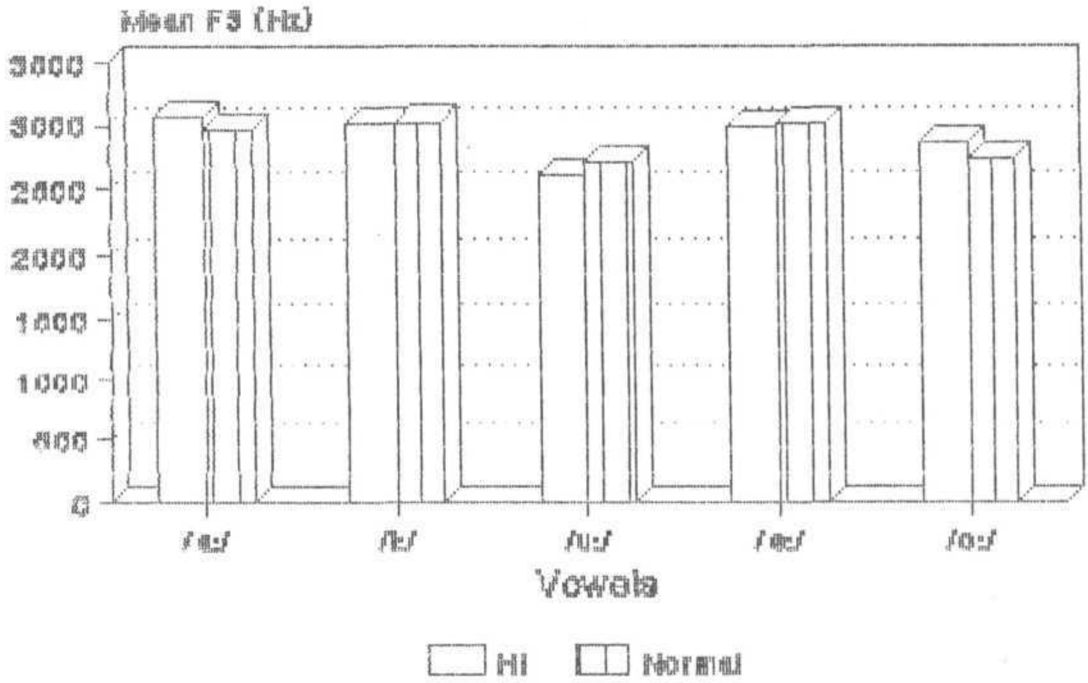
F3 Female Vowels	Hearing Impaired			Normals			Mean diff
	Mean	SD	Range	Mean	SD	Range	HI & Nors
/a:/	3069	(396)	2468-3693	2969	(373)	2041-3136	+100
/i:/	3006	(384)	2268-3569	3026	(398)	2498-3697	-20
/u:/	2615	(376)	2023-3156	2718	(374)	2296-3543	-103
/e:/	2983	(374)	2098-3368	3017	(393)	2138-3696	-34
/o:/	2863	(389)	2054-2936	2743	(343)	2196-3463	-120

difference in mean values of F3 between the hearing impaired females and normal females for short vowels /a/ /i/ /u/ /e/ and /o/ were 82 Hz, 63 Hz, 53 Hz, 100 Hz and 77 Hz respectively. The differences in mean values of F3 between the hearing impaired female and normal female subjects for

Gr.9a Mean F3 of HI and normal for short vowels (Female)



Gr.9b Mean F3 of HI and normal for long vowels (Female)



long vowels /a:/, /i:/, /u:/, /e:/, and /o:/ were 100 Hz, 20 Hz, 103 Hz, 34 Hz, and 120 Hz respectiveiy.

The hypothesis stating that there is no significant difference between the mean F3 values of hearing impaired and normal children both in case of males and females was accepted for both short and long vowels.

A comparison was also made within the groups of both normal and hearing impaired groups. it was found that there were no statistically significant differences between males and females of both the groups for long as well as short vowels.

Therefoe the hypothesis stating that there is no significant difference between the normal males and normal females and between hearing impaired males and hearing impaired females was rejected.

BANDWIDTHS

The three bandwidth Bl, B2 and B3 were determined for all the vowels and it was found that Bl in the case of hearing impaired males was lower for vowels /i/ /u:/ and /e/

and significant differences were found only for vowel /u/ and /e:/ when compared to normal male group. Bl for the hearing impaired females was found to be lower for vowels /a/ /a:/ /e:/ /e/ and /e:/ and significant differences were found for vowels /u:/ and /o:/ as compared to normal group.

B2 for the males of hearing impaired was found to be lower for all the vowels except /i/ and /u/ and significant difference was found for vowel /o/ when compared normal male group.

B2 in hearing impaired females was found to be lower for ail the vowels except /a/ /i:/ and significant difference was found only for vowel /e/ between normal females and hearing impaired females.

B3 in the vowels uttered by hearing impaired males were found to be lower for all the vowels except /a/ /o:/ and significant difference was found only for /o:/ and/e:/ when compared to normal male groups. Thus overall, it was found that the bandwidths of vowels shown by the hearing impaired groups both males and females were found to be lower than the normal groups.

Thus the hypothesis stating that there is no significant difference between the two groups in terms of bandwidths Bl, B2 and B3 was rejected both in case of males as well as females.

The hypothesis stating that there is no significant difference between male and female hearing impaired was accepted.

The hypothesis stating that there is no significant difference between normal male and normal female children was accepted.

PAUSE DURATION

On an average intra-word pauses were found in the hearing impaired than in normals. There was a statisticaiiy significant difference between the normal males and hearing impaired males and also between the normal females and hearing impaired females for intra-word pause value words.

On comparison for within the groups in normals, and hearing impaired there was no significant difference for intra-word pauses. Hence overall it was found that the hearing impaired produced more amount of intra word pauses than normals. Though normals produced some amount of pause it could be attributed to the unfamiiiarity of the second syllable, slow reading, habitual vowel prolongation or other unknown reasons.

The hypothesis stating that there is no significant difference between the mean of intra-word pause duration of hearing impaired and normal groups both in case of males as well as females was rejected.

The hypothesis stating that there is no significant difference within the hearing impaired group i.e. between males and females of the group.

Similarly in case of normal group also no significant difference was found between males and females in terms of intra-word pauses. Hence the hypothesis was accepted.

FUNDAMENTAL FREQUENCY

The descriptive statistics for average fundamental frequency of hearing impaired and normal group for both males and females showed that the hearing impaired group had higher

Fo than that of the normal hearing children, both in case of males and females.

In normal males highest Fo was found for vowel /i:/ (275.4 Hz) followed by /u:/ (265.3 Hz) etc. In normal females the highest Fo was found for vowel /u:/ (286.5) followed by /e:/ (274.3 Hz).

In case of hearing impaired males the highest Fo was 316.5 Hz for /i:/ and /u:/ followed by /a:/ (306.5 Hz). in female hearing impaired highest Fo was found for vowel /e/ (314.5 Hz) followed by /o/ (296.5 Hz).

Statisticaiiy significant difference was found for the vowel /u:/ in both males and females. Hence the hypothesis stating that there is no significant difference for the Fo for normal and hearing impaired was accepted for ail the vowels except /u:/ which was rejected.

The hypothesis stating that there is no significant difference in mean values of Fo within the groups was accepted for both males and females.

DISCUSSION

In the present study it was seen that the total duration of words were longer in the hearing impaired group when compared with the normal hearing children. Similar findings have been reported by Leeper (1987). Total duration of words would be more in hearing impaired children as they prolong the speech segments. Osberger and Megarr (1982) reported prolongation of speech segments present in the production of phonemes, syllables and words in the speech of hearing impaired. The hearing impaired children had longer vowel duration when compared the normal hearing group. This finding is in agreement with the studies of Angelocei (1962), Calvert (1962), John and Howart (1965), Boone (1966), Hevitt et al. (1974), Osberger and Hevitt (1979), Rajanikant (1986), Heeper et al. (1987), Shukla (1987), Sheela (1988), Jagadish (1989), Rasitha (1994).

These studies reported that a general tendency towards iengthening of vowels and consonants was seen in the speech of hearing impaired. Results of the present study were similar to the results obtained by the previous investigators as listed above. It was also observed that the hearing impaired children showed more variability when compared to normal hearing children. These findings were in agreement with the reports of Monsen (1974), Osberger (1978), Rajanikant (1986), Shukla (1987), Sheela (1988), Jagadish (1989).

In the present study the mean Fl values for all the vowels were found to be higher in the hearing impaired group compared to the normal group. Similar results were reported by Sheela (1988), Sowmyanarayan (1992), and Rasitha (1994). The difference in the mean Fl values between normal and hearing impaired groups was significant only for the short vowels in /i/ /u/ and/e/ and long vowel /a:/.

In general the hearing impaired had higher F2 values compared to that of the normals except for vowel /e:/ and significant difference was found between the two groups for short vowels /i/ /u/ and /e/ and long vowels /i:/ /u:/ and /e:/.

The mean F3 values of hearing impaired were found to be around the F3 values of that of normals. No significant difference was observed between the normal and hearing impaired group in terms of F3. Similar studies were carried out in the past by Rajanikanth (1986), Shukla (1987), Sheela (1988), Jagadish (1989), Sowmyanarayan (1992), Rasitha (1994) and Rahul (1997); on the same parameters discussed above. The present results were in accordance with the results of previous studies on all the parameters.

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

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

Results of the present study showed that hearing impaired children had higher fundamental frequency when compared with the normal hearing children. Few explanations have been put forward in order to explain the higher fundamental frequency in case of hearing impaired. Pickett

(1968) suggested that increase in fundamental frequency was due to increased subglottal pressure and tension of vocal folds. Thus the increased vocal effort was directed at the laryngeal mechanism for better kinsthetic feedback and thus leading to increase in Fo. Willemain and Lee (1971) hypothesised that the deaf speakers used extra vocal efforts to get an awareness of the onset and progress of voicing and this lead to the high pitch which was observed in their speech.

Therefore the results of the present study obtained from Telugu speaking children were similar to the results obtained from the studies on Malayalam, Tamil, Punjabi, Kannada and English speaking children for the parameters, word duration, vowel duration, pause duration, average fundamental frequency and formant frequencies. These results can be used in providing therapy to hearing impaired children i.e. to reduce the pitch, eliminate the pauses and reduce the prolongation of vowels and consonants, so that the overall intelligibility of speech improves in case of hearing impaired.

SUMMARY AND CONCLUSION

Human speech production is dviserse and fascinating endeavour, the diversity of which is highlighted by the capacity for human communication by speech to be examined at several levels; physiological, acoustical, psychophysicai, linguistic and psychoiinguistic levels underlying both production and perception of speech (Weinberg, 1986).

"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 30 dB) are often related to language and other eudcational deficits. The speech of the deaf differs from that of normals in ail regards (Black, 1971). Inall 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).

Great strides have been made in undestanding the speech of the hearing imparied, but our knowledge in this area is far from complete (Osberger and McGarr, 1986).

Present study aimed at determining some of the acoustic characteristics of speech of Telugu speaking hearing impaired children. Thirty normal children in the same age range and sex and language were used as control group. All the hearing impaired children had severe to profound sensory neural hearing loss, and were using hearing aids and were undergoing speech and language therapy. All these children were able to read simple bisyiiabic words in Teiugu.

The speech samples of ail the children were recorded and the samples were analysed using computer programs of VSS, Bangalore. The parameters analysed were total word duration, vowel duration, intersyilabic pauses, and average fundamental frequencies (Fl, F2 and F3). The data obtained was subjected to statistical analysis to determine the mean, SD and significance of difference between the two groups.

The results of the present study led tothe conclusions that;

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

3. In general hearing impaired children had higher first formant (Fl) than normal group.
4. Hearing impaired children also exhibited higher second formant frequency (F2) values compared to the normal groups.
5. The F3 values were found to be similar tothat of the normal values.
6. Normal hearing children did not show any inter syllabic pauses (Intraword) whereas children in the hearing impaired group inserted intersyilabic pauses at least once in each word.
7. Hearing impaired children had higher average Fo than that of the normal hearing group.

Recommendations

1. Similar studies on a larger population may be undertaken.
2. Other parameters like VOT, closure duration, formant amplitude etc. may also be studied using various CVC combinations.

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