ANALYSIS AND SYNTHESIS OF SPEECH OF HEARING-IMPAIRED

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DEPICTED

MY PARENTS, BROTHERS AND SIS
FOR THEIR BOUNDLESS LOVE
UNDERSTANDING
AND
TOLERANCE

WHICH CONTRIBUTED SIGNIFICANTLY TO MY EDUCATION
AND PERSONAL LIFE

TO MY LOVE
FOR BEING THE SPECIAL PERSON THAT YOU ARE

CERTIFICATE

This is to certify that the dissertation entitled : ANALYSIS AND SYNTHESIS OF SPEECH OF HEARING-IMPAIRED is the bonafide work in part fulfilment,for the degree of Master of Science (Speech and Hearing), of the student with Register No.M.9210.

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CERTIFICATE

This is to certify that this dissertation entitled ANALYSIS AND SYNTHESIS OF SPEECH OF HEARING-IMPAIRED has been prepared under my supervision and guidance.

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DECLARATION

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

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LIST OF CONTENTS

INTRODUCTION

Speech may be viewed as the unique method of communication evolved by man to suit the uniqueness of his mind (Eisenson and Irwin, 1963).

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

It is clear from the results of deligent specialized teaching that the difficulty in the oral production skills, in principle, can be overcome. Levitt, et al. (1974) write that "however, only few deaf individuals attain a speech quality that is adequate for normal conversation. Many more deaf children could be trained to speak proficiently if we had greater insight into the essential problems. For example, much could be done to improve the efficiency of speech training programs if more was known about how errors or combinations of errors reduce intelligibility most severely. From information on the acoustic, and articulatory correlates of these errors it should be possible to develop more effective techniques and instrumentation to eliminate those errors.

Many factors like residual hearing, segmental errors, supra segmental errors have been correlted with the poor speech intelligibility of the hearing-impaired individuals speech. Studies have been attempted to determine the cause and effect relationship between the speech errors and intelligibility. These causal studies can be sub-divided into two major categories.

1. Studies in which hearing-impaired children receive intensive training for the correction of the errors, and

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

The major problem with the studies involving training is that it may result in changes in the child's speech other than those of interest and hence this can be controlled using computer processing techniques.

There have been no studies in Malayalam in this regard. Hence, the present study was planned to determine the relationship between some of the suprasegmental errors and intelligibility of the Malayalam hearing-impaired children.

Aim of the study:

This study aims to obtain the effect of some of the suprasegmental corrections on the intelligibility of the speech of hearing–impaired children.

Three aspects of suprasgmental errors have been considered for the study because of their relationship with speech intelligibility. They are:

1. Correction of the vowel duration
5. Correction of pauses, if any.
3. These corrections have been made either in isolation or in combination.

<u>Hypothesis-I:</u> There is no significant difference in the utterance of normal hearing and hearing–impaired in terms of

a) Vowel duration
b) Intersyllabic pauses

c) Total duration of words

d) Average Fo

e) Formant frequencies

f) Bandwidths.

Hypothesis—2: There is no significant difference in the intelligibility ratings of unaltered utterances and the corrected utterances.

Auxiliary hypotheses:

6. Correction ofvowel duration:

There is no significant differnce between the intelligibility scores of original unaltered utterances and the utterances where the vowel duration alone has been corrected.

B. Correction of pauses/

There is no significant differnce between the intelligibility scores of original, unaltered utterances and the utterances where the pauses alone has been corrected.

C Correction of vowel duration and pauses:

There is no significant differance between the intelligibility scores of original, unaltered utterances and the utterances where the vowel duration and pauses have been corrected.

Five congenitally hearing-impaired children in the age group of 5-9 years were selected from the therapy clinic of All India Institute of Speech and Hearing for the study. All these children had severe to profound sensorineural hearing loss. They had no additional handicap other than that directly related to the hearing-impairement. All read simple bisylabic words in Malayalam.

Ten simple bisyllabic Malayalam words meaningful were selected. The speech samples of all the four children were recorded as they read the words. Recordings were also obtained of a matched group (for age and sex) of five normal hearing children reading the same set of words.

Experiment-1: The samples were then analysed using compute programmes of VSS, Bangalore. The following parameters were obtained.

1. Vowel duration
E. Duration of pauses
3. Total duration of words
4. Average F0
5. Formant frequencies (F1 and F2)
6. Bandwidth (B1 and B2.)

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

Experiment—II: Some aspects of the suprasegmental errors in the digitized data of hearing-impaired children's speech were modified in this stage. Two measures were considered. They are:

1. Correction of pauses, if any

5. Correction of vowel durations and

3. Combination of these two ie. correction of both vowel duration and pauses.

All the measures were corrected towards the mean values of normal hearing group.

Thus, these two measures were corrected in isolationand in combination. All together three types of corrections were performed.

Experiment-III: The unaltered utterances and the corrected (total 152 utterances) were recorded randomly. This recording was presented to three judges for word identification task and intelligibility rating.

The number of words identified correctly were converted into percent scores using the formula.

$$\frac{\text{No.of words identified correctly}}{\text{Total number of words present}} \times 100$$

The judges had to rate the intelligibility on a five point interval scale, ranging from 0' (intelligible) to '4' (highly intelligible).

Implications of the study:

1. The results of this study would help to understand the speech of the hearing—impaired children better.

2. The results of this study would help to know how the suprasegmental errors effect the intelligibility of the speech of the hearing-impaired.

3. Thi study also would help to plan and develop therapy programmes with the hearing-impaired children.

Limitations of the study:

1. The study was limited to only five subjects.

2. The study was limited to the correction of suprasegmental errors only.

3. The speech samples studied were limited to words with combinations only.

REVIEW OF LITERATURE

Speech is an integrated function involving the reception of words by the ear or the eye, their interpretation and synthesis as language within the brain and the expression of this language response is further spoken or written words. It includes the whole of this receptive, formative and expressive activity. Words are composed of sequences of sounds. They are symbolic and have a consistent range of meaning (Morley, 197S).

"It is through the auditory mode that speech and language are normally and usually effortlessly developed" (Ross and Biolas, 197S).

The normal hearing child is exposed to sounds from the very beginning itself. By continual auditory stimulation by the constant feeding of speech into his ears, by unceasing encouragement from his mother, by hours and hours of practice a normal child attains speech. The task is more difficult for the child born deaf and yet often enough the deaf child is deprived of these very means which alone make speech possible. Thus hearing controls speech and without hearing speech fails (w'hetnall and Fry, 1964).

Hearing-impairment has a marked effect on a child's ability to acquire speech. The orderly and seemingly natural development of speech language and communication is interferred with by presence of hearing loss (Stark, 1979).

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,

The oral communication skills of the hearing-impaired children have long been of concern to educators of the hearing-impaired, speech pathologists and audiologist, because the adequacy of such skills can influence the social, educational and carriers opportunities available to these individuals (Osberger and McGarr, 198S).

The ultimate goal in aural rehabilitation is, for the hearing—impaired individual, to attain, as far as possible, the same communication skills as those of the normal hearing individual. Wthin 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. The technological advances have also been applied to the analysis of the speech of the hearing-impaired and to the development of clinical assessment and training procedures (Osberger and McGarr, 1982).

It is clear from the results of specialized teaching that the difficulty in the oral production skills, can be overcome. However, only few deaf individuals attain a speech quality that is adequate for normal conversation. Many more deaf children could be trained to speak proficiently if we had greater insight into the essential problems (Levitt, 1974).

Researchers concerned with speech production of the hearing-impaired have employed a variety of physiological (Metz et al. 1985) acoustic (Monsen, 1976 a, 1976 b. 1974. 1978; Angelocci, et al. 1964; Gilbert, 1975, McClumphe, 1966; Calvert, 1962; Skula, 19B5; Rajanikanth, 1986; Sheela, 1988; Jagdish, 1989) perceptual methods (Levitt, et al. 1976; Stevens, et al. 1983; Hudgins and Numbers 1995; Harkides, 1970; Geffner, 1980, etc).

Acoustic analysis of speech is extremely useful to researchers since the methodologies employed are typically non–invasive, relatively basic with regard to instrumentation, may be used routinely to depict changes in the physical characteristics of frequency, intensity and the duration of speech segments (Leeper, et al. 1987). Acoustic analysis of speech of hearing-impaired permits a finer grained consideration of some aspects of both correct and incorrect production than would be possible using methods applied in the subjective procedures (Obserger and McGarr, 1982). It provides objective descriptions of speech of the hearing-impaired. More information 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). Thus, analysis of speech of hearing–impaired becomes important.

2.5

Intelligibility of speech of the hearing–impaired:

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

Speech intelligibility of the hearing-impaired as a measure of their speech potential has been studied by a number of investigators. There is a difference of opinion regarding the intelligibility of speech of hearing-impaired.

Hudgins and Numbers 1942) studied the speech intelligibility of 192 hearing-impaired subjects of 8-19 years of age. A group of experienced listeners were asked to listen to the speech samples (sentences) of the hearing-impaired and write down whatever was understood by them. The mean score for the group was found be only 59%.

Brannon (1964) worked with twenty children of age 12-15 years. Whose hearing levels were 75 dB or more; possessed at least normal intelligence and had no known additional handicaps. he found only 20-25% of the words in their practiced speech intelligible to listener unfamiliar with hearing-impaired children speech.

Markides (1970) studied 58 hearing-impaired children who were 7 and 9 years old. About 31% of their words were intelligible to their teachers whereas 19% intelligible to naive listeners.

According to Smith (1975) who studied 40 hearing-impaired children in the age group 8-10 and 13-15 years, word intelligibility, as assessed by 120 listeners unfamiliar with the speech of hearing impaired was 18.7%.

Investigation in recent years have indicated that only about SOX of the speech output of the deaf is understood by the person-on-the street. This lack of intelligibility has been associated with some frequently occurring segmental and suprasegmental errors (Toni Gold, 1980).

According to Osberger and Levitt (1782) on the average, the intelligibility of profoundly hearing-impaired children's speech is very poor. Only about one in every five words they say can be understood, by a listener who is unfamiliar with the speech of this group. On the other hand Metz et al (1982) one of the opinion that the speech produced by many deaf persons is frequently unintelligible to even experienced listeners.

Monsen (1978) reported a relatively high mean intelligibility score of 76%. He attributed this high scores to the simpler test materials used to study the speech intelligibility.

The results of various studies suggests that the overall levels of speech intelligibility are utterly inadequate for oral communication (Ling, 1976).

According to Ling (1976), intelligibility ratings can vary not only with the type of judge employed but also with the materials used and with the methods of analysis applied.

Intelligibility ratings have been reported to be 10-15X higher when judged by teachers or experienced listeners than those by the naive listeners (Geffner et al. 1978; Mangan, 1961, and 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).

Several factors have been found to effect the intelligibility of speech.

The low speech achievement of the hearing-impaired has lead to several attempts in the past to correlate speech intelligibility with several variables related to reception and production of speech.

Among the perceptual variables of residual hearing (Montgomery, 1967; Elliot, 1969; Boothroyd, 1969; Mariddes, 1970; Smith, 1975; Stoker and Lake, 19S0; Ravishankar, 1985) lip reading (Stoker and Lake, 1980) abilities have been studied. The results have indicated that residual with the speech intelligibility.

On the production side speech intelligibility has been studied with relation to segmental and suprasegmental errors. Errors involving individual speech phonemes, ie. segmental errors have been studied by Hudgins and Numbers, 194E; Nober, 1963; Markides, 1970; Smith, 1973; . McGarr, 1980; Ravishanakar, 1985, etc. According to these studies there is a high negative correlation between the frequency of segmental errors on intelligibility ie. the higher the incidence of segmental errors the poorer the intelligibility of speech (Parkburst and Levitt, 1980).

Studies on acoustic features of speech of the hearing-impaired have supported the findings of the above mentioned studies (Calvert, 1961; Monsen, 1974, 1976 a, 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 omission, and vowel and diphthong errors include, substitution, neutralization of vowels, dipthongization of vowels, errors involving diphthongs, either the diphthong was split into two distinctive components or the final component was dropped.

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

The difference in VOT between /t/ and /d/, the difference in Snd formant location between /i/ and /r/ and acoustic characteristics of the nasal and liquid consonants.

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

Consonant errors have been generally found to be highly correlated with speech intelligibility than are the vowel error (Hudgins and Numbers, 1945).

Timing

Rate:- Physical measures of speaking rate have shown that profoundly hearing-impaired speakers on the average take 1.5 to 5.0 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 hearing speakers. Mhen hearing-impaired speakers and normals have been studied under similar conditions the measured rates of syllables or word omission have often differed by a factor of two or more (Hood, 1966).

Nikerson, et al. (1974) tested slightly older deaf and control groups on reading rate and found large differences between the groups although the mean rate for the deaf was as high as 108 words/minute.

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

i) increased duration of phonemes, and

ii) improper and often prolonged pause within uttrance (Gold, 1980).

Increased duration of phonemes

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

Durational changes in vowels serve to differentiate not only between vowels themselves but also' between 5imilar consonants adjacent to those vowels (Raphel, 1975; Gold, 1980).

There is a general tendency towards lengthening of vowels and consonants in the deaf (Angelocci, 1965; Boone, 1966; Levitt, et al. 1974; Levitt and Parkburst, 1978).

Calvert (1961) was among the first to obtain objective measurements of phonemic duration in the speech of hearing-impaired by spectrographic analysis of bisyllabic words. The results of this study showed that hearing–impaired speakers extend the duration of vowels, fricatives and the closure period of plosives upto 5 times the average duration for normal speakers.

Monsen (1746) studied 12 deaf and 6 normal hearing adolescents as they read 56 CvCs 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 longer than /I/ always, for a particular consonantal environment, but the absolute durations of the two vowels could overlap if the accompanying consonants differed. Thus, although the vowels produced by the deaf subjects were distinct in terms of duration, they were still less intelligible since the listener could not rely or normal decoding strategies to interpret the speech that was heard.

The hearing-impaired fails to produce the appropriate modifications in the vowel duration as a function of the voicing characteristics of the following consonant. Hence the frequent voiced-voiceless confusion observed in their speech may actually be due to vowel duration errors (Calvert, 1961).

Shukla (1787) compared vowel duration and consonant duration in thirty normal and hearing-impaired individuals who were matched for age and sex. The results showed that:

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

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

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

d) In normally hearing subjects the mean duration of the vowels /a/, /i/ and /u/ in the final position, that is preceeded by different consonants were around 500 msecs., 195 msecs. and 185 msecs. respectively. In the hearing-impaired speakers /i/ and /u/ tended to be longer then 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 normally hearing speakers.

f) In the normally 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) There was a vowel lengthening phenomenon in Kannada language "vowel lengthening phenomenon is the final syllable vowel durational increment of 100 msec, or more in English language for phrase final and utterance final positions" (Klatt, 1975 a, 1976).

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

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

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

k) In the speech of the normally hearing subjects voiceless consonants were significantly longer than the voiced consonants. Uhereas, in the speech of the hearing-impaired the durational difference between voiced and voiceless consonants was considerably reduced.

1) In both the groups of subjects the lateral sound /l/ among the voiceless sounds were the shortest in duration.

m) In the speech of the normally hearing the affricates /c/ 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.

n) Durations of all the consonant were longer in the speech of the hearing—impaired than in the normally hearing speakers.

o) Hearing speakers showed a grater variation in controlling the length of all the consonants than normally hearing speakers.

Sheela (1988) studied vowel duration in four normal and four hard—of—hearing individuals, and the results indicated that cm 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, on the average in the speech of the hearing-impaired than in the speech of normal subjects (Levitt, 1979; Stevans, et al. 1978).

Osberger and Levitt (1979) found that the mean duration ratio for stressed and unstressed vowels was 1.49 to 1.S8 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 smaller, on the average, in the deaf children's speech than in the normal hearing children's speech. They also found that the average duration of both stressed and unstressed syllables was in the speech of the deaf children.

These studies show that the hearing-impaired produce only stressed syllables and that there is an overall tendency for increased duration of all phonemes in the speech of 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.

As a result of lack of differentiation between the length of stressed and unstressed syllables contribute to the perception of improper accent in the speech of the hearing-impaired (Gold, 1980).

The way in which the hearing-impaired speakers use temporal manipulations to convey differences in syllabic stress pattern is not clear. McGarr and Harris (1980) found that eventhough intended stressed vowels were always longer than unstressed vowels in the speech profoundly impaired speaker, the intended stress pattern was not always perceived correctly by a listener. Thus, the hearing-impaired speaker was using some other suprasegmental features to convey contrastive stress. Variation in fundamental frequency would be a likely alternative, but McGarr and Harris (1980) also found that while the hearing–impaired speaker produced the systematic changes in the fundamental frequency associated with syllable stress, perceptual confusions involving stress pattern were sill observed.

Pauses

Pauses may be inserted at syntactically inappropriate boundaries such as between two syllables in a bisyllabic word or within phrases by the hearing-impaired (Osberger and McBarr, 1985).

It has been reported that profoundly hearing-impaired speakers typically insert more pauses, and pauses of longer duration them do speakers with normal hearing (Boone, 966; Boothroyd, et al. 1974; Stevens, et al. 1978 etc.)

Stork and Levitt (1974) reported that the deaf subjects tended to pause after every word and stress almost every word. Oral readings of sentences especially designed to test the use of pause and stress were analyzed in this study.

Nickerson et al (1974) reported that total pause time in the speech of the children constituted 25% of the time required to produce the list sentences while the pause time in the speech of the deaf was 40% of the total time.

Boothroyd, et al (1974) considered that within phrase pauses were more serious problem them between phrase pauses in deaf speakers.

Closely related to the problem of excessive and inappropriately placed pauses is that of poor rhythm. The inappropriate use of pauses along with the timing errors lead 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. l'?74).

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. The results showed that deaf children used short, irregular breath groups often with only one or two words and breath pauses that interrupts the flow of speech at inappropriate places. Also there was excessive expenditure of breath or single syllables, false grouping of syllables and misplacement of syllables.

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

Voice quality

There seem to be general agreement that the deaf speakers have a distinctive voice quality (Bodycomb, 1946; Calvert, 1965; Boone, 1966). However, what exactly is meant by voice quality is not entirely clear. Hearing-impaired is reported to have breathy voice quality (Hudgins, 1937; Peterson, 1946) a characteristics that was attributed in large to inappropriate positioning of the vocal cords and poor control of breathing during speech.

In particular too large a glottal opening may be produced by failure to close properly the vocal folds. "The 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 and few of them are tense, flat, breathy, harsh and throaty.

Calvert (1965) also attempted to determine empirically whether in fact the speech of deaf persons is distinguishable on the basis of quality from that of people with normal hearing. He had teachers of the deaf attempt to determine by listening whether recorded speech sounds (vowels and diphthongs in isolation, non-sense syllables, words and sentences) had been produced by profoundly deaf speakers, speakers imitating deaf speakers, speakers simulating harsh and breathy voice or normal hearing speakers. Isolated vowels from which onset and termination characteristics had been clipped could not be distinguished as to source, but the sources of the sentences were identified with 70X accuracy. Calvert (1971) concluded that: deaf voice quality is identical not only on the basis of relative intensity and fundamental and the harmonics but also by the dynamic factors of speech such as transition gestures that change one articulatory position into another.

Pitch and Intonation

Fundamental Frequency

The fundamental frequency varies considerably in the speech of given speaker and the average or characteristic fundamental frequency varies over speakers. Overage fundamental frequency (Fo) decreases with increasing age until adulthood for both males and females (Fairbanks, 1940; Usha, 1979; Gopal, 1980).

The Fo is often loosely called the pitch.) Hard-of-hearing speakers often tend to vary the pitch much less than do hearing speakers and the resulting speech has been described as flat or monotone (Calvert, 1962; Hood,1966 Martony, 1968).

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

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

Overage fundamental frequency

Several investigators have reported that the hard-of-hearing speakers have a relatively high average pitch than that of normals of comparable ages (Angelocci, 1965; Calvert, 1965; Thornton, 1964; Boone, 1966; Campbell, 1980).

Angelocci, et al. (1964) noted that the Fo of hearing-impaired individuals were higher than those of normal hearing individuals, also that the average Fo for different individuals spanned a wider range.

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

Ermovick (19765) and Gruanewald (1966) reported values that were equal to or lower than values for normally hearing speakers.

Some differences in average Fo have been found as a function of the age or sex of the hearing-impaired speaker. The results of several studies have shown that there were no significant differences in average Fo between young normal hearing and hearing-impaired children in the 6-12 years age range (Boone, 1966; green, 1956; Monsen, 1979). Differences have been reported between groups of older children. Boone, (1966) found higher average Fo for 7-18 years old males than females Osberger (1981) found that the difference in Fo between hearing-impaired speakers in the 13-15 years age range was grater for females than for males. The Fo for female hearing—impaired speakers ranged between 550—300 H. This value is about 75 Hz higher than that observed for the normal hearing females.

Meckfessel (1964) and Thornton (1764) reported Fo speaking (FFS) values in post - pubertak hearing-impaired males that were higher than those obtained for normally hearing post - pubertak males, while values obtained by Greene (1956) were similar to those for normal hearing males.

Gilbert and Campbell (1980) studied FFS in three groups (4-6 years; 8-10 years, 16-55 years) of hearing-impaired individuals, and reported that the values were higher in the hearing-impaired groups when compared to values reported in the literature for normally hearing individuals of the same age and sex.

"The average Fo value of the utterances of the male hearing—impaired speakers was slightly lower than that of the 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 ie. 10-15 years and 16-20 years.

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

Shukla (1987) reported that in majority of the hearing-impaired speakers the Fo fell within the normal range.

The auditory feedback system is the pain channel for appropriate establishment and production of. pitch (Fo). Fo or pitch, has been a particularly difficult property of speech for deaf children to learn to control (Boothroyd, 1970).

There have been explanations offered to the pitch deviation noted in the hearing-impaired. "One possible reason for the difficulty is that deaf children may lack a conceptual appreciation of what pitch is'' (Anderson, 1960; Martony, 1968).

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

willeman and Lee (1771) 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

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

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; Calvert, 1965; Martony, 1968; Nandyal, 1981). This would result in the monopitch observed in the speech of the hearing-impaired.

A particular problem is that of inappropriate or insufficient pitch change at the end of a sentence (Sorenso, 1974). A terminal pitch rise such as occur ing at the end of some questions may be even more difficult for deaf to produce 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 (mono) 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, whereas insufficient pitch variation has been noted as a problem for some speakers, excessive variations has been reported for others (Martony, 1968). Such variations are not simply normal variations that have been somewhat exaggerated but, rather, pitch breaks and erratic changes that do not serve the purpose of intonation. These speakers may raise or lower the Fo by 100 Hz or more, within the same utterance. These are reports that often, after a sharp rise in Fo the hearing-impaired speaker loses all phonatory control and thereafter there is a complete cessation of phonation (Smith, 1975; Stevens, et al. 1978).

"Mousen (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 on words of short duration. The Fo change may be more than 10 Hz per 100 msec. but the total change may be small.

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

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

Monsen (1963) 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, again with large individual variations" (Rajanikanth, 1985).

Segmental Influence on Fo Control

It is seen that some hearing-impaired children produce the vowels /i/ /I/ /u/ on 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 formant of the vowel (House and Fairbanks, 1953; Peterson and Barney, 1952).

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

According to Honda (1981 moving the tongue root forward for the production of high vowels causes the hyoid bone to move forward tilting the cartilage anteriorly. As a result of this, there is increased tension on the vocal folds resulting in an increased Fo.

Bush (1981) found that vowel to vowel variations produced by the hearing-impaired speakers were in some way, a consequence of the same articulatory maneuver used by normal speakers in vowel production. Bush has postulated that because of the nonlinear nature of the stress strain relationship for vocal fold tissue, increase in vocal fold 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 variations have been considered to be the major cause of faulty intonation in the hearing-impaired. There are also evidences which suggest that the hearing-impaired individuals know and use some of the rules as used by the normal speakers.

Velar Control

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

Improper control of velum has long been recognized as a source of difficulty in the speech of the deaf (Beehm, 1925; Hudgin, 1934). Miller (1968) has speculated that the type of hearing loss may be a causative factor in some nasalization problems. Hyponasality, he suggests, may be more prevalent among people with conductive loss than those with sensori-neural loss because nasal sounds may appear excessively loud to the former due to the transmittability of nasal resonances via bone conduction. 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 for two reasons:

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

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

Improper velar control is difficult to judge subjectively, in part because the distinctive perceptual features of nasalization have not been clearly defined and in part because the perception of nasality may be affected by factors in addition to the activity of the velum. Some researchers have suggested that such factors as misarticulation, pitch variation and speech tempo affect the proper judgement (Colton, and Cooper, 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 harmonis (Delattre, 1955). attempts to detect nasalization directly have included the measurement of acoustic energy radiated from the nostrils (Fletcher, 1970; Shelton, Knox, Arudt and Elbert, 1967) and measurement of the vibration on the surface of the nose (Holbwook and Crawford, 1970; Stevens, Kalikow and Millemain, 1974).

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

The role of suprasegmental features of speech in the intelligible verbal discourse has been well documented by several investigators (Eisenson, 1971; Lieberman, 1975; Eeers, 1978). The suprasegmental errors that are studied in relation to speech intelligibility are timing errors, pitch and intonation errors and errors in nasality. Most of these errors have been found to be detrimental to speech intelligibility.

Due to suprasegmental deviation, the speech of deaf talkers has been characterized as Staccato, teaching to the perception of improper grouping of syllables (Gold, 1980).

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

1. Correlational studies

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

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

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

Correlational studies - The suprasegmental errors examined most extensively in relation to intelligibility have been those involving timing. One of the earliest attempts to determine the relationship between deviant timing patterns and intelligibility is the study by Hudgins and Numbers (1945).

Although they correlated rhythm errors with intelligibility, many of these errors appear to be due to poor timing control and erroneous Fo (Osberger and McGarr, 1985). They found that sentences spoken with correct rhythm were substantially more intelligible than those that were not. The correlation between speech rhythm and intelligibility was 0.73. The other correlational studies have shown a moderate negative correlation between excessive prolongation of speech segments and intelligibility (Monsen, Leiter, 1975; Levitt, 1978).

Reilly (1979) reported that the better the profoundly hearing-impaired speaker was able to produce the segmental,, lexical and syntactic structure of the utterance, the mere intelligible the utterances likely to be.

Parkburst and Levitt (1978) indicated another type of timing error, the insertion of short pauses at syntactically appropriate boundaries had a positive affect of intelligibility. The presence of these pauses actually helped to improve the intelligibility. They added that excessive or prolonged pauses appeared to have a secondary effect in reducing the intelligibility.

Studies have also been done to determine the relationship between errors involving Fo control and intelligibility. The inability to control while speaking Fo by the hearing-impaired contributes to the low intelligibility of their speech (Boothroyd and Decker, 1975). Monsen and Leiter (1975) measured the amount of Fo variation in the speech production of deaf children. This measure was not found to correlate highly with speech intelligibility.

"Suprasegmental aspects of phonation have been emphasized by some investigators as indicators of speech intelligibility" (Levitt, 1974).

McGarr, et al. (1976) found that the hearing-impaired children were unable to sustain phonation and showed pitch breaks and marked fluctuations in pitch were consistently judged to have poor intelligibility. Such children were also reported to show timing errors and very low phoneme production scores in continuous speech. They found a significant correlation between speech intelligibility and rated subjective evaluation pitch deviancy in their hearing-impaired subjects.

McGarr and Osberger 91978) found that for the majority of the children studied, there seemed to be no simple relationship between pitch deviancy and intelligibility. Some children whose pitch was judged appropriate for their age and sex had intelligible speech, while others did not. The exception to this pattern were the children who were unable to sustain phonation and whose speech contained numerous pitch breaks. Their speech was consistantly judged to be unintelligible.

Results of Monsen (1979) showed pitch contours to correlate significantly with voice quality ratings, suggest that significant correlation with intelligibility will only be found when intonation patterns are taken into account.

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

The effect of prosody of deaf speech intelligibility has been evaluated mainly by correlational techniques. In studies using subjective ratings of all prosodic features combined (Fo, temporal structure and intonation) it was found that errors in rhythm (Hudgins and Numbers, 1945) poor phonatory control (Smith, 1975) and staccato prosody (HcGarr and Osberger, 1978) or syllable speech (Levitte, et a. 1976) all show moderate to high negative correlations with speech intelligibility (Povel, 1984).

Studies that attempted to determine the cause and effect relationship between speech intelligibility have dealt primary with timing (Osberger and McGarr, 198S).

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

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

There have been no such studies on the role of pitch correction on speech intelligibility (Harris and McSarr, 1980).

Studies have been conducted in which the errors are corrected in hearing-impaired children's recorded techniques to bring about improvement in intelligibility.

A major problem with the training studies is that the training may result in changes in the child's speech other than those of interest. In addition to this, the effect of phoneme production and of prosodic feature production upon intelligibility have not been separated sufficiently in these studies (Osberger and McGarr, 1985).

Recent investigations have attempted to eliminate thi confounding variables by using

In such studies speech is either synthesized with timing distortion (Lang, 1975; Hudgins, 1977; Bernstein, 1977) or synthesized versions of the speech of the hearing-impaired are modified so that the errors (timing or pitch and intonation errors) are corrected selectively (Osberger and Levitt, 1979; Povel, 1984; Oster, 1985; Maassen, 1986).

In such studies speech is either synthesized with timing distortion (Lang, 1975; Hudgins, 1977; Bernstein, 1977) or synthesized versions of the speech of the hearing-impaired are modified so that the errors (timing or pitch and intonation errors) are corrected selectively (Osberger and Levitt; Povel 1984; Oster, 1985; Maassen, 1986).

Gold (1980) gave a detailed review of a large number of studies dealing with the production characteristics of hearing-impaired individual. The conclusions of the study are as follows:

"Whereas there is much documentation of the kinds of segmental and suprasegmental errors in the speech of hearing-impaired, there is far less evidence of the direct effects of each of these error types on overall speech intelligibility". "Thus, although we may be able to identify those errors to occur most frequently in the speech of the deaf, we need further research to indicate how these error types interact to reduce speech intelligibility and to determine which error types should be the first to be considered when planning a training program for improved speech production in the hearing-impaired children".

The advantage of using computer processing techniques is that it is possible to determine the causal relationship between the errors and the intelligibility without the presence of the confounding variables than are seen in the training studies (Osberger and Levitt, 1979).

In digital manipulation techniques it is easy to correct errors in the time domain (suprasegmental) but more difficult to correct segmental errors (Huggins, 1977; Kruger, et al. 197S; Osberger and Levitt, 1979). If speech synthesis techniques are used, both types of errors can easily be corrected or inserted, especially if a synthesis—by-rule system is used (Bernstein, 1977).

Lang (1975) used an analysis-synthesis approach to correct timing errors in the speech samples produced by hearing-impaired speakers, and also to introduce timing distortions in the samples of normal speakers. Minimal improvements in intelligibility were observed for the speech of the hearing-impaired and minimal decrements in intelligibility were observed for the normal speakers.

Bernstein (1977) found no reduction in the intelligibility of speech samples produced by a normal speaker when synthesized with timing errors. In contrast to this Higgins (1977) found that when normal speech was synthesized with the durational relationship between stressed and unstressed syllables reversed, there was a substantial reduction in intelligibility. even greater reductions in intelligibility occured when the stress assignments for both pitch and duration were incorrect.

In an attempt to resolve some of the conflicting information in this area, Osberger and Levitt (1979) quantified the relative effect of timing errors on intelligibility by means of computer stimulation. Speech samples produced by hearing-impaired children were modified to correct timing errors, only, leaving all other aspects of the speech unchanged. Three types of corrections were performed, relative timing, absolute syllable duration and pauses. Each error was corrected alone and together with one of the other timing errors. Six stage approximation procedure was used to correct the deviant timing patterns in the speech of six deaf children. They were:-

a) Original unaltered sentences
b) Correction of pause only
c) Correction of relative timing
d) Correction of relative timing and pauses
e) Correction of relative pauses
f) Correction of absolute duration and pauses.

An average improvement is intelligibility was observed only when relative timing errors alone were corrected. The second highest intelligibility score was obtained for the original, unaltered sentences. The intelligibility scores obtained for the other four forms of timing modification were poorer than those obtained for the original sentences, on the average. However, the improvement was very small (4X0). Since the timing modifications for this condition involved only the correction of the duration ratio for stressed - to unstressed vowels, the overall durations of the vowels (eg. syllables) were still longer than the corresponding duration in normal speech. "These data indicate that the prolongation of syllables and vowels, which is one of the most obvious deviancies of the speech of the hearing-impaired, does not in itself hence a detrimental effect on intelligibility (Osberger and McEarr, 198S).

Maassen and Povel (1984 a) changed the syllable and phoneme duration such that they were either absolutely or relatively equal to durations of the corresponding segments in the normal utterances. Intelligibility improved from 25% to 30% when a phonemic relative correction was performed for 26 out of 30 sentences.

Here, each phoneme got the same relative duration as the corresponding phoneme in a normal utterances. Improvement in speech intelligibility was 11% to 17% when syllabic relative correction was done, for 8 sentences out of 30 sentences where the syllable was the unit of transformation. For 5 sentences largest increase resulted from a phonemic absolute correction (intelligibility rise from 21% - 28%).

Maassen and Povel (1985) conducted three experiments to study the effect of segmental and suprasegmental corrections in the intelligibility and judged quality speech of deaf. By means of digital signal processing structure and intonation were carried out on 30 dutch sentences spoken by ten deaf children. The transformed sentences were tested for intelligibility and acceptability by presenting them to inexperienced listeners. A complete segmental correction improved the intelligibility from 24% to 72% which for a major part was due to correction of vowels. The correction of temporal structure and intonation caused only a small improvement from 24% to 34% combination of segmental and suprasegmental corrections yielded almost perfectly understandable sentences, due to a more than additive effect of the two corrections. Quality judgements were in close agreement with intelligibility measures. "The results show that, in order for these speakers to become more intelligible improving their articulation is more important than improving their production of temporal structure and intonation" (Maassen and Povel, 1985).

Osier (1985) took speech samples from three hearing-impaired children and analyzed them individually to find errors in vowels, consonants and prosody. Based on this analysis, a phonetic system for each child was established and a synthetic speech containing different combination of errors was generated. A group of normal hearing subjects listened to the synthetic deaf speech could understand. The results of the study showed that synthesis by rule system can be used to establish the relative impact on intelligibility of different types of speech errors and to develop an individualized program for speech improvement. The individualized program suggested for the three deaf children imply that the segmental errors should be given more emphasis and should be corrected first and then the suprasegmental errors. The segmental error correction will improve the intelligibility upto 66% to 97%.

Studies in the recent years, eventhough, only few, show that the computer correction of temporal aspects and intonation contour of hard-of-hearing speech only caused a small increase in intelligibility.

In this studies, there have been no such studies in Malayalam reported so far in India. Therefore, the present study was undertaken to see the effect of the correction, using computer, of some of the temporal aspects in the speech of the hearing-impaired in the speech intelligibility.

Oster (1985) took speech samples of the hearing-impaired children and analyzed them individually to find errors in vowels, consonants and prosody. Based on this analysis, a phonetic system for each child was established and a synthetic speech containing different combinations of errors was generated. A group of normal hearing subjects listened to the synthetic speech and wrote down all the words that they could understood. The results of the study showed that synthesis by rule system can be used to establish the relative impact on intelligibility of different types of speech errors and to develop an individualized program for speech improvement. The individualized program suggested for the three deaf children imply that the segmental errors should be given more emphasis and should be corrected first and then the suprasegmental errors. The correction segmental error will improve the intelligibility upto 66% to 97%. Attempts have also been made to study speech and hearing-impaired children, speaking Indian languages, by making correction of the durational of frequency parameters of speech.

Sheela (1989) 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, 4 normal and 4 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 8 bisyllabic Kannada words. The recorded words were digitized and acoustic analysis was carried out to obtain of the vowel duration, word duration, fo, f1, f2, f3, BW1, BW2, and BW3. Later the corrections of vowel duration, pauses and Fo were made in the speech of the hearing-impaired for those words where in these parameters were deviant from the normal individuals mean value in order to match the mean values of the normals.

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

1) longer vowel duration when compared to the normals,
5) 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.

The correction of timing errors and average Fo did effect the intelligibility of speech of the hearing-impaired.

The correction of different types of errors either in isolation or in combination had differential effect on the intelligibility.

It was seen that the maximum improvement in intelligibility was observed when the vowel durational one was corrected and it was noticed that when pause alone was corrected and when the combination of vowel duration and pause was corrected the scores were less.

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 6 children 3 normal and 3 hearing-impaired between 9-1S 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 bisyllabic 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 were there was any significant difference between the values of the normal hearing group from the hearing-impaired group was 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.

E) Intersyllabic pauses were present in hearing-impaired and was absent in that of the normal.

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

The intelligibility rating indicated that speech intelligibility improved when the vowel duration was altered with the elimination of pauses and there was only slight improvement when only one condition was changed.

As Oster (1985) points out the errors in the speech of the hearing-impaired may be individual or universal ie. language specific. Therefore it was considered that it will be interesting to study the errors in the speech of the hearing—impaired speaking different Indian languages and to see the effect correction of errors temporal of acoustic, on such speech.

There have been no such studies in Malayalam. Therefore, the present study was undertaken to see the effect of the correction using computer of some of the temporal aspects in the speech of the hearing-impaired on the speech intelligibility.

METHODOLOGY

Introduction:

The study was aimed at finding out the difference in the speech at Malayalam speaking normal and hearing-impaired children who are using hearing aid and undergoing therapy, and then to modify some of the deviant speech parameters in the speech of the hearing—impaired using signal processing techniques to approximate normal speech, to determine the influence on intelligibility.

A. Subjects and test material:

Five normal and five hearing—impaired between 5-9 years were selected for the study. The hearing-impaired children were selected from among the cases who are attending therapy at All India Institute of Speech and Hearing satisfied the following conditions:

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

2. Had no other problems/deviations other than that are directly related to the hearing-impaired.

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

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

The test material consisted of ten bisyllabic Malayalam words. Words were simple so that both normal and hearing-impaired children (Given in Appendix-I)COULD READ THEM-WORDS WERE TAKEN FROM "ARTICULAION TEST BATTERY IN MALAYALAM "(MAYA-S-1990 WHICh WAS USED FOR AGE GRROUP OF 3-4YRs.

B. Instrumental set-up:

The speech samples were recorded in a spool tape using the tape recorder of the sound spectrograph (voice identification is 700 series).

C. Recording procedures:

The recordings were made in a sound treated room of Speech Science Laboratory. Each subject had to read a list of ten words in front of unidirectional microphone which was place at about four inches away from the subjects mouth.

Acoustic analysis:

The recorded words were digitized at a sampling frequency of 16000 Hz and the block duration and resolution were 50 msec, and 10 msec, respectively using a A/D converter and stored on the hard-disk of the computer using the programme by voice and speech system, Bangalore.

The parameters were analysis the following vowel duration, duration of pauses (intra word if any), total duration of the word, Fo, formant frequencies (F1 and F2) and bandwidth (B1 and B2). These were noted down for all the 10 children and for all the words (ie. 10 words each).

Statistical analysis:

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

To check whether there were any significant differences between the values of the normal hearing group and hearing-impaired group, Wilcoxin, signed ranks test was applied using NCSS programme.

Modification of speech parameters in the speech of hearing–impaired to approximate normals:

The parameters corrected were:

1. Vowel duration
5. Pauses (intra word pauses)

All the combinations of these three were used. Thus words with three types of corrections were obtained altogether. They were:

1. Elimination of pause only
3. Correction of vowel duration only
3. Correction of pauses and vowel duration.

In all instances corrections were made to match the mean values of normal hearing group.

Correction procedures:

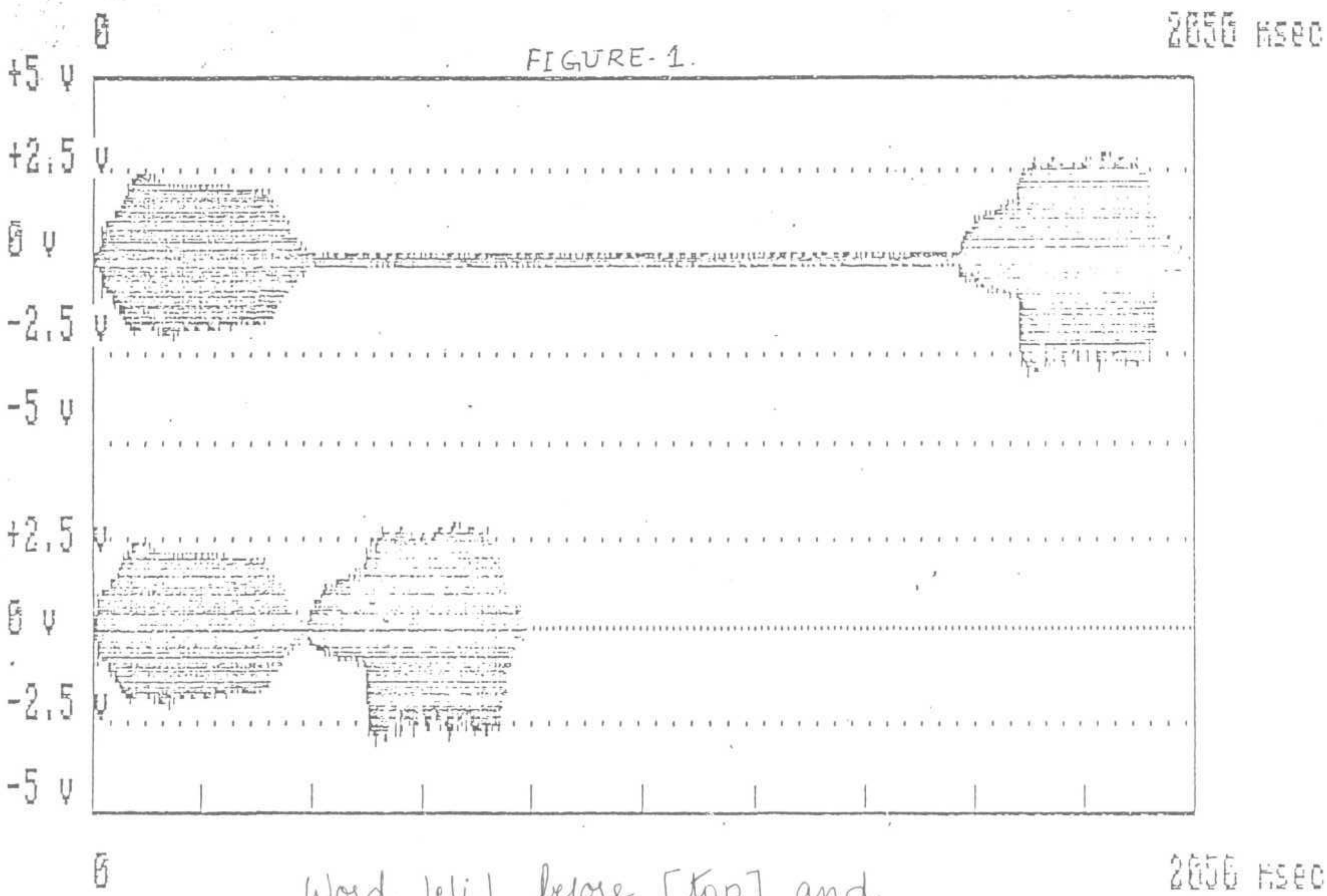
1) Correction of pauses only : Since the normal hearing children did not show any within the word (inter syllabic pauses), all the pauses were eliminated from the speech samples of the hearing-impaired children. If there were any. Care was taken to preserve the transition portions of the wave form. All together there were 26 words.

3) Correction of the vowel duration only: Here the vowel duration of the hearing—impaired childrens speech samples were either reduced or increased so as to match with the mean values of the normal hearing group. Care was taken so that all the transition portions of the wave forms were not altered. The correction was done only in the stable portions of the wave forms. Except for one vowel all the other vowels had increased vowel duration.

3. A combination of the above two procedures were used to obtain the words with combination of corrections.

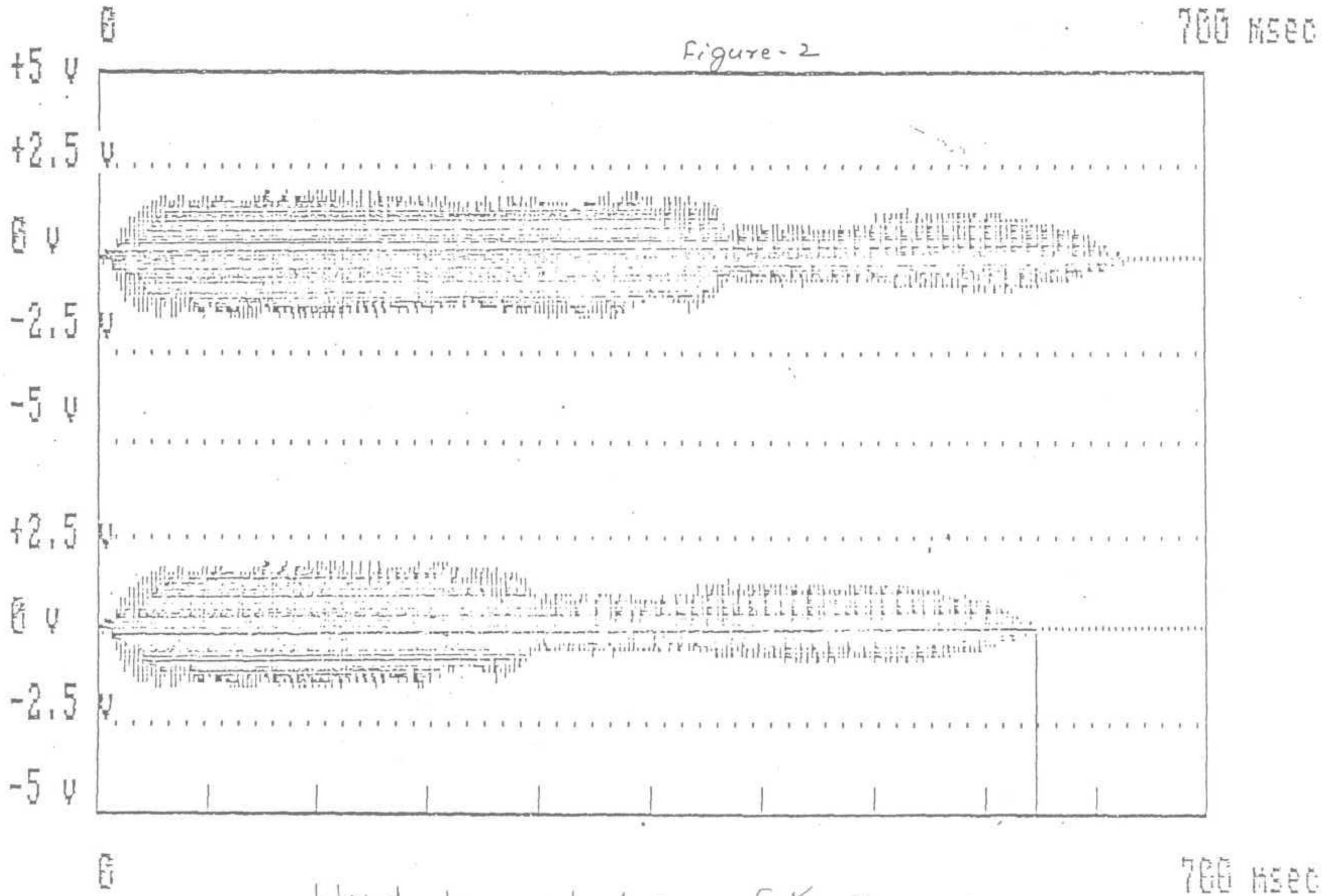
Thus a total of 102 words were obtained.

FIGURE-1.



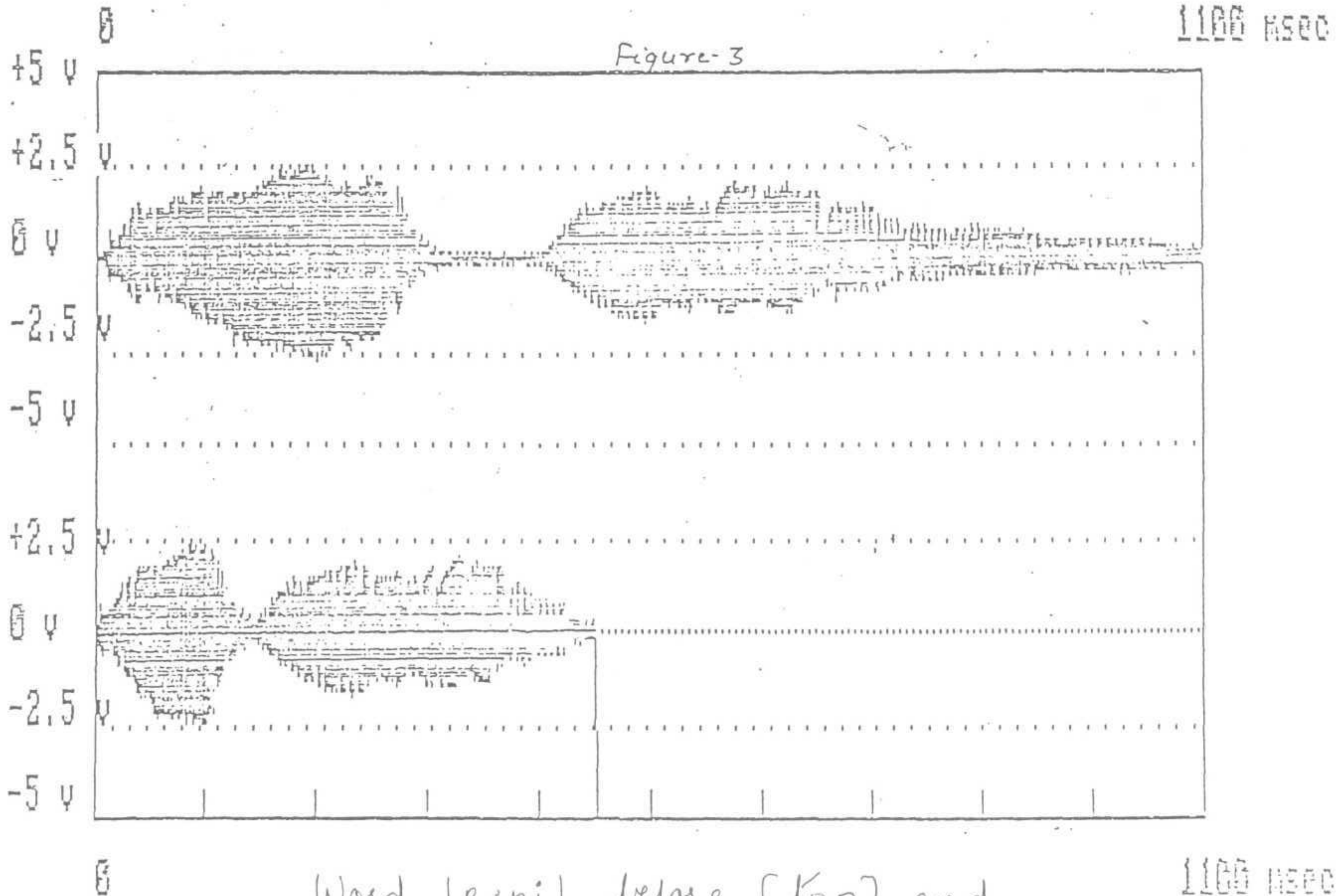
Word |eli| before [top] and after [below] pause correction.

Figure - 2



Word |a:ma| before [top] and after [below] vowel duration correction.

Figure-3



Word |e:ni| before [top] and after [below] pause and vowel duration correction.

Re-recording the speech samples.

The unaltered and altered speech samples were recorded onto cassette tapes. There were 50 unaltered utterances and a total of 102 altered utterances. All the 155 words were randomized so as to eliminate practice effect.

Perceptual analysis:

Three judges were requested to listen to the speech samples and to write down the words that they heard (word identification task). Words were presented in a randomized manner and repetitions increase of words were also present in order to increase the reliability. They were also requested to rate the intelligibility of the words on a five point interval scale (intelligibility rating) from 0 denoting unintelligible to four denoting highly intelligible.

The three judges formed a heterogeneous group consisting of one post graduate student one graduate student, in speech and hearing, and one person with no previous experience in listening to the speech of the hearing-impaired. All knew Malayalam well. No clues were given regarding the words used in the study.

Statistical analysis:

a) The number of correct identification by each judge in each category was converted into percentage of scores as follows:

$$\frac{\text{Number of correct identification}}{\text{Total number of utterances}} \times 100$$

b) The intelligibility rating.

The rating made by majority of the judges was considered to be the intelligibility rate of the particular word.

Descriptive statistics was obtained for both altered and unaltered utterance.

Wilcoxin signed rank test was performed to check whether there was any significant difference between unaltered and each type of altered utterances.

The results were also analyzed to find out the words that are identified correctly majority of the time.

A measure was carried out to check the intra judge reliability using the words which were repeated.

RESULTS

The objective of the present study was to find out the effect of correction of some timing error on the intelligibility of speech of hearing-impaired children speaking Malayalam.

Acoustic Analysis:

Ten bi syllabic words uttered by five severely hearing impaired and five normal hearing children were analyzed to obtain the following acoustic parameters:

1. vowel duration
2. Total duration of the words
3. Formant frequencies F1 and F2.
4. Band widths Bw1 and BW2

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

1. Vowel duration:

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

Out of all the ten vowels measured ail the ten vowels (a, a:, i, i:, u, u:, e, e:, o and o:) had longer vowel durations than the normal subjects. iA6n-t T? CiEAPW t

Table-1 : Showing the descriptive statistics for vowel duration.

Vowels	Normals		Hard-of-Hearing	
	Mean (msec)	Standard Deviation	Mean (msec)	Standard Deviation
a	163	63.7	554.8	107.5
a:	287.6	70.6	592.4	165.6
i	189	58.3	352	95.8
i:	280	111.5	348	107.3
u	108.8	33.07	192.4	154.5
u:	331.4	98.3	555.4	251.7
e	509	59.13	344.8	146.1
e:	355	104.5	633.6	508.07
o	220.5	58.5	224.8	148.6
o:	575.6	109.3	487.4	163.6

In the normal group, among the ten vowels the vowel /e:/ had the longest duration (355 msec) followed by /u:/ (331.4 msec), /a:/ (287.6 msec), /i:/ (280 msec), /o:/ (275.6 msec), /o/ (220.5 msec), /e/ (209 msec), /i/ (189 msec), /a/ (163 msec), /u/ (108.8 msec.).

Similarly in the case of hearing-impaired also the vowel /e:/ had the longest vowel duration (633.6 msec) followed by /a:/ (592.4 msec) /u:/ (555,4 msec), /o:/ (487,4 msec), /i/ (352 msec), /i:/ (348 msec), /e/ (344.8 msec), /a/ (254.8 msec), /o/ (224.8 msec), /u/ (192.4 msec).

There was an overlap between the ranges of the values of two groups. For the normal group minimum values varied from 69-550 msec, and the maximum values ranged from 165-500 msec. And in the hearing-impaired group the minimum value ranged from 50—400 msec and maximum from 375-500 msec.

Wlilcoxin signed rank test performed showed a significant difference between the two groups at 0.05 level of significance.

Thus the hypothesis l(a) stating that there is no significant difference in the utterances of children with normal hearing and hearing-impaired children in term of vowel duration is rejected.

Pauses

The normal hearing children did not show any intersyllabic (intra word) pauses. Pauses were observed in the utterances of four hearing-impaired children. One subject in the hearing-impaired group did not show any pauses. First subject showed pauses in eight words, second in six word, third in four and the fourth subject in six word. The duration of pauses ranged from 90 msec, to 1210 msec.

Thus the hypothesis 1(b) stating that there is be significant differences in the utterances of children with normal hearing and hearing-impaired children in terms of intersyllabic pauses were rejected.

2. Total duration of the words:

The words uttered by the hearing-impaired subjects had longer durations in general when compared to the normal hearing group which is also depicted in Table-II and Graph-2.

Table-E: Descriptive statistics for total duration of words.

Words	Normals		Hard-of-Hearing	
	Mean (msec)	Standard Deviation	Mean (msec)	Standard Deviation
./amma/	752.2	. 230.14	785	271.9
/a:ma/	768	272.5	1096	244
./ila/	698.4	102.65	837.4	249
./i:cha/	819.4	315.8	825	169.5
./uppu/	108.8	33.07	192.4	154.5
/u:nu/	750.2	558.3	988.2	166.03
./eli/	694.6	556	797.4	259.6
./e:ni/	841.6	519.8	1194.6	506.7
./onnu/	736.6	508.1	854.8	109.7
./oto/	759.2	191.4	947.4	290

The word /e:ni/ had the longest mean total duration (841.6 msec) followed by /i:cha/ (819.4 msec) /a:ma/ (768 msec) /0:to/ (759.2 msec), /amma/ (752.5 msec), /u:nu/ (750.2

msec), /onnu/(736.& msec), /ila/ (698.4 msec), /eli/ (694.6 msec), /uppu/ (108.8 msec).

In the case of hearing-impaired group the word /e:ni/ . (1194 msec), had longest mean total duration followed by /a:ma/ (1096 msec), /u:nu/ (988.5 msec), /o:to/ (947.4 msec), /onnu/ (854.8 msec), /ila/ (837.4 msec), /i:cha/ (825 msec), /eli/ (797.4 msec), /amma/ (785 msec), /uppu/ (192.4 msec).

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

The minimum values for the words ranged from 80-58 msec, for normals and the maximum ranged from 162 - 1087 msec.

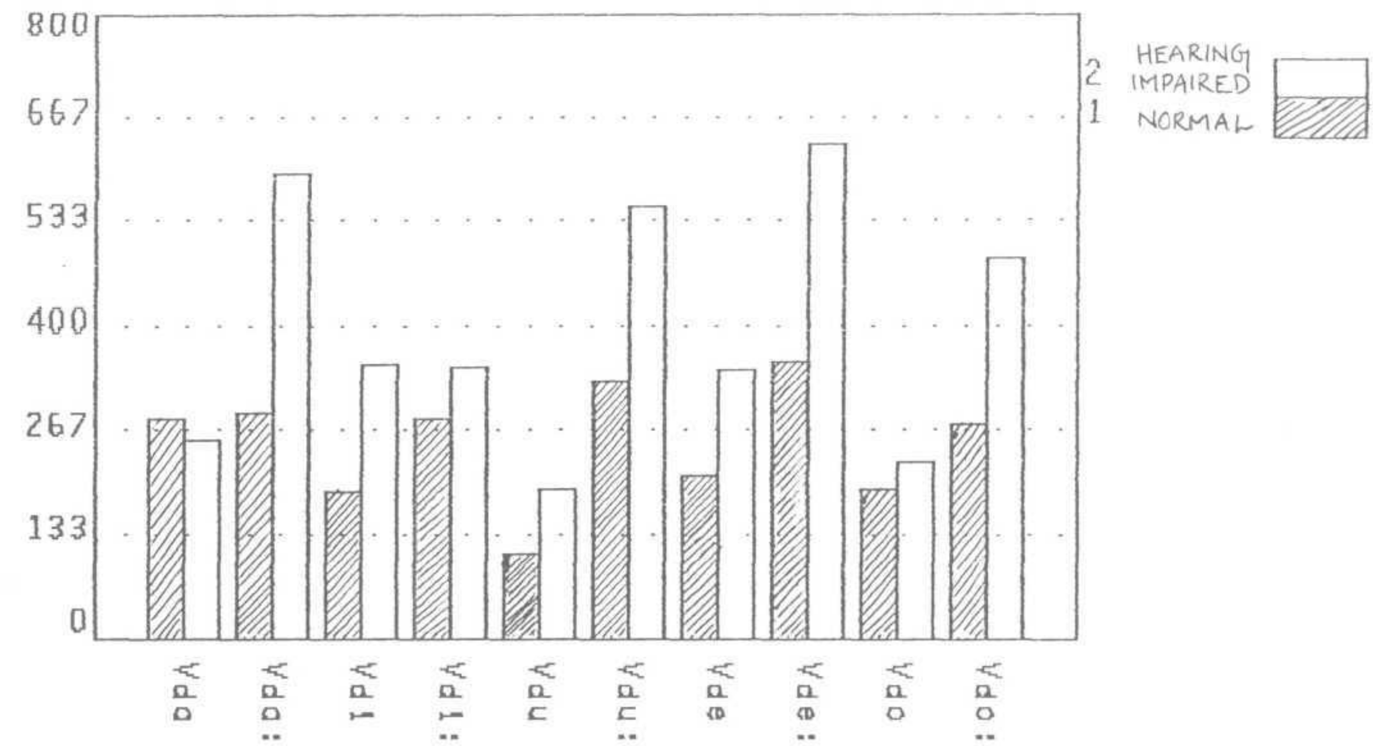
In case of hearing-impaired the minimum values ranged from 50 - 755 msec and the maximum values from 480 - 1900 msec.

Wilcoxin signed rank test performed shows significant difference between the two groups at 0.05 level of significance.

Thus the hypothesis l(c) stating that there is no significant difference in the utterances of children

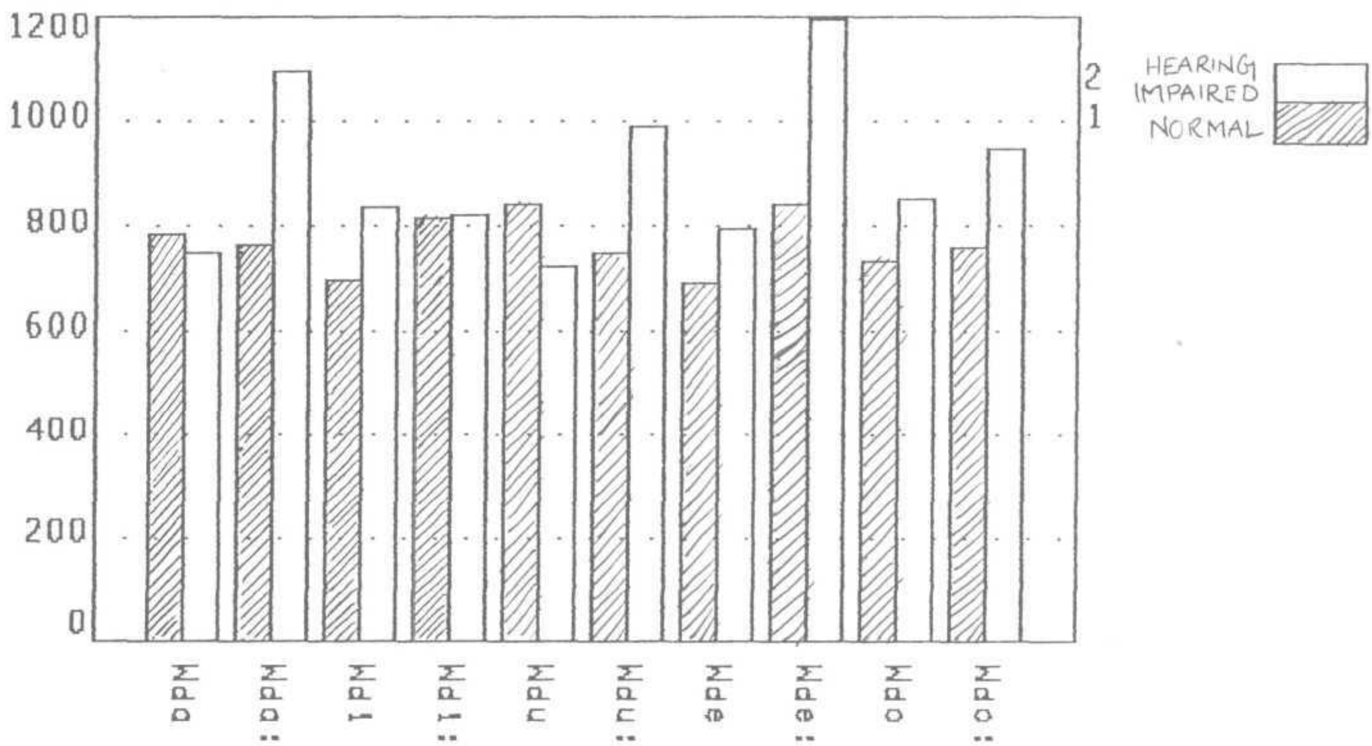
GRAPH - 1

VOWEL DURATION



GRAPH - 2

WORD DURATION



with normal hearing and hearing-impaired children in terms of total duration of words is rejected.

Average fundamental frequency

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

TaPle-3: Descriptive statistics for average fundamental frequency

vowels	Normals		Hard -of-Hearing	
	Mean (msec)	Standard Deviation	Mean (msec)	Standard Deviation
/a/	248.2	15.5	403.6	241.1
/a:/	246.7	51.37	437	577.15
/i/	338.2	60.31	452	76.06
/i:/	248.6	12.97	366	139.2
/u/	259	21.4	393.2	119.05
/u:/	253.6	15.17	399.8	224.7
/e/	244.4	11.01	418.8	189.033
/e:/	252.4	14.32	369	157.67
/o/	256.6	17.5	357.2	185.01
/o:/	258.6	76.35	373.4	167.43

As shown in Table III and Graph (3) In the normal hearing group the highest Fo was for the vowel'/i/ (338.5 Hz) followed by /u/ (259 Hz),/o;/ (258.6 Hz), /o/ 9556.6 Hz) /u:/ (253,6 Hz),/e:/ (252.4 Hz), /i;/ (248.6 Hz) /a/ (248.5 Hz), /a:/ (246.7 Hz), /e/ (244.4 Hz).

In case of hearing-impaired subjects the highest Fo was for the vowel /i/ (452 Hz) followed by /a/ (437 Hz), /e/

(418.8 Hz), /a/ (403.6 Hz) /u:/ (399.8 Hz), /u/ (393.2 Hz) /o:/ (373.4 Hz), /e:/ (369 Hz), /i:/ (366 Hz), /o/ (357.5 Hz).

The minimum values ranged from 212.5 - 277 Hz and maximum from 554 - 427 Hz in normals.

The minimum values ranged from 200 - 579 Hz and the maximum values ranged from 579 - 920 Hz in hearing impaired.

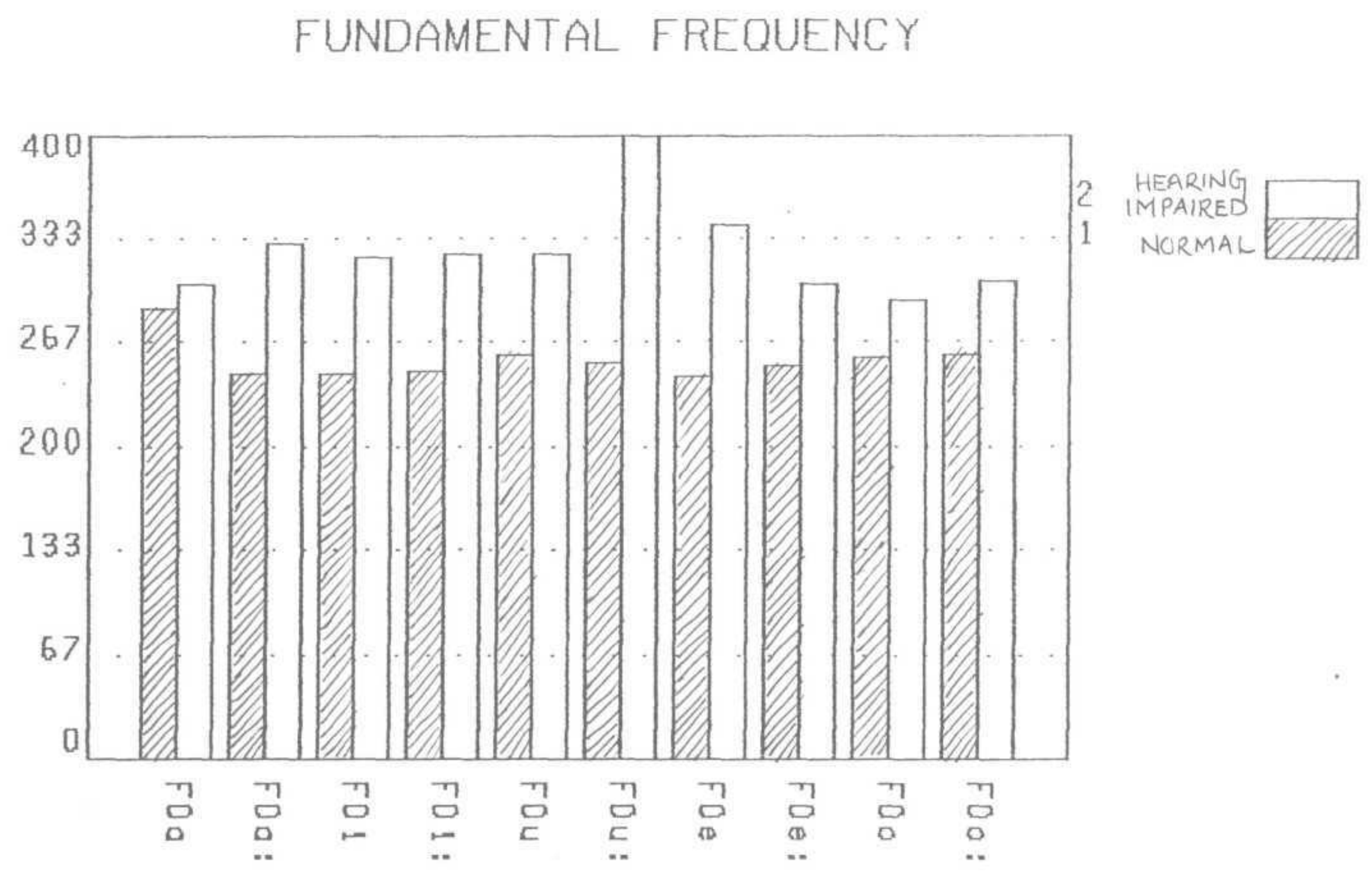
Wilcoxin signed rank test indicates significant difference between the two groups at 0.05 level of significance.

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

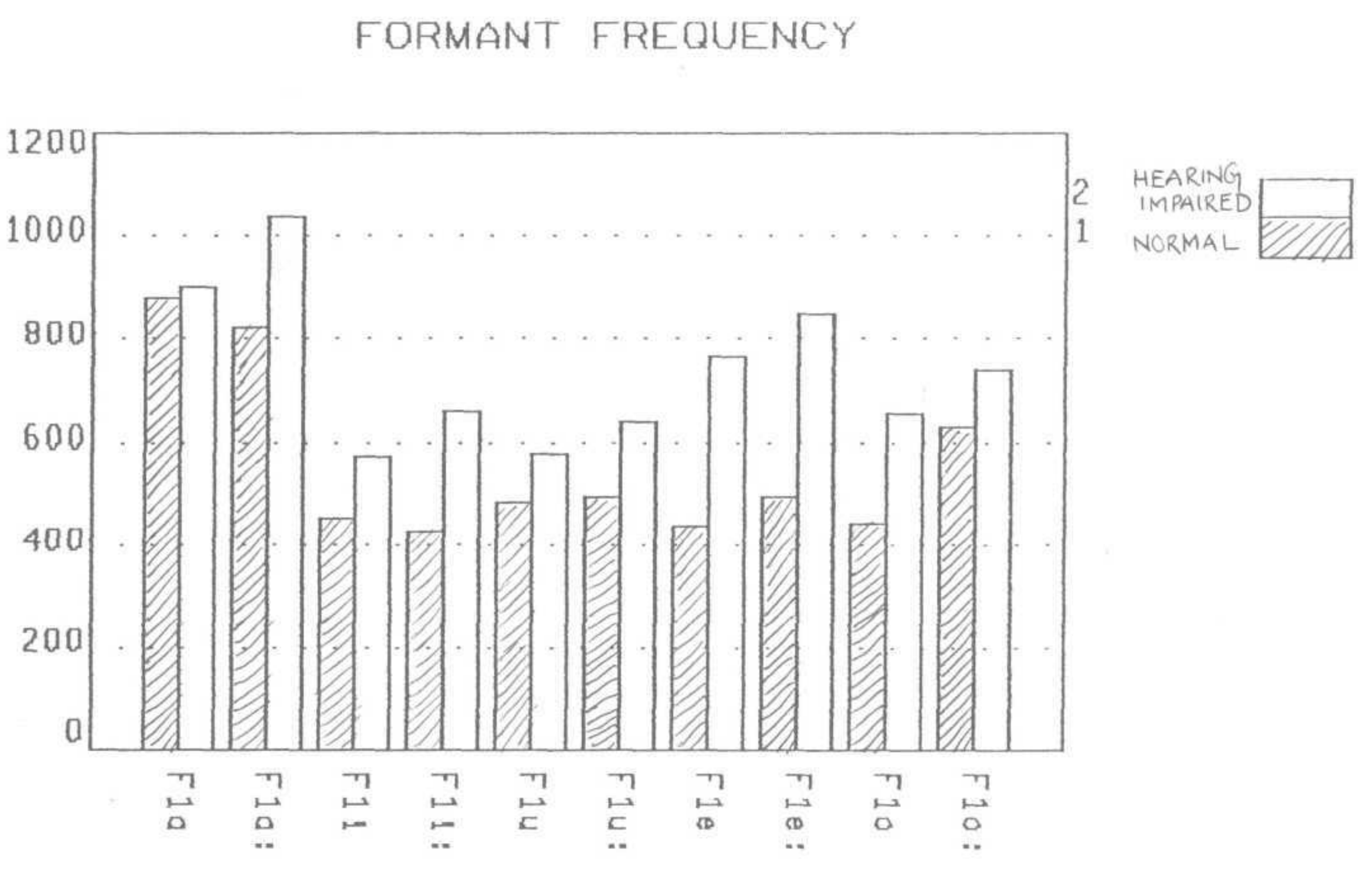
Formant frequencies.

Two formant values namely F1 and F2. for each vowel was obtained.In general the hearing impaired children had higher F1 as shown in the graph (4), they also had higher F2 values than those of the normal hearing group. The hearing-impaired group showed greater variability.

GRAPH-3



GRAPH-4



Wilcoxin signed rank test performed to check the significant difference between the two groups shows a significant difference between the 5 group at 0.05 level of significance for F1 and no significant difference at 0.05 level of significance for F2.

Thus the hypothesis l(e) stating that there is no significant difference in the utterances of children with normal hearing and hearing-impaired subjects in terms of first formant of the vowel is rejected and the second formant of the vowels is accepted.

Band widths

The two band width B1i and B2 were determined for all the vowels. The hearing-impaired children had smaller values of band width.

The Wilcoxin signed rank test performed shows a significant difference between the two group at 0.05 level of significance for Bw2 and not for Bw21

Thus the hypothesis l(f) stating that there is no significant difference in the utterances of children with normal hearing and hearing impaired children in term of Bw2.

of the vowels is rejected and in terms of BW1 of the vowel is accepted.

Part-2

CORRECTION OF DEVIATION FROM NORMALS IN THE SPEECH OF HEARING IMPAIRED.

In the second part, the digitized data of hearing impaired subjects were corrected in terms of vowel duration and pauses. As these measures were considered to be more important in determining the intelligibility (Sheola, 1*780; Jagadish, 1989).

Each of these measures were corrected individually and later a combination of the two corrections were made. Three corrections were made as described in the methodology.

Part-3

PERCEPTUAL EVALUATION

All the corrected utterances were mixed with the unaltered utterances and thus 207 utterances were randomized and given to 5 judge for word identification task and intelligibility rating. The number of words identified correctly were converted into percentage scores. The intra and inter judge judgement were found to be highly reliable.

Table 4: Showing the word identification sentence of percentage.

Parameters corrected	Jl	J2	J3	Mean
Unaltered	40	36	34	36.36
Pause	22.2	19.4	25	22.2
Vowel duration	60	54	66	60
Vowel duration & pause	16.6	18.18	22.7	19.16

The study of Table-4 show that the mean scores obtained for the words with vowel duration correction was highest (60%) followed by unaltered words (36.36%) pause correction (22.2%) and vowel duration and pause correction (19.16%). This result indicate that vowel duration itself has positive effect on speech intelligibility and all the other correction have a negative effect on speech intelligibility. Wilcoxins signed ranks test was applied to check whether the improvement shown when the vowel duration was corrected was significant or not. The results showed it was significant at 0.05 level.

HYPOTHESIS

A. <u>Correction of the vowel duration:</u>

The hypothesis, stating that there is no significant difference in the intelligibility scores of original unaltered utterances sand uttenaces when the vowel duration alone is altered is rejected.

There was a significant improvement in the intelligibility scores when the vowel duration alone was corrected.

B. Correction of pauses:

The hypothesis stating that there is no significant difference between the intelligibility scores of original unaltered utterances and the utterances where the intersyllabic pause alone have been corrected is rejected.

There was a decrement in the intelligibility scores when pauses (intersyllabic) alone were corrected.

C. Correction of vowel duration and pauses:

The hypothesis stating that there is no significant difference between the intelligibiiity score of original unaltered utterances and the utterances were the vowel duration and pauses have been corrected is rejected.

There was a decrement in the intelligibility scores when the vowel duration and pauses were corrected.

Results were further analyzed to find out which of the eight words have been identified correctly most of the time. It was seen that the word /amma/ was identified the most followed by /:ma/, /i/a/, /i:che/, /o:h/ /onnu/ /i/a/, /i/i// /e:ni/ and /u:nu/ (Table 5).

Table-5: Showing the correct identification scores in terms of percentage for the words.

Words	Jl	J2	J3	Mean
/amma/	60	60	80	66.6
/a:ma/	40	80	60	60
/i:cha/	60	40	40	46.6
/uppu/	40	60	40	46.6
/o:to/	40	40	40	40
/onnu/	60	40	0	33.3
/ila/	20	40	40	33.3
/eli/	20	0	20	13.3
/e:ni/	20	0	0	6.6
/unu/	0	0	0	0

Besides word identification task, the judges were also requested to rate the intelligibility of each word on a 5 point interval scale as follows:

0 - unintelligible

1 - poorly intelligible

2 - fairly intelligible

3 - quite intelligible

4 - highly intelligible

The analysis of intelligibility rating revealed the following: (Table–6).

Table–6: showing the scores sand percentage of scores of intelligibility ratings.

0	1	2	3	4
33		35	14	4
21.7%	43.42%	23 .02%	9.21%	2 .6%

The intelligibility rating:

21.7% as unintelligible (rating o)
43.42% as poorly intelligible (rating no.l)
23.02% as fairly intelligible (rating no.2)
9.2% as quite intelligible (rating no.3)
2.6% as highly intelligible (rating no.4).

DISCUSSION

The hearing -impaired children had longer voWel durations when compared to the normal hearing group. This finding is in agreement with the studies of angelocci.,1962, Calvert, 1962: John and Howarth, 1965; Boone, 1966; Levitt et. al., .1974; Osberger and Levitt, 1979; Rajanikanth, l986; Leeper et. al., 1987; Shukla, 1987; Sheela, 1988; Jagadish, 1989. These studies reported that a general tendency towards lengthening of vowels and consonants in the speech of hearing-impaired.

IN the present study it was also observed that the hearing impaired children showed more variability when compared to normal hearing children. These findings are in agreement with the reports of Honsen (1974), Osberger (1978), Rajanikanth (1985), Shukla (1987), Sheela, (1988), Jagadish (1989).

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

The longer vowel durations reported in case of hearing-impaired children can be attributed to this because it was seen that on the average, these children had higher fundamental frequency than that of the normal hearing children.

It has been reported that the profoundly hearing impaired speakers insert more pauses and pauses of longer durations than do speakers with normal hearing Boone (1966), Boothroyd (1974), Heidinger (1972), Stevens (19787), Osberger and McEarr (198S), Sheela, (19S8), Jagadish (1989).

In the present study, it was found that out of the five hearing impaired children, four inserted pauses between two syllables whereas one subject did not do so.

Pauses were present in eight of the ten utterances in one subject, six in two subjects and four in one subject.

"The frequent pauses observed in the speech of the hearing impaired may be the result of poor respiratory control". H

Forner and Hixon (1977) found that the muscle activity to be normal for deaf individuals during quite breathing but noted that they do not take enough air while breathing for speech.

In this study it was also seen that the total duration of words were longer in the hearing-impaired group when compared with the normal hearing children.

Similar findings have been reported by Leeper (1987). Total duration of words would be more is hearing impaired children as they prolong the speech segments. Osberger and McGarr (1982) reported prolongation of speech segment present in the production of phonemes, syllables and words in the speech of hearing impaired.

In the present study, it was seen that the hearing impaired children had higher fundamental frequency when compared to the normal hearing children.

Few explanations have been put—forward in order to explain the higher fundamental frequency in case of hearing-impaired.

Pickett (1968) suggested that the increase in fundamental frequency is due to increased subglottal pressure and tension of the vocal folds. Thus his opinion has been that the increased vocal effort is directed at the laryngeal mechanisms for kinesthetic feedback and thus leading to increase in Fo.

Willemain and Lee (1771) hypothesized that the deaf speakers use extra vocal effort to get an awareness of the onset and progress of voicing and this becomes the cause for the high pitch which is observed in their speech.

Speech intelligibility is a measure indicating how well the speaker could make himself or herself understood to a group of listeners.

It is reported that the intelligibility of the profoundly hearing impaired children's speech is very poor (Hudgins and Numbers, 1942), Goda 1959; Angelocci, 1962; Nober, 1967; Smith (1975); Osberger (1978); Ling (1981), Ravishankar (1985), Sheela, (1988), Jagadish (1989).

In the present study, the words were presented randomly to three judges and they were asked to identify the words.

The responses of the judges for unaltered, original utterances ranged from 34% to 40% with a mean score of 36.6%.

This result indicates that the speech intelligibility was poor. This may be attributed to the subjects used and the type of material used or may be due to methodological differences.

Ling (1976), states that intelligibility ratings vary not only with the type of judge employed, but also with the materials used and with the method of analysis. Thus sentences 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 which are tape recorded.

The words are less redundant and the utterances were tape recorded. These might have led to the poor intelligibility scores.

The assessment of the speech of the hearing-impaired is important as it would help in program planning and program evaluation and research.

Subtelny (1977) reports that speech intelligibility assessment cannot be used with confidence for training purposes without knowledge of the properties of speech that can influence intelligibility.

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

Gold (1980) reports that even though there was much documentation of the kinds of segmental and suprasegmental errors in the speech of the hearing impaired, there was far less evidence of the direct effects of each of these error types on overall speech intelligibility. Having knowledge in this aspect will help in planning suitable training program for each hearing-impaired child for improving the speech production ability.

Manipulations of speech, by means of digital speech processing on speech synthesis techniques to study the direct effect of various segmental and suprasegmental errors on speech intelligibility of the hearing impaired children's speech is of recent origin. There have been few studies in this regard (Kurger, 197S; Land, 1975; Maassen, 1986).

The present study also aimed at finding out the effect of some timing errors on the speech intelligibility of the hearing-impaired children's speech.

The following conclusions have been drawn from the present study:

1. The correction of timing errors did effect the intelligibility of the hearing impaired children's speech.

2. The conclusion of different types of errors either in isolation or in combination had differential effect on the intelligibility.

Out of the three types of corrections made, (1) correction of pauses only, (2) correction of vowel duration (3) correction of pause and vowel duration.. Maximum improvement was observed when the vowel duration alone was corrected. The values ranged from (54—60%) with the mean value of (60%) and was statistically significant at 0.05 level of significance.

This maybe attributed to the importance of vowel duration in the perception of speech.

Studies on vowel duration on production and perception in normals (Nooteboom, 1973) suggest that listeners are extremely sensitive to the duration that a vowel should have in a given context. It has been shown by Calvert (1961) that experienced listeners to hearing impaired speech can not identify speech as that of hearing impaired unless they hear at least syllable lengthened productions. "This shows that the effect of the characteristic deaf syllable prolongation were to make the deaf conspicuous and tedious to listen to" (Harris and McGarr, 1980).

In the present study when the correction of pause was done it was seen that it had a detrimental effect on the speech intelligibility. The values ranged from (19.4% to 25%) width a mean value of 22.2%.

Similar reports have been made in the literature (Parkhurst and Levitt 1978); Osberger and Levitt (1979); Maassen (1986).

Osberger and Levitt (1979) reported that elimination of pauses had significant negative effect on speech intelligibility.

They attributed this to the reduction in the amount of time available to the listeners to process the speech of the deaf. Osberger and Levitt stated that "thus, it appears that the presence of long pause may actually provide the listener with additional time with which to process the numerous distortions which occur in the speech of the deaf".

In the present study it was noted that when the correction of pauses and vowel duration was simultaneously done, there was a negative effect on intelligibility.

This might be because the correction of pauses had more dominating effect on the intelligibility than that of vowel duration correction. This also shows that there was an interaction between timing correction when two types of timing errors were corrected simultaneously.

An analysis of intelligibility rating revealed that most of the utterances got rating 1' meaning that the words were poorly intelligible. (66%) rated poorly intelligible (35%) as fairly intelligible (14%) as quite intelligible (4%) as a highly intelligible and (33%) as unintelligible.

Further it is interesting to note that the intelligibility deteriorated further from 2S.SX to 19.IX when both the correction (i.e. removal of pauses and altering the voiAtel duration) were made. Thus it can be concluded tti3t the alteration of vowel duration has a positive significant effect on the intelligibility of speech of hearing impaired. Uhere as the altering of pauses has a significantly negative effect.

These results also indicate the need for the detailed study of relationship between the vowel duration and pauses and other possibly related parameters.

SUMMARY AND CONCLUSION

"Deafness is a fearsome problem largely because of the barrier to communication which it creates. The obvious effect of this barrier is to prevent the deaf from understanding what others say, but it may also impede them from speaking intelligibly. The magnitude of their problem is illustrated by recent studies suggesting that of prelingually deaf children, hearing losses of 90 dB or more, about 75X have speech classified as "barely intelligible" or worse" (Conrad, 1979).

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

The low speech achievement of the hearing-impaired has led to several investigators in the past to correlate speech intelligibility with several receptive and productive variables of speech.

Some attempts have been made to study the direct effect of segmental error corrections of speech of the hearing-impaired using modern computer processing techniques (Lang, 1975; Osberger and Levitt, 1979; Maassen and Povel, 1984 a, b, 1985; Oster, 1985). The advantage of such technique is that it is possible to determine the causal relationship between the error type and intelligibility without the presence of any other confounding variable. Also results of such studies will help in determining, the error type and kinds of errors that should be considered first while planning a training program for the improvement of speech of the hearing-impaired child.

No such studies have been reported in Malayalam speaking hearing-impaired children. The present investigation was undertaken in order to study the effect of some suprasegmental error corrections on the intelligibility of speech of the hearing-impaired.

Five congenitally hearing-impaired children in the age group of 5 — 9 years were selected from the therapy clinic of All India Institute of Speech and Hearing for the study. All these children had severe to profound sensori-neural hearing loss. They had no additional handicap other than that directly related to the hearing-impairement. All read simple bisyllabic words in Malayalam.

Ten simple bisyllabic Malayalam words meaningful were selected. The speech samples of all the four children were recorded as they read the words. Recordings were also obtained of a matched group (for age and sex) of five normal hearing children reading the same set of words.

Experitiment—I: The samples were then analysed using computer programmes of VSS, Bangalore. The following parameters were obtained.

1. Vowel duration
S. Duration of pauses
3. Total duration of words
4. Average F0
5. Formant frequencies (F1 and F2,)
6. Bandwidth (BW1 and BW2)

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

Experiment-II: Some aspects of the suprasegmental errors in the digitized data of hearing-impaired children's speech were modified in this stage. Two measures were considered. They are:

1. Correction of pauses, if any
S. Correction of vowel durations and
3. Combination of these two ie. correction of both vowel duration and pauses.

All the measures were corrected towards the mean values of normal hearing group.

Thus, these two measures were corrected in isolation and in combination. A11 together three types of corrections were performed.

Experiment-III: The unaltered utterances and the corrected (total 155 utterances) were recorded randomly. This recording was presented to three judges for word identification task and intelligibility rating.

The number of words identified correctly were converted into percent scores using the formula.

No.of words identified correctly
----------=x100
Total number of words present

The judges had to rate the intelligibility on a five point interval scale, ranging from 0' (intelligible) to '4' (highly intelligible).

The judges showed that the correction of vowel duration had a significant effect on intelligibility, while all the other types of corrections had determinantal effect on intelligibility.

The correction of vowel duration showed 23.4% of improvement when compared with the unaltered utterances.

The results were also analysed to find out which of the ten words has been identified correctly most of the time. The word /amma/ topped the list in both the conditions followed by /a:ma/, /i:cha/, /uppu/, /o:to/, /onnu/, /ila/, /eli/, /e:ni/, /u:nu/.

Analysis of the intelligibility ratings revealed that the words (21.7%) were rated as unintelligible, words with (43.42%) as poorly intelligible, (23.02%) as fairly intelligible (9.21%), as quite intelligible (2.6%), as highly intelligible.

Thus, it was seen that the correction of some of the suprasegmental characteristics of speech of the hearing-impaired caused a decrease in the speech intelligibility whereas the correction of vowel duration alone has a beneficial effect on the speech intelligibility. This result is in agreement with the results of previous studies quoted in the literature (Lang, 1975; Osberger and Levitt, Maasen and Povel, 1984; Oster, 19B5).

It is suggested that the segmental correction may be started first in the training program so as to get a more intelligible speech. Once this is achieved, we can go for correcting the suprasegmental aspects to have positive effects both on intelligibility and naturalness.

"How to achieve this results, that is, how and to what extend these suggestion can be applied in practical speech training especially in view of the high correlation between segmental and suprasegmental aspects in speech production is a question that can only be solved in practice (Maasens and Povel, 1985).

Results of the present study shows:

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

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

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

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

5. The hearing—impaired children had higher first formant (F1) and second formant frequency (F2.) smaller than the normal hearing group.

The synthesis of speech of the hearing-impaired children showed that the intelligibility.

a) Improved:

i) when the vowel durations were corrected.

b) Decreased:

1) when the intersyllabic pauses were corrected.

S) klhen the vowel duration and pauses were corrected.

Thus, the study established that there is significant difference in term of vowel duration, pauses, formant frequencies F1, F2 and bandwidth Bw1 Bw2, between the normal and hearing-impaired speech and the intelligibility improves by correction of vowel duration alone and combination of the two ie. correction of pause and vowel duration had negative effect on intelligibility.

Recommendations:

1. Similar studies can be carried out with sentences as speech material.
2. Similar study may be carried out for segmental errors.
3. A study to find out the effect of correction of both the segmental and suprasegmental aspects of speech may be undertaken.
4. A study to establish relative impact on intelligibility of different types of speech errors and to develop an individual program for speech improvement can be carried out.
5. Study of larger population with suggested modification will be useful.

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APPENDIX - 1

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/u:nu/

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