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.

Guide,
N.P.NATARAJA,
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DECLARATION

This dissertation is the result of my own study under the guidance of Mr. N.P. Nataraja, Reader & Head, 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.

Mysore-6. Reg. No:8610

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ANALYSIS & SYNTHESIS
OF
SPEECH OF HEARING IMPARIED

REG.NO.8610

ALL INDIA INSTITUTE SPEECH & HEARING MYSORE-6.

SUBMITTED TO THE UNIVERSITY OF MYORE

IN PART FULFILMENT FOR THE DEGREE OF

MASTER OF SCIENCE (SPEECH & HEARING)

1988

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 Number : M-8610.

Dr. N. RATHNA,
Director,
AIISH, Mysore-6.

To

My Guide

who has been my guiding light throughout the work.

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Dr. N. RATHNA,
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CONTENTS

INTRODUCTION

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

- Monsen (1978)

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

"Even though the history of teaching speech to the hearing impaired spans several centuries the level of speech competence achieved such that the individual can make himself understood to the naive person on the street still remains to be SL (Ling. 1976).

The results of many studies have suggested that the speech of many hearing impaired children is act a viable instrument for verbal communication and can be the cause of daily communication break down, a frustrating and unrewarding experience for the children and their listeners alike (Smith, 1975). Attempts to over come this problem through intensive speech training have met with only limited success. (Nickerson, 1975).

Many factors like residual hearing, segmental errors, supra sagmental errors have been correlated with the poor speech intelligibility of the hearing impaired individuals speech. Studies have been attempted to determmine 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
2. Studies in which the errors are corrected in hearing impaired children's recorded speech samples using modern signal processing techniques.

A major problem with the studies involving training is that the training may result in changes in the child's speech other than those of interest. This can be controlled by using computer processing techniques.

There have been no studies in this regard in India and there have been some studies in the West. (Kruger, Stromberg & Levitt, 1972, Lang, 1975; Bernstein, 1977, Huggins, 1978; osberger & Levitt 1979, Maassen & Povel; 1984 a, b, Maassen & Povel, 1985).

Hence, the present study was planned to determine the relationship between some of the suprasegmental errors and intelligibility of the haering impaired children's speech.

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 suprasegmental errors have been considered for the study because of their probable relationship with speech intelligibility they are:

1. Correction of the vowel duration - both in the initial and final position
2. Correction of pauses, if any
3. Correction of the fundamental frequency. These corrections have been made either in isolation or in combinations.

Hypothesis: (1) There is no significant difference in the
of normal hearing and hearing impaired children.
utterance in terms of

(a) Vowel duration

(b) Intersyllabic pauses

(c) Total duration of wrods

(d) Average Fo

(e) Formant frequencies

(f) Bandwidths

Hypothesis: (2) There is no significant difference between the intelligibility ratings of original unaltered utterances and corrected utterances.

A. **Correction of vowel duration:**

1. There is no significant difference between the intellgibility scores of original, unaltered utterances and the utterance where the vowel duration alone has been corrected.

B. **Correction of pauses:**

1. There is no significant difference between the intellgibility scores of original, unaltered utterances and the utterances where the pauses (intraword) have been corrected.

C. **Correction of fundemental frequency:**

1. There is no significant difference between the intelligibility scores of original, unaltered utterances and the utterances were the fundamental frequency has been corrected.

D. Correction of vowel duration and pauses:

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

E. Correction of vowel duration and fundental frequency:

1. These is no significant difference betweent he intelligibility scores of original unaltered utterances and the utterances where the vowel duration and fundamental frequency have been corrected.

F. Correction of pauses and fundemental frequency:

1. There is no significant difference between the intelligibility scores of original, unaltered utterances and the utterances where the pauses and fundamental frequency have been corrected.

E. Correction of vowel duration,pauses and fundental frequency:

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

Implications of the study:

1. the results of the study would help in better understanding of the speech of the hearing impaired.
2. the results of the study would provide data regarding the effect of some of the suprasegmental errors on the intelligibility of the speech of the hearing impaired.
3. The information obtained from the present study would help planning and developing therapy programmes with the hearing impaired children.

Implications of the study:

1. The study was limited to only 4 subjects
2. The study was limited to the correction of suprasegmental errors only. That too only three parameters were considered.
3. The speech samples studied were limited to words with VCV combinations only.

REVIEW OF LITERATURE

Speech maybe viewed as the unique method of communication evolved by amn to suit the uniqueness of his mind. ((Eisenson,J, Amer J.P., and Irwin J V, 1963).

The ability to communicate through speech is of enormous values. It provides a range of opportunities and options in pesonal, educational and social life, as well as in employment, that cannot exist through any other form of interchange (Ling, 1976).

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

"The auditory pathway is the naturl and most effective way to learn speech and language, in addition to providing all the other auditory information from cur environment such as, music,door bell, bird song and so on" (Pallack,1981).

"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" (Whetnall and Fry, 1964).

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

Several have reported the effect of hearing loss on acquisition and maintainance of speech. 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 interfered with by the presence of hearing loss. (Stark, 1979; Charmaks, 1981).

The deaf child is faced with a doubly severe communication handicap. Normal speech is unintelligible to him and as a result of lack of auditory feed back of his own speech production he has considerable difficulty la learning to speak correctly, (Levittet al,l974; Cowie & Cowie, 1983).

One of the most recognised but probably least understood concomitants of deafness is a deficit of oral communication skills. The speech produced by many deaf parsons 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. Wthout a clear understanding of the underlying and nature of unintelligible speech of deaf, the development of effective cliniks lisat is limited (Metz et al. 1982).

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

It is important to ensure that, hearing impaired children develop effective spoken language skills from early infancy. (Ling. 1973).

The ultimate goal in aural rehabilitation is , for the hearing imparied individual, to attain, as far as possible the same communication skills as those of the normal hearing individual. within the lasr decade, advances have been made in studying the speech. this is largely due to the development of sophisicated processing and analysis techniques in speech science, elctrical engineering and computer science. These technological advances have also been applied to the analysis of the speech of the hearing impaired and to the development of clinical, assessment, training procedures. (Osberger and McGarr, 1982).

It is clear from the results of diligent specalized teaching that the difficulty in the oral production skills in principle, can be over come. 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, such could be done to improve the efficiency of speech training programs if more was known about how errors occur in the speech of deaf children and which 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.

Researchers concerned with speech production of the hearing impaired have employed a variety of physiological (Metz at al 1985) acoustic (Mensen 1976 a, 1976b, 1974; 1978; Angelocci et al, 1964, Gilbert 1975; Mc Clumpha, 1966; Calvert, 1962, shukla, 1985; Rajanikanath, 1986) & perceptual methods (Levitt et al 1976; Staves et al 1983; Hudgins & Numbers 1942; Mangan 1961; Nober 1967; Markides 1970; Smith 1975; McGarr, 1978; Geffner, 1980 etc).

Acoustic analysis of speech production is extremely useful to researchers since the methodologies employed are typically noninvasive, relatively basic with regard to instrumentation, may be used routinely to depict changes is the physical chatacteristics of frequency, intensity and the duration of speech segments. (Leeper et al 1987). Acoustic analysis of speech of hearing impaired permits a finer grained conideration of some aspects of both correct and incorrect productions than would be possible using methods applied in the subjective procedures. (Osbeyger & McGarr 1982). It provides objective descriptiions of speech of the hearing impaired. More informations 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 population.

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 the various errors and abnormal speech patterns on the intelligibility (Parkhurst and Levitt, 1978) thus analysis of speech of hearing impaired becomes important.

Intelligibility of speech of the hearing impaired:

"Speech intelligibility referato how much of what a child says can be understood by a listener" (Osberger and McGarr. 1982).

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

Inspite of the recent advances made in the areas of speech, education and hearing the problem of unintelligible speech in the hearing impaired has been acknowledged by several investigators.

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

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

Recent studies (Brannon, 1964, Mankides 1970; Smith 1973) have showed that inspite of the provision of hearing aids, speech training, the average intelligibility of speech of the severely and profoundly deaf child to the naive listener is not more than 20% (Stark, 1979).

Conrad (1979) reports that about 75% of prelingually deaf children with hearing losses of 90dB or more have speech classified as "barely intelligible" or worse.

'The speech of profoundly hearing impaired children is usually less than 30% intelligible" (Ling, 1976).

Hudgins & Numbers (1942) studies the speech intelligibility of 192 hearing impelled subjects of 8 - 19 years age. A group of experienced listeners heard the speech sample (sentences) of the hearing impaired and wrote down Whatever was understood by them.The Mean score for the group was found to be 29% . Brannor (1964) worked with twenty children selected from a large day school. They were 12 - 15 years old, had hearing levels of 75 dB or more, possessed atleast normal intelligence and had no known additional handicaps. He found only 20 - 25% of the words in their practiced speech intelligible to listeners unfamiliar with hearing impaired childrens' diction.

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

Heidinger (1972) studied the speech of 20 hearing impared children (more than 85 dB hearing loss in the better ear). Her 3 judges, who were experienced teachers of the deaf and knew what the children were trying to say rated leas than 20% their words in short sentences as intelligible.

According to Smith (1972) 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 children, was 18.7%.

Several other studies have shown that hearing impaired children have poor levels of speech achievement. (Kerridge,1938; Hood. 1966) Goda, 1959; Quigley and Frisins,1961; Angelocci 1962; John & Howarth,1965; Nontgoner, 1967, Toback,1967, Braverras,1974; Conrad 1976; Kyele, 1977).

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 suggest that overall levels of speech intelligibility are utterly inadequate for oral communication (Ling, 1976).

The differences in speech intelligibility scores obtained by various studies may be attributed to the differences in methodologies employed and the heterogeneity of the samples studied.

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

Intelligibility ratings have beta reported to be 10- 15% higher when judged by teachers or experienced listeners than those by the naive listeners (Geffner et a l 1978, Mangan, 1961, Mc Garr,1978, Monsen, 1978).

Sentences, when used as test materials tend to be more intelligible than words and sentences which are spoken directly to listener in a face to face situation are more intelligible than sentences to are tape recorded. /which (Hudgins, 1949, Thomas, 1964).

factors
Several/have been found to factors affect the intelligibility of speech.

According to Sabtelny (1977) the speech intelligibility is the single most practical index of hearing impaired person's oral communication abilities. But aha cautions that intelligibility assessment can not be used with confidence for training purposes without the knowledge of the properties of speed that influence intelligibility. Stevens et al (1978, 1983) reinforced this notion, who suggested that the fundamental problem of speech assessment with hearing impaired persons is to identify those properties of speech that determine its intelligibility. Identification of speech properties that determine intelligibility is a methodologically complex task (Metz et al 1980, Nickerson and Stevens,1980) but one that clearly has utility for the development of effective remedial strategies for improvement of speech of hearing impaired.

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

Among the perceptual variables reaidual hearing (Montgomery, 1967; Elliot, 1967; Boothroyd,l969; Mar Kiddes 1970; Smith; 1975; Kyle,1977; Monsen 1978; Stoker and Lape, 1980; Ravishankar 1985) lip reading (Stoker & Lape,1980) and tactile perception (stroker and Lape,l980) abilities have been studied The results have indicated that residual hearing ability above the maximum correlation with the speechintelligibility.

On the production side speech intelligibility has been studied with relation to segmental and suprasegmental errors. Errors involving individual speech phonemes, i,e., segamental errors have been studied in depth by number of researchers (Hudgins and Number, 1942) Nober, 1963; Mariddes,197o; Smith,1973; 1975a;; Monsen,1977; Brannon,1966; Gold,19781 McGarr,1980; Ravishankar, 1985; Levitt et al 1974 etc). According to/studies there is a /these high negative correlation between the frequency of segmental errors on intelligibility i.e. the higher the incidence of segmental errors and the poorer the intelligibility of speech, on the average (Parkhurst and Levitt, 1980).

Studies on acoustic features of speech of the hearing impared have supported the findings of the above mentioned studies. (Calvert,l961; Monsen,1974; 1976a,b,c, Rothman,l976).Both consonant and vowel errors have long been recognised in the speech of the hearing impaired.

Consonant errors include:

- voicing errors
- Substitution errors
- omission errors.

Vowel and dipthong errors include:

- substitution errors
- neutralization of vowels
- dipthongization of vowels
- errors involving dipthongs, either the dipthong was split into two distinctive components or the final component was dropped.

Hudgins and Numbers,(l942) and Smith.(1975) reported a high negative correlation between speech intelligibility and total number of consonant errors and total number of vowel errors. Among consonant errors omission of initial consonants, voiced - voiceleea confusions, and errors involving compound consonants had most detrimental affect on speech intelligibility, substitution errors, nasality errors, omission of final consonants and errors involving sbutting consonants had a lower correlation with intelligibility and contributed to a much lesser extent to the reduced intelligibility of hearing impaired children's speech.

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

1. the difference in VOT between /t/ and /d/
2. the difference in 2nd forwent location between /i/ and /I/
3. acoustic characteriatica of the nasal and liquid consonants

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

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

Supra Segmental errors:

"Supra segmental or prosodic features of a language are variations larger than individual segments overlaid upon a word, phrase or sentence. They are the direct bridge to meaning" (Borden and Harris, 1980). They involve characteristics of speech that extend over units composed of more than one phonetic segment.

In normal speech production, the suprasegmental aspacts include the contour of fundamental frequency versus time the durations of certain of the speech events and pauses and the assignment of relative prominance or stress to differentsyllables,(stevenseetal 1979).

Although much attention has been given to the segmental errors made by the deaf, it has long been recognized that suprasegmental deficiencies contribute as much or more to the problem of poor intelligibility in the speech of the deaf (Gold, 1978).

Hudgins and Numbers (l942) reported that those utterances marked by faulty rhythm (55% of all utterances) accounted for only 26% of all of the intelligible sentences read by their deaf subjects. However, the remaining utterances which were characterized by good use of rhythm, regradings of whether there were numerous articulatory errors, accouated for 74% of all of the intelligible sentences read. Thus it would seem that if a sentence is produced with appropriate rhythm it stands a better chance of being understood. The proper rhythm or timing of speech is affected by various factors like overall rate, duration of phonemes pausing and grouping of syllables. (Gold,1980).

Smith (1975), on the basis of her finding i.e. some of the subjects in her study who had approximately the same frequency of segmental errors had speech intelligibility scores differing by as much as 30% hypothesized that these differences appeared to be related, in part.

to certain suprasegmental errors that interacted in a complex manner with the segmental errors to reduce the intelligibility.

The suprasegmental errors include faulty rhythm, deviant voice quality of errors in velar control (Ravishankar. 1985).

Timing:

Rate: On the average, deaf speakers speak at a much slower rate than normals speakers. (Rawlings, 1935; 1996; Voelker, 1938; Calvert, l962; Boone, 1966; Brannon, l986; Hood, 1966; Martony, 1965; 1966; Calton and Cooker, 1968; Boothroyd et al, 1974; Wicherson at al, 1974).

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

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

This supports Boone's (1966) findings that the rate of the speech of the deaf increases with age but still remains considerably slower than that of normal speakers. Nickerson et al (1978) studied their subjects utterances in terms of number of syllables/sec. Their study showed that an average of 2.0 syllables or 4.7 phonemes/sec for the deaf as compared with 3.3 syllables and about 8.0 phonemes/sec for normal speakers. The number of syllables/sec for the normal group was identical with the predicted number suggested by Pickett (1968).

Physical measures of speaking rate have shown that profoundly hearing impaired speakers on the average take 1.5 to 2.0 times longer to produce the same utterance as do normal hearing speakers.(Boone,1966; Heidinger, 1972; Hood 1966, John & Howarth. 1965; Voelxer. 1935, 1938).

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

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

I. Increased duration of phonemes and

II. improper and often prolonged pause within utterances (Gold, 1980).

Increased duration of phonemes:

The duration of a phoneme bears important information in the perception of a spaech massage.

The literature contains very little about such gross aspects of speech timing as the duration of vowels and consonants(Kent,1976).

Dutational changes in vowels serve to differentiate not only between vowels them selves but also between similar consonants adjacent to those vowels. (Raphal,1972; Gold,l980

Vowels are longer in the presence of voiced stops and continuants (House and fair banks, 1953; Denes, 1955; Raphel, 1972; Peterson and Lehiste,1960; Lindblom, 1968; Dix Simoni,l974 a,b). This lengthening of the vowel contribution to the perception of the consonants. Schwertz,(1969) also noted that consonant duration were lengthened when the post consonant vowel was /i/ no matter that the proceeding vowel (in a VCV utterance). Unfortunately, however the duration of phonemaa is distorted in the speech of the deaf.

There is a general tendency towards a lengthening of vowels and consonants (Angelocci, 1962, Calvert, 1962, Joha and Howarth, 1965/ Hoone,1966/ Levitt et-al,1974, Parkhurst & Levitt, 1978). "The prolongations of speech segments such as phonemes, syllables and words are often passent in the speech, of the hearing impaired" (Osberger and Levitt, 1979, Osebirger and Mc Garr, 1982).

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

Angeloccl (1962) claimed that his deaf subjects took 4 to 5 times as long to produce to fricatives as did his normal hearing subjects. The closure periods for plosives were also considerably prolonged. According to Hood (1966) training on duration of phonemes would improve intelligbility significantly if articulation was good.

Monsen (1976) studied 12 deaf and 6 normal hearing adolescents as they read 56 CVC$_s$ containing the vowels /i/ or /I/. He found that the deaf subjects tended to create mutually exclusive duratlonal 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 pretence of different consonants. For the normal subjects, the duration of /i/ was always longer than /I/, for a particular consonant 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 terme of duration, they were stil1 less intelligible since the listener could not rely on normal decoding strategies to interpret the speech that was heard.

Sussman & Hernandez (1979) did spectrographic analysis of several suprasegmental aspects of the speech of ten hearing impaired adolescents. Among other findings, they observed that the hearing impaired speakers did produce longer vowels before voiced stops than before voicelees stops. However, they noted that the increase in vowel duration due to the presence of voicing was considerably smaller than for normal speakers.

Whiteheed and Johns (1976, 1978) noted that vowels were significantly longer in duration in a voiced than in a voiceloss consonant environment and were longer in duration in a fricative than a plosive consonant environment. However, unlike normal speakere/they found that, the hearing impaired speakers produced longer /s/ and / / segments in the /a/ vowel environment than / i / enviroment.

Osberger & Levitt (1979) observed that syllable prolongation in the speech of the hearing impaired was due srimarily to prolongation of vowels. Duration of vowels, glides and nasals were longer in the speech of the deaf children. On the other hand the durations of fricatives, affricates and polsoves were found to be shorter in the deaf subjects.

The hearing impaired fall to produce the appropriate modifica in the vowel duration as a function of the voicingcharacteristics of the following consonant. (Calvezt, 1961, Monsen 1974)". Hence, the frequent voiced - voiceless confusion observed in their speech say actually be due to vowel duration errors:. (Calvert, 1964

Leeper et al (1987) studied VOT, total syllable duration for VCV syllables, initial and final vowel duration in nine hearing impaired children and nine normal hearing children who served as controls. They were matched for age and sex with hearing impaired children. The speech stimuli employed were bisyllabic(vcv) utterances with a symomotrical vowel / /- obstruent /p/ vowel / / formant. The stimuli were in three utterance contexts of increasing length; i.e. /appa/, apa saw apa / or apa saw age with apa/ the results showed that hearing impaired children took significantly longer time than their controls to produce syllables. In addition, there was a numerical trend for the first word like utterance in the phrase to be shorter than the next word for both groups of children. Again variability was almost twice as large for the hearing impaired children than normals. Analysis of the temporal characteristics of initials final towels in the /apa/ utterances showed that the hearing impaired children had significantly larger durations on both petitions of the syllable than did their controls. For the normal hearing children ( ) the initial vovel in the VCV utterance was significantly shorter in the first word than in subsequent initial vowels in the sentence like frames of increasing length that is, the first vowel in the three word like "/apa/ saw /apa/" task was significantly shorter than the 2nd initial vowel. The findings were the same for the initial vowel in the five word like length utterances for the normal hearing children. The hearing impaired children did not show a significant systemstic shortening of the initial vowel in the syllabic productions for either three or five word like utterance length. The only trend that was noticeable for the hearing impaired children was for the length of the initial vowel in the single word repetition event to be longer than all other initial vowels in the other utterance length task. Similarly, the hearing impeired children demonstrated signiflcantly longer durations of the final vowel in the /ape/ syllable during alterations of utterance length, when compared with their normal controls.

"The hearing impaired showed a significantly longer vowel duration, as compared with normals." (Rajanikanth, 1986)

Shukla (1987) compared vowel duration and consonant duration in thirty normal and hearing impaired individuals who were watched for age and sex. The rereults 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 then 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 /a/ within the voiceless sopunds category.

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

d) In normally hearing speakers the mean duration of the vowels /a/, / i / , and/u/ in the final position, that is, proceeded by different consonants were around 200 m.secs, 195 m.sec and 185 m.sec, respectively. In the hearing impaired speakers / i / and /u/ tended to be longer than in normal speakers and the vowel /a/ tended to te either longer or shorter when compared to the length of the vowel /a/ in normal speakers.

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

f). In the normally hearing speakers vowel /a/ in the final positionwas longer than vowels /i/ and /u/ where as in the hearing impaired speakers, vowel /a/ was shorter than vowels / i /and/u/.

g) There was a vowel lengthening phonomenon in Kannada language, "vowel lengthening phonemenon is the final syllable vowel durational increment of 100 m.sec or more in English language for phrase final and utterance final positions" (Klatt. 1975a, 1976).

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

i) In both the groups of subjects durations of consonants were longer in vowels /i/ and/u/environoments 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 the voiceless categories.

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

l) In both the groups of subjects the lateral sound /l/ among the voiced sounds and the fricatives /s/ 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 consonants were longer in the speech of the hearing impaired than in the normally hearing speakers.

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

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

The duration of segments also gets influenced by factor operating at the level of syllables, word and phrases. In English, changes in contractive stress have been found to produce systematic changes in vowel duration. When vowels are stressed, they age longer in duration than when the same vowels are unstressed. (Parmenter & Trevino, 1936), This durationsl variation has also been found be important for the perception of stress (Fry 1995, 1958).

Several investigations have shown that while hearing impaired speakers make the duration of unstressed syllables shorter than that of the stressed syllables, the proportional shortening is smaller, on the average in the speech of the hearing impaired than in the speech of normal subjects, (Osberger, Levitt, 1979; Stevens et al 1978). In contrast tothisreilly(1979) found larger than normal duration differences between vowels in primary and weak stress syllables produced by a group of profoundly hearing impaired children.

Another manifestation of the problem of duration of phonemensis that the hearing impaired speakers fail to make the difference between the durations of stressed and unstressed syllables sufficiently large. (Angelocci. 1962; Nickersonetal.,1974.)

Although they prolong, the durations of both stressed and unstressed syallbles, the increase tended to be proportionally greater for the unstressed sounds. Hearing speakers lengthen stressed syllables and syllables ia word final and sentence final positions (Fry,1958, Klatt, 1974).

Nickerson et al (1974) found that the deaf children fsil to produce differences between the durations of the stressed and unstressed syllables that were as great as those produced by normal hearing children. Although, subjects of both the groups tended to prolong the syllable in phrase or sentence final position, the deaf subjects produced the unstressed syllables also with increased duration.

Boothroyd et al (1974) found that the unstressed syllables in the deaf were twice longer than those of normals. Angelocci (1962) reported that the durations of the unstressed vowels produced by deaf speakers were 4 to 5 times longer than those of normal speakers. Durational increase for stressed syllables also has bean repotted (John & Howatth, 1965).

Onberger and Levitt (1979) found that the mean duration ratio for sttessed and unstressed vowels was 1.49 to 1.28 for the normal hearing children and the deaf children respectively. The reduced ratio for the deaf children indicates that while the average duration of unsttessed vowels is shortet 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, (Osberger & Levitt, 1979). They also found that the average duration of both stressed and unstessed syllables was prolonged in the speech of the deaf children, the mean duration ratio for stressed to unstressed syllables was also reduced in case of the hearing impaired.

The review of literature shows that the hearing impaired speaker seems to produce only stressed syllables and that there is an overall tendency for increased duration of all phonemes in the speech of the hearing impaired.

Some investigators have attributed this partly to the training where a great emphasis on the articulation of individual speech sounds or isolated consonant vowel syllables. (Boone, 1966, John & Howarth 1965). As a result lack of differentiation between the length of stressed and unstressed syllables contributes to the perception of improper accessed in the apeech of the hearing impaired. (Gold, 1980).

Several investigators have reported that the word duration itself haa been found to be excessive in the speech of the hearing impaired. (John & Howrath, 1965,Osberger,1978) Electromyographic data have supported these findings (Huntington et al,l968). The tongue movements of the deaf have been found to be extremely slow and some times unnecessary motions of the tongue have also been observed. (Brannon. 1964, Huntington at al, 1968).

The way in which the hearing impaired speakers use temporal manipulations to convey differencea in syllabic stress pattern is not clear. McGarr and Harris (1980) found that even though intended stressed vowels were always longer than unstressed vowels in the speech of one profoundly hearing 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 McGerr and Harris (1980) also found that while the hearing impaired speaker produced the systematic changes in the fundamental frequency associated with syllable stress, perceptual confusions involving stress pattern were still observed. (Osborger & McGarr 1982).

Interphonemic Transitions:

Transitional elements between phonemes and between syllables play an important role for the flow of normal speech.

Speech sounds that require the precise coordination of the timing of different articulatory movement or the rapid transition from one articulatory position to another may be a problem for the hearing impaired. (Nickerson, 1975). Many studies support the view that the deaf do not move their articulators correctly in proceeding from one phoneme to the next. (Halvert, 1961 1962; Angelocci, 1962; John and Howrth, 1965; Martony, 1965, 1966; Brannon,1966; smith,1973; Stevens et al 1976; Parkhurst & Levitt, 1978).

Levitt (1971) reported that while moving from one articulatory position to next, tha deaf child unintentionally omits sounds.

Other kinds of transitional problems repented include the timing of voice enset relative to the release of voiceless stops (Angelocci, 1962) defective timing during the onset of nasalization for nasal consonants (Stevens et al 1976)/during the end of nasalization of nasal /and consonants. (Martony, 1965, 1966).

Another suprasegmental temporal effect occuring in normal speech is prepausal lengthening, When a syllable occurs before a pause that marks a positive major syntactic boundary, It is longer in duration than when it occurs la other positions in a phrase. (Klatt, 1975). It has been observed that hearing impaired speakers do not always lengthen the duration of phrase final syllables relative to the duration of the other syllables in the phrase. (Osberger and MeGarr, 1982).

Stevens et al (1978) observed that when there was evidence of prepausal lengthening in the speech of hearing impaired talkers, the increase in the duration of the final syllable was much smaller for the hearing impaired than for the normal hearing speakers. On the other hand, Reilly,(1979) found that the hearing impaired speakers in her study used duration to differentiate prepausal and non-prepausal syllables. Reilly (1979) observed a larger than normal differences between the duration of syllables in the prepausal and nonprepausal position in the samples produced by the hearing impaired children.

It has been reported that profoundly hearing Impaired speakers typically insert more pauses, and pauses of longer duration than do speakers with normal hearing (Boone, 1966; Boothroyd et.al.,1974; Heidinger,1972; Hood, 1966;John & Howarth 1965; Stevens etal.1978).

Pauses may be inserted atsyntacticallyinappropriate boundaries such as between twosyllablesin abisyllabicword or within phrases. (Osberger & McGarr,1982).

Stark & Levitt (1974) reported that the deaf subjects tended to pause after every word and stress almost every ward. Oral readings of sentences spacially designed to test the use of pause and stress were analyzed in this study. According to John and Howarth (l965) the silences between words seen in the speech of deaf subjects often accounted for one half the total time taken in uttering the test sentences. Nickerson et al (1974) reported that total pause time for hearing children constituted 25% of the time required to product the test sentences while the pause time for the deaf was 40% of the total time.

Boothroyd et al(1974} have considered that within phrase pauses were more serious problem than between phrase pauses in deaf speakers.

Osberger and Levitt (1979) repotted that there was no evidence of within phrase or within sentence pauses in the utterances produced by the normal hearing speakers. The deaf children paused frequently within a phrase and they often inserted pauses between syllables in bi-ayllabic words. The mean number of pauses per sentence was 5.7 in the deaf childrens' speech. The greatest difference between normals and hearing impaired speakers has been observed in the durations of inter and intraphrase pause (Stevens et al 1978).

Closely related to the problem of excerssive and inappropria¬tely 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 thus contributes to the poor rhythm perceived in the speech of the hearing impaired (Euggins 1946, Nickarson et al 1974).

The results of the studying Huggins (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 abort, irregular breath groups often with only one or two words and breath pauses that interrupt the flow of speech at inappropriate places. Also, there was excessive expenditure of breath on single syllables, false grouping of syllables and misplacements of accents. Forner & Hixon (1977) confirmed this from their study. They found the muscle activity to he normal for deaf individuals during quiet breathing but noted that they do not take enough air while breathing for speech. Thus,hearing impaired children distort many temporal aspects of speech. These distortins, excessively prolonged speech segments and the insertion ef both frequent lengthy pauses, are perceptually prominent and disrupt the rhythmic aspects of speech. Inspite of these deviences 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 speakers with normal hearing.

Voice quality:

There seems to bo a general agreement that the speech of the hearing impaired has a distinctive quality that differentiates this population from other speakers (Calvert 1962; Boone 1966).

Calvert (1966) reported that the voice quality ef the hearing impaired can be recognized easily. However, the characteristics that contribute to this perceived deviation are difficult to characterise (Nickerson 1979).

The voice quality of the deaf children were often described as 'tense','flat','breathy','throaty',and 'harsh' by the teachers of the deaf. (Calvert, 1962). This deviant quality of voice has been presumed to be a consequence of improper positioning of the vocal folds with too wide an average glottal opening during voiced sounds

(Hudgins, 1937; Stevens et a1 1978)

Pitch & Intonation:

Fundemental frequency patterns:

The fundemental frequency (Fo) often loosely called the pitch of the voiced speech sounds varies considerably in the speech of given speaker and the average or characteristic fundamental frequency varies over speakers. Average fo decreases with increasing age until adulthood for both males and females. (Fairbanks, 1940; Hollien & Paul, 1969; Samue1,1973; Usha,1979; Gopal. 1980).

For any given age, average individual Fo spans oves a considerable range, but about 90% would be expected to be within plus or minus 30-40 Hz of the population norms. (Fiarbanks,1910, Fairbanks et al, 1929; Mollien & Paul 1969).

The poor phonatory control in the hearing impaired individuals may be devided into two major parts:

1. Inappropriate average fundamental frequency (Fo)
2. Improper intonation. This inturn can be divided into -

a) Little variation in Fo resulting la flat and monotonous speech.

b) Excessive or erratic pitch variation.

Among the most noticeable speech disorders at the hearing impaired are those involving F0.

Several investigators have reported that the deaf speakers have a relatively high average pitch than that at normals of comparable ages. (Angelocci. 1962; Calvertl962; Engelberg,l962; Angelocci et al 1964; Mecfessel, 1964; Thornton, 1964; Boone,1966; Martony,1968; Gilbert & Campbell, 1980).

Angelocci et.al.,(l964) found that mean fundamental frequency (Fo) of hearing impaired adolescent between 11 to 14 yeara was 43 Hz higher than that of the normally hearing subject. Boone (1966) reported that this problem was greater for teenegers than for pre-adolescetns and that it was particularly adolescent boys.

Angelocci et.al.,(l964) not only noted that the F0 of hearing impaired individuals were higher than those of noraml hearing individuals, but also that the average Fo for different individuals spanned a wider range.

Thornton (1964) has reported essentially normal speaking frequencies for hearing impaired speakers. This contradicts the findings reported by many researchers.

Whitehead and Make (1977) reported that while the speaking fo was higher for deaf adults than for normally hearing adults on the avarage, a majority of the deaf adults had speaking Fo valuts / fell within the normal /whi range.

Monsen (1979) in a group of 24 hearing impaired children, found that Fo waa within the range of normal hearing children.

Meckfessel (1964) reported speaking fo (SFF) data for 7 and a years old hearing impaired speakers that were higher than values for normally hearing speakers. Ermovick (1965) 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 reaults 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 ;66, Green,1956; Monsen 1979). Differences have been reported between groups of older children. Boone (1966) found a higher average Fo for 17 - 18 years old males than females. Osberger (1981) found that the difference in Fo between hearing and hearing impaired speakers in the 13 - 15 years age range was greater for females than for males.The Fo for female hearing impaired speakers ranged between 250 - 300 Hz this value is about 75 Hz higher than that observed for the noramal hearing females.

Greene (1956) reported higher values of SFF for hearing impaired females than for normal hearing females. While Ermovick (1965) and Gruenewald (l968) reported values that were similar.

Meckfesel (1964) and Thornton (1964) reported speaking fundamental frequency (spy) values in post-pubercent hearing impaired males that were higher than those obtained for normally hearing post-pubescent males, while values obtained by Greene (1956) were similar to those for normal hearing males.

"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 impiared male speakers overlapped for the last half of the utterance (Osberger 1981).

Gilbert & Campbell (1980) studied SFF in three groups (4 to 6 years, 8 to 10 years, 16 to 25 years) of hearing impaired individuals, and reported that the values were higher in the hearing impaired groups when compared to values repotted in the literature for normally hearing individuals of the same age and sex.

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

In another study it was found that the fundamental frequency was higher, on the averag, in the speech of the hearing impaired. However, a majority of the hearing impaired speakers fell within the normal range (Shula,1987).

Differences have been reported for the older hearing impaired children in the adolescent and post adolescent groups, but it is not clear if pitch deviation is greater for hearing impaired males or females (Meckfessel 1964, Thronton 1964; Boone 1966; McGarr & Osberger 1978; Osberger 1981). Age related factors such as laryngeal growth accompanied by adolescent voice changes are not auditorily detected in the deaf have been attributed to cause pitch deviation in this group. (Bush, 1981;, Bush (1981) observed excessive segmental variations in Fo for a small group of profoundly heazing impaired females in the same age range as those in the Osberger's (1981) study.

The auditory feedback system is a main channel for appropriate establishment and production of pitch (Fo). To or pitch, has been a particularly difficult property of speech for deaf children to learn to control. (Boothroyd 1970). the possible reason for the difficulty is that deaf children may lack a conceptual appreciation of what pitch is "(Anderson 1960, Martony, 1968).

There have been other explanations offered to the pitch deviation noted in the hearing impaired.

Willemain and Lee (1971) hypothesised 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. Pichett (1968) has suggested that the increase in pitch was due to increased subglottal pressure and tension of the vocal cords. That is the increased vocal effort is directed at the laryageal mechanisms for Kinesthetic feed back. Angelocci et al. (1964) hold a similar opinion. They contended that the deaf speaker tends to achieve vowel differentiation by excessive laryngeal variations with only minimal articulatory variations. Buch (1981) does not support this view. She found greater variability in Fo for the hearing impaired speakers who produced a wide range of vowel sounds.

Martony (1968) proposed that this laryngwal tansion is a 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 cricold and thyroid (artilages extra effort in their use would result in tension and a change of position in the laryageal structures. This would ultimately cause a change in pitch.

Fo variation:

Appropriate To variation (intonation) is another problem of voice that the deaf individuals present. Two major types of Fo variation in the speech of the deaf individuals have been noted.

1) Lack of variation of Fo and
2) Excessive variation of Fo

The speech of the deaf has been Observed to contain errors often referred to as 'monotonous' and 'devoid of melody'.

Several investigations have shown that the hearing impaired speakers do produce pitch variations, but the average range was less than the ranges of normal speakers. (Green, 1956; Calvert. 1962; Hood, 1966; Martony 1968; Hood and Dixon 1969; and Nandyal 1981). This would result in the monopitch observed in the speech of the hearing impaired.

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

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

Pitch problems 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 exagerated 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 ware, within the same utterance. There are reports that often, after asharp rise in fo the hearing impaired speaker loses all phonatory control and thereafter there is a complete cessation of phonation. (Smith, 1P75, Stevens et el 1978).

A wider range of pitch for the deaf subjects has also been reported. (Angelocci et al., 1964, Boone, 1966, Martony, 1968).

"The hearing impaired showed almost double the frequency range as compared with normal again with large individual variations". (Rajani Kanth, 1985).

It has been suggested that some of the unusal piton variations seen may result from attempts to increase the amount of proprioceptive feed-back during speech. Martony (1968), Willemin and Lee (1971) have observed that deaf speakers sometimes tend to begin a breath group with an abnormally high pitch and then to lower the pitch to a more normal level. Willemain & Lee (1971) also noted that the average pitch of the deaf speakers sometimes increases with the difficulty of the utterances.

Monsen (l979), 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 were

1. A falling contour, characterized by a smooth decline in fo at an average rate greater than 10 Hz per 100 m.sec.
2. A short falling contour, occuring on words of short duration. The fo change may be more than 10 Hz per 100 m.sec. but the total change may be small.
3. A falling flat contour characterised by a rapid change in frequency at the beginning of a words followed by a relatively unchanging flat portion
4. A changing contour, characterized by a change in frequency, the duration of which appears uncontrolled, and extends over relatively large segments.

Monsen found that the type of contour appeared to be an important characteristic separating the better from poorer hearing impaired speakers.

Segmental influences 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 &Fo in normal speech. High vowels are produced with a higher Fo than low vowels; resulting in an inverse relationship between Fo and frequency location of the 1st formant of the vowel. (House and Fairbanks, 1953, Peterson & Barney 1952). Angelocci et-al., (1964) first examined some of the vowel changes in fo in the speech of the hearing impaired. Their results showed that the average Fo and amplitude for all vowels were considerably higher for the hearing impaired than for the normal subjects. In contrast, the range of frequency and amplitude values for the vowel forments were greater for the normal hearing than for the hearing impaired speakers. So, they suggested that the hearing impaires subjects attempted to different vowels by excessive laryngeal variation rather than with articulatory maneuvers as do normal hearing speakers.

A study by Bush (1981) did not support a simple trade off between Fo variability and articalatary skill. She observed a close relationship between vowel-related variability in Fo and articulatory skill for the majority of profoundly hearing impaired subjects in her study. Greater Fo variability was observed for the hearing impaired speakers who produced a wide range of vowel sounds (in terse of F_1 & F_2 value) and who were more intelligible than speakers whose articulatory skills were more limited, Bush (1981) also noted that although the amount of Fo variation with vowels used by hearing impaired speakers was greater, on the average, than that used by the hearing speakers, the direction in the Fo varied as a function of vowel height was similar for the two groups of speakers. On the basis of these observations, Bush (1981) concluded 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, increases in vocal fold tension may be greater in magnitude when the tension on the vocal folds is already relatively high (as in the case with hearing impaired) resulting in some what longer increases in Fo during the articulation of high vowels. According to Honda (1981) moving the tongue root forward for the production of high vowels causes the hyoid bone to move forward, tilting the cartilage anteriorly. As a result of this, there is increased tension on the vocal folds resulting in an increase in Fo.

Thus there is sample evidence to suggest the presence of pitch deviation ia the speech of the hearing impaired. The abnormal pitch variations have been considered to be the major cause of faulty intonation of the hearing impaired. But there is also evidence to suggest that they know and use some of the same rules by normal hearing speakers.

Velar Control:

The velum or soft palate functions as a gate between the oral and nasal cavities. It lowers to open tha passage to the nasopharynx for the production of nasal consonants. On the other head, it raises to seal off the passage for the production of non-nasal sounds. If the velum is raised, whan it should be lowered, the resulting speech is described as hyponasal, if it is lowered when it ahould be raised the speech is described as hypernasal.

Improper control of the velum has long been recognized among the hearing impaired speakers (Hudgins, 1934). Improper velar control may affect the resonant properties of speech and also may result in articulatory errors. (Osberger and McGarr, 1982).

Hypernasality has been reported to be present in the speech of many hearing impaired individuals. (Hudgins & Numbers, 1942, Boone, 1966, Calton & Cooker, 1968; Norman, 1973).

Stevens et al (1976) reported oral/nasal substitutions in the speech of the deaf individuals. They also found that 76% of the profoundly hearing impaired children had excessive nasalization when compared to normals.

Learning velar control is difficult fo impaired children because:

1. raising and lowering movements the velum deiectable via lipreading and

2. the activity of velum produces very little proprioceptive feed back (Nickeoson l975).

Deviant nasalization characteristics in the speech of the hearing impaired has been reported to be the result of improper posture of the velopharyngeal structure (Hudgins 1934; Mc Clumpha 1966; Stevens et al 1976), inappropirate timing of the opening and closure gestures of the velum (Stevens et a l , 1976) and faulty palato-pharyngeal valving (Subsently et al 1980).

The studies have pointed out that for many deaf speakers, the velum remains lowered much of the time and thus many vowels are nasalized.

Another deviation reported is the way the tongue body is positioned in the mouth. For some, hearing impaired speakers, the tongue body positions has been found to be relatively immobile as far as front-back movement during speech production is concerned. As a result of this a rather narrow range of variation of the frequency of the 2nd formant has been observed (Monsen, 1976).

Boone (1966), Seaver et al (1980) pointed out that nasalization in the speech of hearing impaired is due to the perceived resonance brought about in the pharyngeal region by an inferiorly retracted tongue position during speech and not due to velopharyngeal insufficiency. Miller (l968) on the other hand, has attributed nasalization problems to types of hearing loss.

Colton and Cooker (1968) have cautioned that the perception of nasality can be influenced by other speech deviations such as misarticulations, pitch variations and speech tempo. The problem of loudness in the speech of the hearing impaired has drawn attention of several investigators (Martony,1968,Miller,1968;Canhart,l970).Many of these studies have shown the occurance of inappropriate loudness in the speeeh of the hearing impaired. Further variations in loudness have also been reported.

Levitt et al (1974) examined segmental and suprasegmental errors in the speech of 70 congenitally of children in the age ranges 8 to 10 and 13 to 15 years. The most common suprasegmetnal errors judged consistently by the raters were inappropriately monotonous rate, insufficient variability of intonation, inappropriate stress and spasmodic control of phonation.

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

Supra segmental errors and speech intelligibility:

Suprasegmental competence once acquired becomes an indispensable part of speech production (Ling, 1976). The role of suprasegmental features of speech in the flow intelligible verbal discourse has been well documented by several investigators (Eisenson 197; Lieberman, 1972; Martin; 1972; Geers; 1978).

Due to suprasegmental deviations, the speech of deaf talkers has been characterised as staccato, leading to the perception of improper grouping of syllables (Gold, 1980).

Suprasegmental errors also been noted to be detrimental to speech intelligibility. Some investigators have attempted to correlate speech intelligibility with suprasegmental errors. (Hudgine and Nembers, 1942; John & Howsrth 1965; Levitt et al., 1974; Smith, 1975; McGarr et a1, 1976; Parkhurst and Levitt, 1978; Monsen, 1979; Ravishanker, 1986, Metz et al 1985).

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.

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

1. Correlational studies
2. Causal studies i.e. studies that attempted to determine the cause and effect relstionship. These types of studies can be subdivided into two major categorises:
   a) Studies in which hearing impaired children receive intensive training for the correction of a particular typeoferror.

   b) Studies in which the errors are corrected in hearing impairedchildren'srecordedspeechsamplesusing 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 found in the study by Hudgins and Numbers (1942). Although they correlated rhythm errors with intelligibility, many of these errors appear to be due to poor timing control and Fo. for (Osberger and McGarr, 1982). They found that sentences spoken with correct raythm were substantially more intelligible than thosethatwerenotact. The correlation between speech rhythm and intelligibility was 0.73. The other correlational studies have shown a moderatenegetivecorrelationbetweenexcessive prolongationofspeechsegments and intelligibility (Monsen Leiter.1975; Perkhurst and Levitt, 1978).

Levitt et al (1974) reported that deviant timing patterns such as excessive prolongation of words and inappropriate pauses in the speeech of the deaf, have a marked effect upon the overall speech intelligibility.

Reilly (1979) found that relative duration (stressed: unstressed syllable nuclei duration ratio) demonstrated a systematic relationship with intelligibility. Reilly (1979) suggested that the better able the profoundly hearing impaired speaker was to produce the segmental, lexical and syntactic structure of the utterance, the more intelligible the utterance was likely to be.

Data reported by Parkhurst and Levitt (1978) indicated that another type of timing error, the insertion of short pauses at syntactically appropriate boundaries had a postive effect 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 intelligbility.

Attempts have also been made to determine the relationship between errors involving Fo control and intelligibility.

"Improper control of pitch Observed la the speech of the hearing impaired has stimulated many lnvestigators to determine the relationship between errors involving pitch control and speech intelligibility" (Ravishankar, 1985).

The inability to control the speaking Fo by the hearing impaired contributes to the low intelligibility of their speech (Booth royd & Decker, 1972).

Smith (1975) found that errors involving poor phonatory control (intermittent phonation, spasmodic variations of pitch and loudness and excessive variability of intonation) had a high correlation with intelligibility.

Monsen and Leiter (1975) measured the amount of 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 emphasised by some investigators as indicators of speech intelligibility (Levitt 1974, Asp, 1975).

McGarr et al (1976) found that the hearing impaired children of thier study who were unable to sustain phonation and showed pitch breaks and marked fluctuations in pitch were consistency 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 ratad subjective evaluation pitch deviancy in their hearing impaired subjects.

It may be that the pitch contours that appear abnormal atleast to the naive listener, may draw attention to themselves and thereby affect the overall speech intelligibility (Wingfield, 1976).

Monsen (1978) found that there was no clear-cut relationship between mean Fo and mean amount of Fo change and intelligibility.

McGarr and Osberger (1975) 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 approppriate 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 speechs was consistantly judged to be unintelligible.

Parkhurat & Levitt's (1978) data also suggested that excessive variations in pitch may reduce intelligibility. In this study, a multiple linear regression analysis was performed, relating intelligibility to various prosodic distortions judged to occur in the speech of the hearing impaired children. Breaks in pitch were one of the prosodic errors showing a significant negative regression with intelligibility. The effect of the less deviant patterns, such as elevated Fo, has not been clearly established, although preliminary data suggest that these problems will not have a serious effect on intelligibility.

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

"The speech intelligibility scores showed a high negative correlation with suprassgmaatal errors." (Ravishankar 1985). His study indicated that the suprasegmental errors were strong deterrents to the speech intelligibility of the subjects. 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,in the same order.

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, 1942) poor phonatory control (Smith, 1975) and Staccato prosody (McGarr and Osverger ,1978) or sylllabic speech (Levitt et al, l976) all show moderate to high negative correlations with speech intelligibility. (Maassen and Povel, 1984).

The suprasegmental errors in the speech of hearing impaired consists of errors of prosody (eg: errors of intonation, stress, and/or phrasing),abnormal voice quality, heypar or hyponasality, inappropriate average pitch and improper control of voicing. (Nickerson,1975; Levitt et al., 1974) of these, errors of duration and timing have received the greatest attention, partly because the errors are perceptually prominent and also because improved timing can be obtained with good training. (Parkhurst and Levitt, 1978).

Studies that have attempted to determine the causes and effect relationship between speech errors/intelligibility /and have dealt primarily with timing. (Osberger & McGarr, 1982).

The classic training study that attemped to determine the causal relationship between timing errors and intelligibility was conducted by John and Howarth(l965). 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.

Heddinger (1972) also reported similar results i.e. he found improvements in the intelligibility of the speech of children who were given training emphasizing timing. On the otherhand, Houde (1973) observed a decrement in intelligibility when timing errors of hearing impaired speakers were correids d, and the reaslts of a similar study by Boothroyd at al (1974) were equivocal.

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

Studies have been conducted in which the errors are corrected in hearing impaired children's recorded speech samples using modern signal processing techniques to bring about improvement in intelligibility.

A major problem with the training studies la 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 & McGarr,1982).

Recent investigations have attempted to eliminate this confounding variables by using computer processing techniques. In such studies, speech is either synthesized with timing distortions, (Long, 1975; Huggins, 1977; Bernstein,1977) or synthesized versions of the speech of the hearing impaired are modified so that the errors (timing/or pich and intonation errors) are corrected selectively. (Osberger & Levitt, 1979, Maassen & Povel, 1984 a; 1984b; 1985; 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 review ends with the following conclusions:

"Whereas there is much documentation of the kinds of sigmental and suprasegmental errors in the speech of the 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 he 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".

During the last years the studies have gradually been more concentrated on the relation between specch errors and the naturalness aad intelligibility of the speech with the aim to imporve training methods in schools (Oster, 1985).

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 that are seen in the training studies. (Osberger aad Levitt, 1979).

In digital manipulation techniques it is easy to correct errors is the time domain (suprasegmental) but more difficult to correct segmental errors. (Huggins 1977, Nruger et al 1972, Maassen and Povel 1984; 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).

A better way to test the hypothesis that inappropriate timing is a significant contributor to the unintelligibility of deaf speech is through an analysis-by-synthesis approach; that is, by examining the perceptual effect of instrumental manipulation of recorded sentences (Harris & McGarr 1980). 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, Huggins (1977) found that when normal speech was synthesised with the durational relationship between stressed and unstressed syllables reversed, there was a substantial reduction in intelligibility. Even greater reductions in intelligibility occurred 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 & 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 3 types of corrections were performed, relative tim ing, absolute syllable duration & pauses. Each error was corrected alone and together with one of the other timing errors. 6 - stage approximation procedure was used to correct the deviant timing patterns in the speech of six deaf children. They were:-

1. Original, uneltered sentences
2. Correction of pause only
3. Correction of relative timing
4. Correction of absolute syllable duration
5. Correction of relative timining and pauses
6. Correction of absolute duration and pauses.

An average improvement in 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 vary small (4%). 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 (& syllables) were still longer than the corresponding durations 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 have a detrimental effect on intelligibility"(Osberger&McGarr,1982).

Maassen & Bowel (1984a) 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 16 out of so 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 sent.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 (1984 b) studied the role of intonation for the intelligibility of deaf speech. The intonation contours of Dutch sentences spoken by 10 deaf children were manipulated using digital signal processing techniques, including LPC analysis. (Linear predictive coding) Sentence intonation was corrected by replacing the original Fo contour of the deaf utterances with an artificial contour derived from a formalized intonation grammar. 3 typas of intonation corrections were produced differing with respect to the underlying accent structure and the type of Fo movements used. The overall reaults showed that intonation correction yields a small but significant improvement in intelligibility of 7%. (from 20% to 27% words correctly identified) To evaluate the ineraction with temporal aspects, intonation corrections were also implemented to temporally corrected sentences. Total growth in intelligibility due to these combined corrections amounted to 13%. Thus, they concluded that no dramatic gain in intelligibility may be expected of speech pathologists succeed in teaching their deaf pupils to have better control over the suprasegmena aspects of their speech.

Maassen & Povel (1985) conducted three experiments to study the effect of segmental and suprasegmental corrections on the intelligibility and judged quality of deaf speech. By means of digital signal processing techniques, including LPC analysis, transformations of separate speech sounds, temporal structure, and intonation were carried out on 30 Dutch sentences spoken by ten deaf children. The transformed sentences were tested for intelligibility and accpetabiligy by presenting them to inexperienced listeners. A complete segmental correction caused a dramatic increase in intelligibiliy 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% cobination of segmental and suprasegmental corrections yielded almost perfectly understandable sentences, due to a more than additive effect of the two corrections. Quality judgments were in close agreement with the intelligibility measures. "The results show that, in order for these speakers to become more intelligible improving their articulation is more important than improving the ir production of temporal structure and intonation" (Maasen and Povel, 1985).

Oster (1985) took speech temples from Three deaf children and analyzed them individually to find errors in vowels, consonants and prosody. Based on this analysis,a phometic 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 deaf speech and wrote down all the words that they could understand. The results of the study showed that synthesis by rule system can because to establish the relative impact on intelligibility of different types of speech errors and to develop an individualized programs 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 than the suprasegmental errors. The segmental error correction will improve the intelligibility upto 66% to 97%.

Maassen (1986) inserted silent pauses with a duration of 160 ms between the words to as to mark ward boundaries of 30 sentences, spoken by 10 deaf children, acoustically. Subseqeunt tests with normal hearing listeners demonstrated that after insertion of pauses the intelligibility of the sentences increased significantly from 27% to 31%.

Osberger & Levitt (1979) write "To date, there have been few studies of this nature (studies using computer processing tecniques) and data which are available are inconclusive. In view of the advantage of using this approach, additional studies employing digital speech processing techniques appear warranted".

Studies in the recent years, though only a few, have shown that the computer correction of temporal aspects and intonation contour of deaf speech only caused a small increase in intelligibility.

There have been no such studies reported in India so far. Therefore the present study was undertaken to see the effect of the correction, using computer, of some of the temporal aspects and average fundamental frequency in the speech of the hearing impaired on the speech intelligibility.

METHODOLOGY

A. subjects and test material:

Eight children - four normal hearing and four hearing impaired - between 8 - 10 years were selected for the study. The hearing impaired children were selected from among the cases who are attending AIISH for therapy. They all satisfied the following conditions -

1. Had congenital bilateral hearing loss (PTA of greater than To dB - ANSI 1969 is the better ear).
2. Had no additional handicap other than that directly related to the hearing impaired.
3. Were able to read simple bisyliabic (VCV combination) words in Kannada.

Four normally hearing children were selected to match each hearing impaired subject in terms of age and sex.

The test materials consisted of eight bisyliabic Kannada words (VCV) These words ware chosen from the Kannada. Articulation Test (Bettageri, Rathna,Babu, 1972) which is used with the children of 3 years and above. Words ware simple so that both normal and hearing impaired children could read them. (See Appendix-1).

B. Experimental instruments:

The speech samples were recorded on spool tape uaing the tape recorder of the sound spectrograph (Voice Identification Ioc.700series)

C. Recording procedures:

The recordings were made in a sound treated room at speech science laboratory. Each subject had to read a list of eight words in front of an unidirectional mic which was placed at about four inches away from the subject's mounth.

Acosutic Analysis:

The recorded words were digitized at sampling frequency of 8000 Hz and the block duration and resolution were 50 m.secs and 10 m.sec. respectively, using a A/D/ converter and a PC/XT (WIPRO).

The parameters which were taken for analysis age vowel duration, duration eg the pauses (intraword - if any), total duration of the word, fundamental frequency, form frequencies (F_1 F_2 and F_3) and Bandwidths (B_1 B_2 & B3). These were noted down for all (8) children and for all the words (8 Words

Statistical Analsyis:

Descrptive statistics consisting of mean, standard deviation minimum and maximum value, were obtained for all the 6 parameters

To check whether there were any significant differences between the values of the normal hearing group and hearing impaired group, Wilcoxon Signed Ranks Test was applied.

Correction of timing errors and Fo:

The parameters corrected were:

1) vowel duration (both initial and final vowela)
2) Pauses, if any (intraword pauses)
3) fo of all phonemes.

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

1. Elimination of pauses only.
2. Correction of vowel duration only
3. Correction of fo only
4. Correction of pauses and vowel duration
5. Correction of vowel duration and fo
6. Correction of pause and fo
7. Correction of pause, vowel duration and fo.

In all instance, 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 hearing impaired children's speech samples, if there were any. Care was taken to preserve the transistion portions of the wave forms. Altogether/ there were nine words. (See figure 1.)

2. Correction of the vowel duration only:

Here, the vowel durations (both initial s final positions) of the hearing impaired children's speech samples were either reduced or increased so as to match with the mean values of the normals 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. In ten vowels the vowel duration was increased and in 41 vowels, the duration was decreased. (see figure 2).

3. Correction of Fo:

The to values of all phonemes (two vowels and one consonant in all words (except /ondu/ where 2 vowels and 3 consonants were present) were changed. The changed valuses were euqal to the mean values of the normal hearing group.

The edited data was synthesized later on using cascading synthesizing procedure.

4. A combination to the above three procedures were used to obtain the words with combination of corrections. (See figure 5,4,5)

Thus a total of 128 words were obtained.

Re-recording the speech samples:

The unaltered and altered speech samples were recorded on 6 cassettes tapes. There were 32 unaltered utterances and 160 altered utterance. 94 utterances (consisting of both altered and unaltered samples) were added as check words to test the intra judge reliability. All the 256 words were randomized so as to eliminate practice effect.

Measures of speech Intelligibility:

Five listeners were asked to listen to the speech samples and to write down the words that they have heard. (Wprd identification task). They ware also requested to rate the intelligibility of the words on a 5 point interval scale (intelligibility rating), from 0, denoting unintelligible to 4, denoting highly intelligible.

The five listeners formed a heterogenous group consisting two trained speech pathologists, two graduates in speech and hearing and on person with no previous experience in listening to the speech of the hearing impaired, All know Kannada well. there were two conditions.

a) Ho clues were given regarding the words used in the study (open set)

b) After stop (a) the judge were asked to repeat the whole procedure once again,. Here, an additional clue was given i.e.they were provided with the list of words recorded and presented for listeners (closed set).

Statistical analysis:

a) The number of correctidentificationby 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 that particular word.

Both the measures [(a) & (b)] were done for both open set and closed set.

Descriptive statistics was obtained for both altered and unaltered utterances and also for open and closed sets.

wilcoxon Signed Ranks Test was performed to check whether these was any significent differences between unaltered and each type of altered sets under both open and closed set.

Interjudge reliability was checked using Pearson's rank correlation method.

The results were also analyzed to find out the words that are identified correctly majority of the time in both open and closed set conditions.

A measure was carried out to chech the intrajudge reliability using the words which were included for the same purpose.

PC/XT (WIPRO)

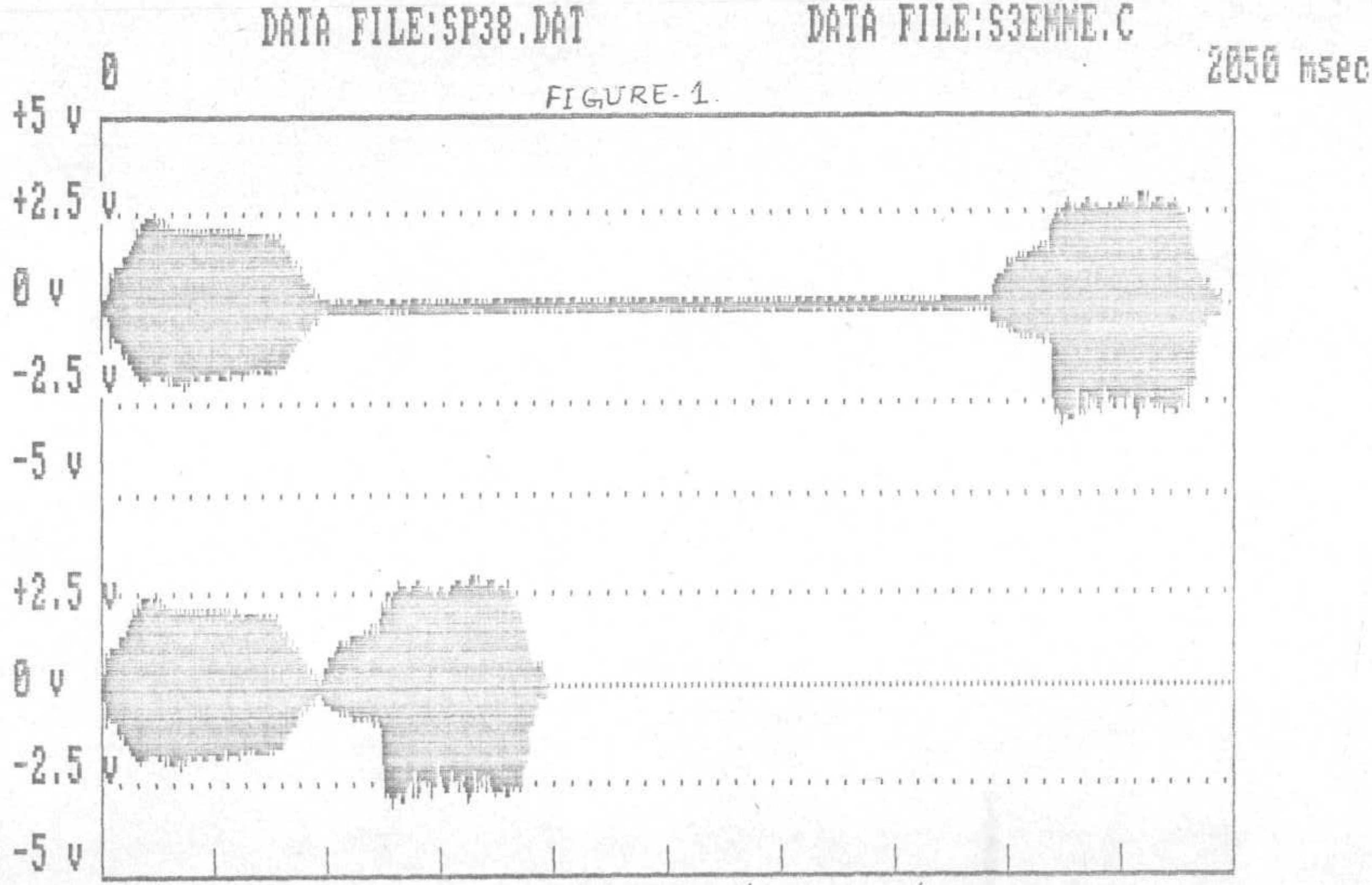
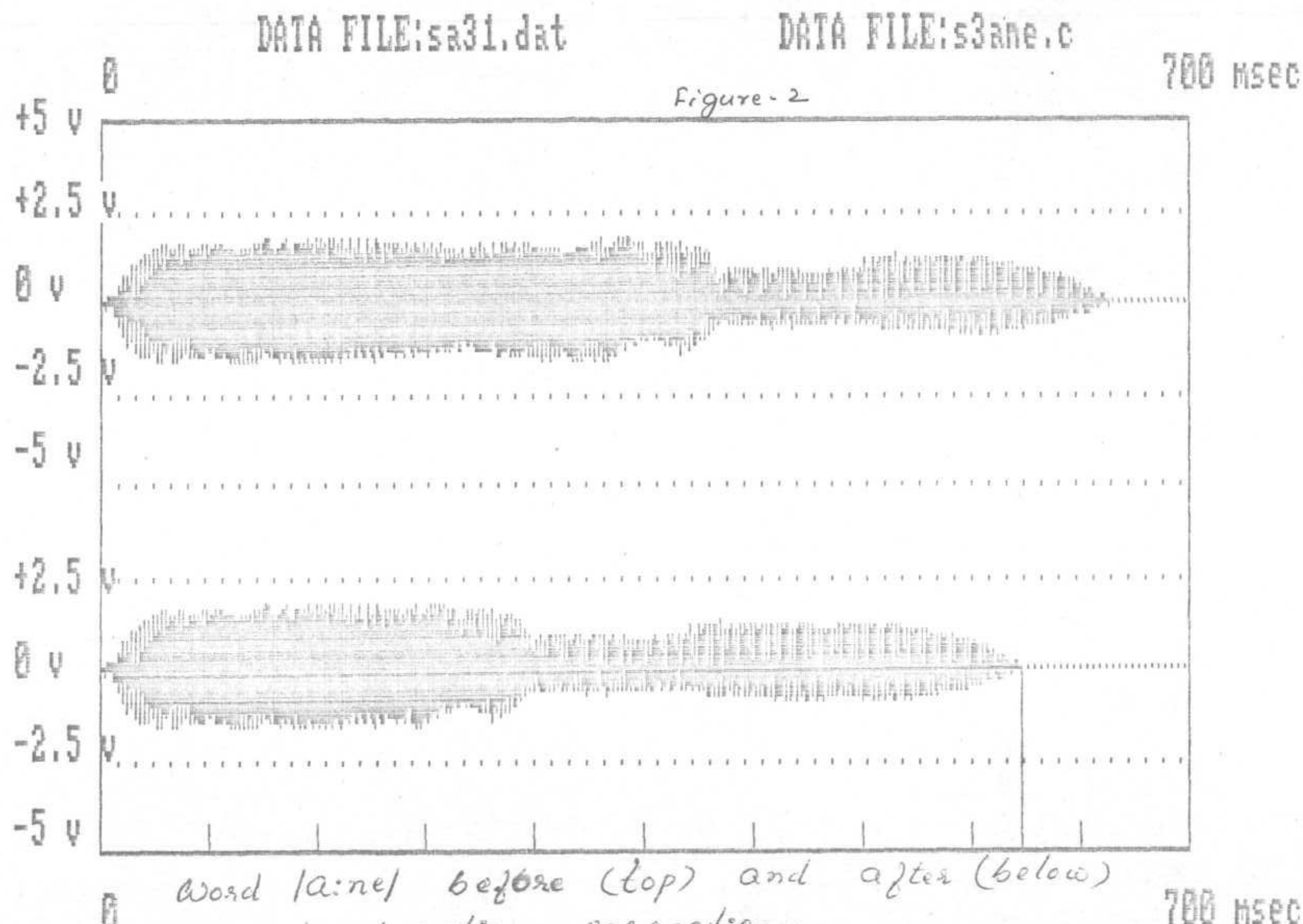


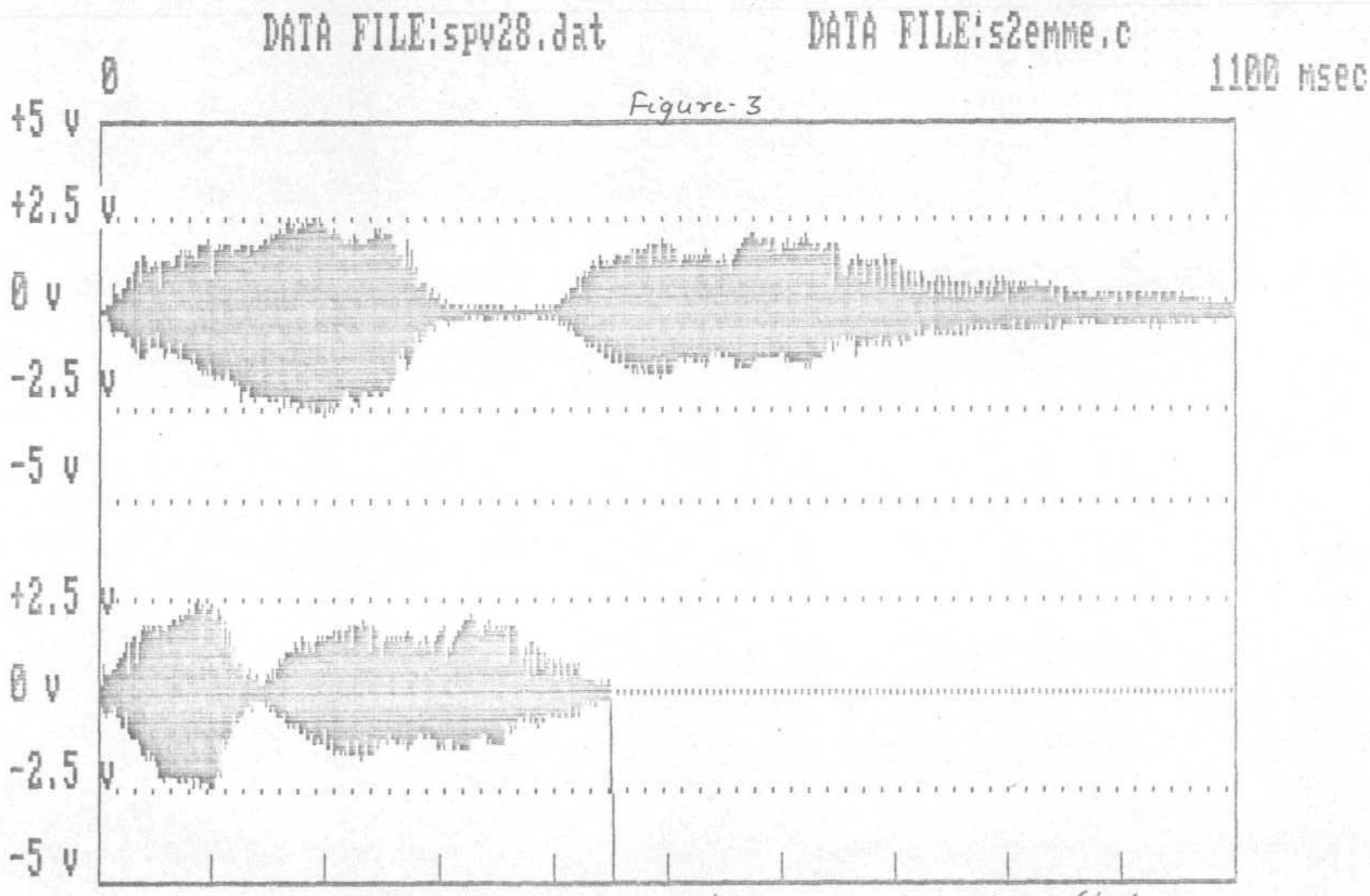
FIGURE-1.

Word /emme/ before (top) and after (below) pause correction.



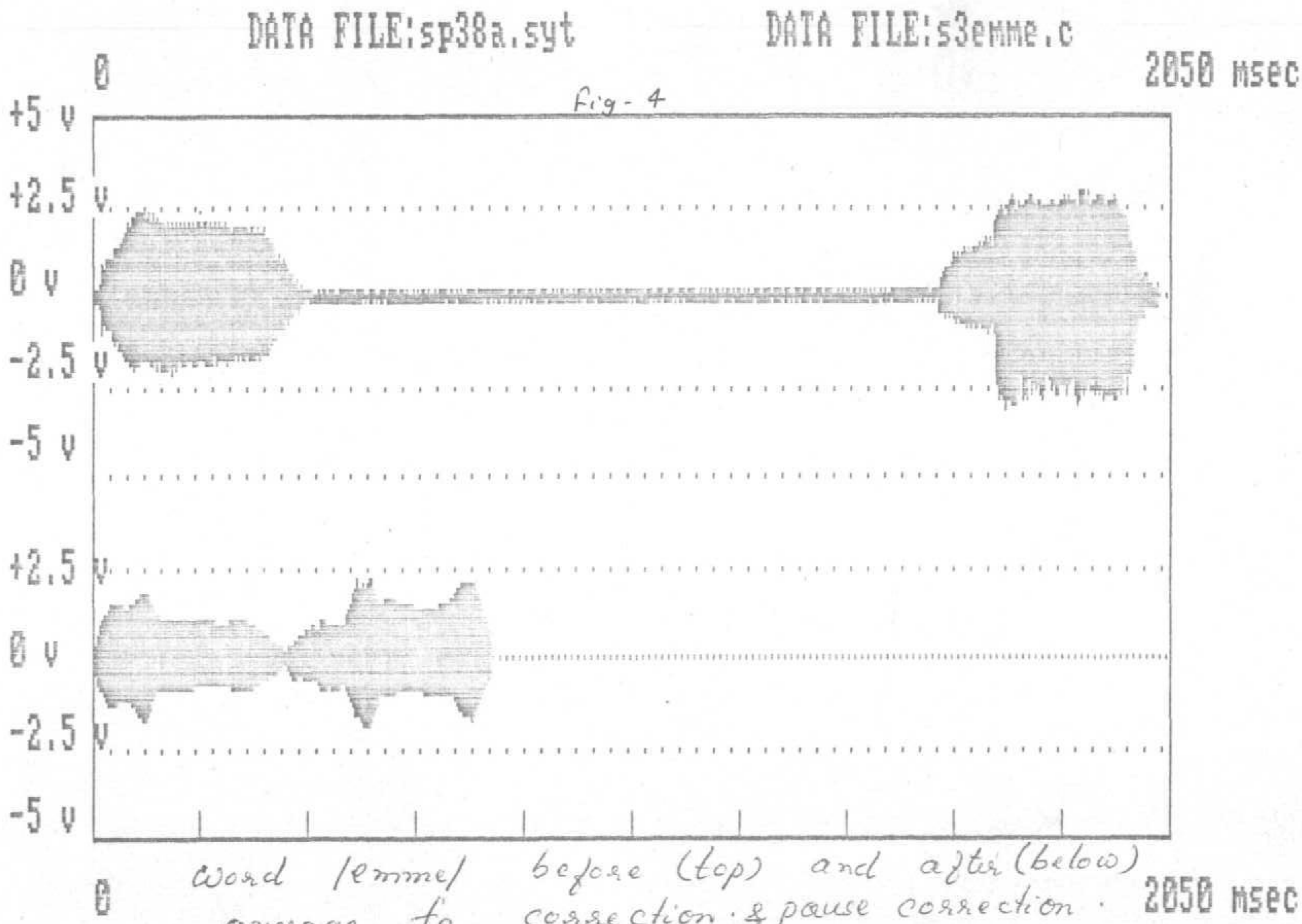
Word /a:ne/ before (top) and after (below) vowel duration correction.

Figure-3



Word lemmel before (top) and after (below) pause and vowel duration correction.

Fig- 4



word /emme/ before (top) and after (below) average to correction & pause correction.

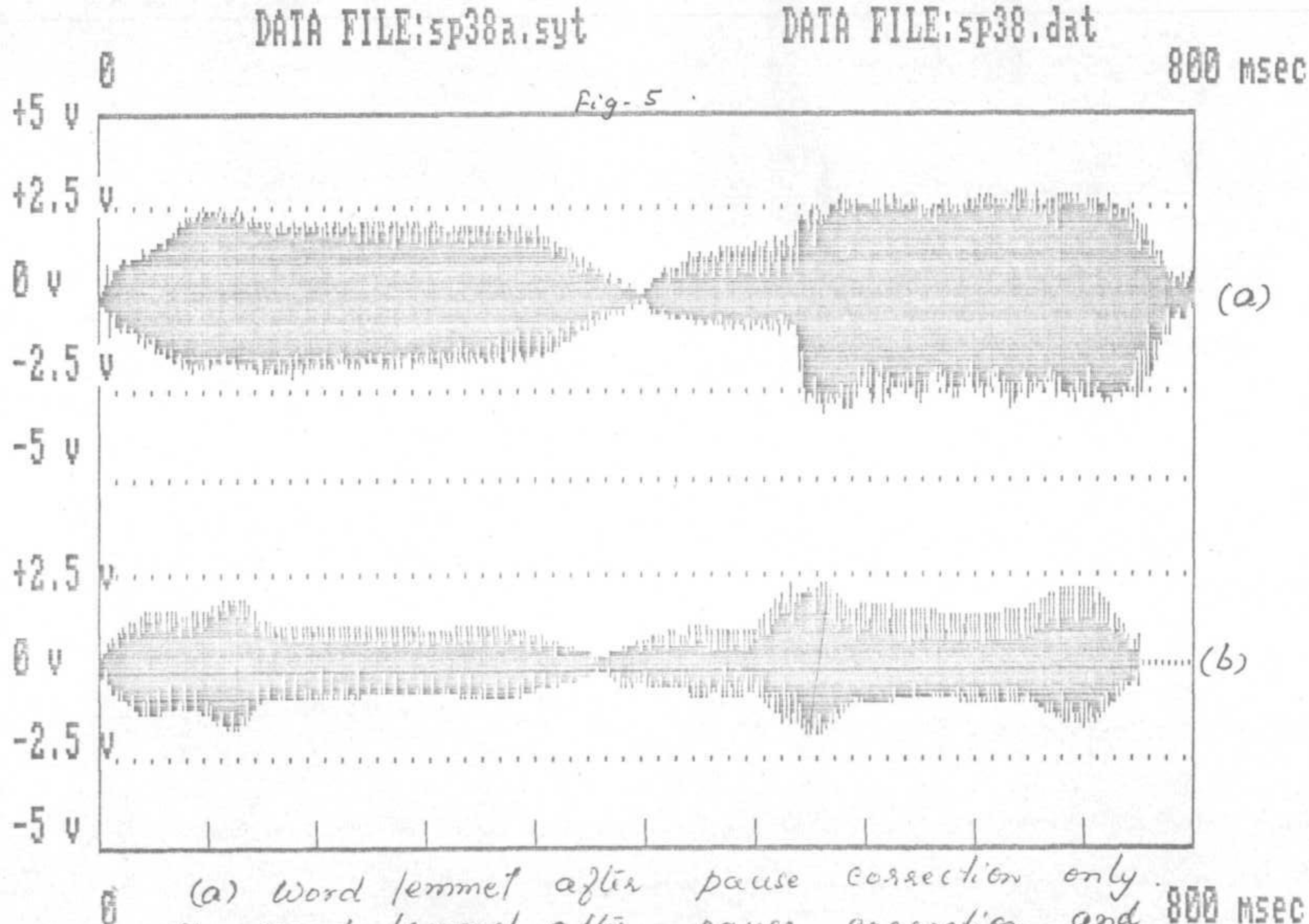


Fig-5

(a) Word /emmet/ after pause correction only.
(b) word /emmet/ after pause correction and fo correction. (synthesized.)

RESULT AND DISSCUSSION

The objective of the present study was to find out the effect of some timing errors and the average to corrections on the intelligibility of hearing impaired children's speech.

Step 1: Acoustion Analysis:

Eight bisyllabic words with VCV combinations uttered by four profoundly hearing impaired and four normal hearing children were need for analysis and corection in the speech of the deaf.

The following six acoustic parameters were noted from the analysed data: They were): —

1. Vowel duration, (both initial and final position)
2. Pause duration, if any
3. Total duration of the words
4. Fo of each phoneme in the word
5. Foramt frequencies (F_1 F_2 F_3)
6. Bandwidths (B_1, B_2, B_3)

Median values of fomant frequencies and bandwidths were calculated. For Fo calculation modal values were considered The median was considered as there were many variations in formant of the word. It **was** oonsidered that the mean of such **a** data may not show the central tendency. Modal values were taken as they most commonly ocurred fo values.

A descreptive statistics was obtained for all the measures. The values are given in Tables (1-4) and graphs. The results indicated that —

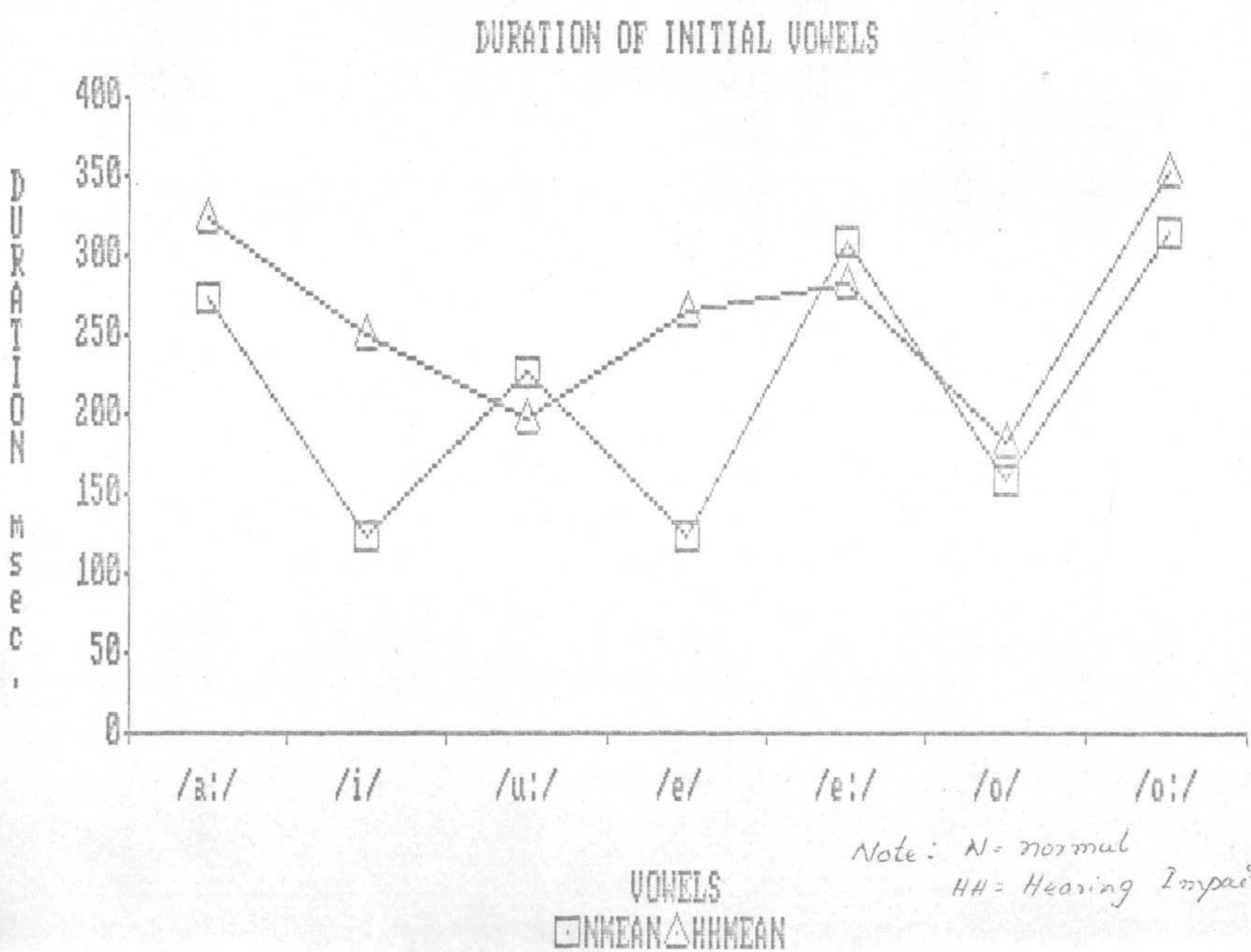
1. Vowel duration: On the average, the hearing impaired subject: had longer vowel durations when compared to the normal hearing group. It was also noticed that occassionally, the hearing impaired subjects had shorter vowel duration, when compared

TABLE:1 Showing the descriptive statistics of the Vowel duration in initial position.

	Vowel	Mean	S.D.	Min.value	Max. value
NORMALS	/a:/	275	70.36	180	350
	/i/	126.25	9.46	120	140
	/u:/	227.5	54.39	150	270
	/e/	125	31.09	90	160
	/e:/	310	64.94	220	360
	/o/	161	13.15	150	180
	/o:/	316	60.19	260	400
HEARING IMPAIRED	/a:/	328.75	104.51	200	420
	/i/	250	101.00	180	400
	/u:/	198.75	92.41	115	320
	/e/	266.25	129.19	130	400
	/e:/	285	490.10	240	990
	/o/	183.75	28.69	145	210
	/o:/	355	80.62	240	420

Table-II Showing descriptive statistics of final vowel duration.

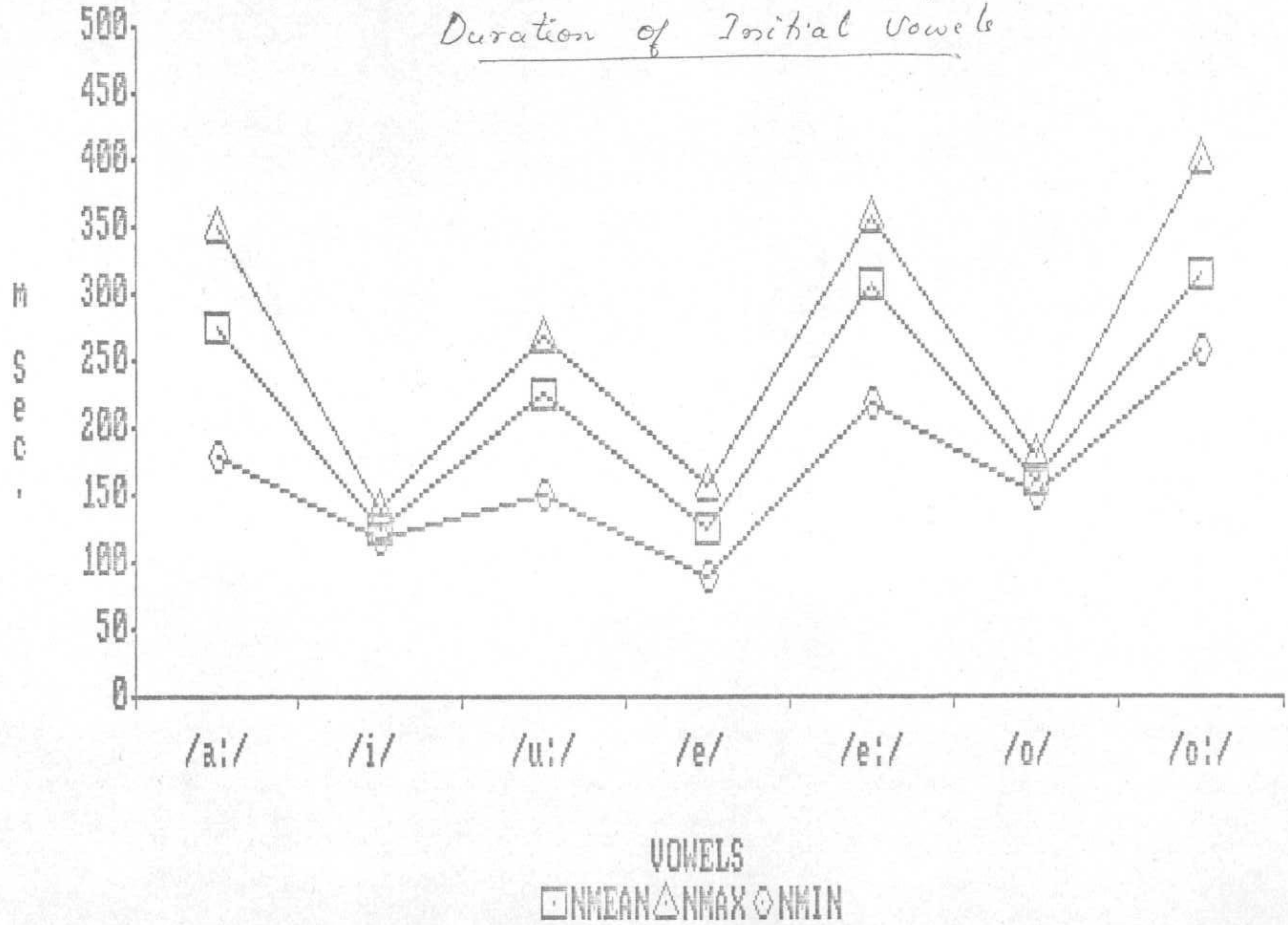
Subjects	Vowel	Mean	S.D.	Min.	Max.
Normals	/e/	201.25	26.58	180	235
	/i/	212.5	15	200	230
	/a/	247.5	73.65	160	340
	/u/	200	59.44	120	250
Hearing Impaired	/e/	231.25	83.90	150	320
	/i/	251.25	99.70	130	370
	/a/	355	52.60	300	400
	/u/	273.75	126.186	185	460



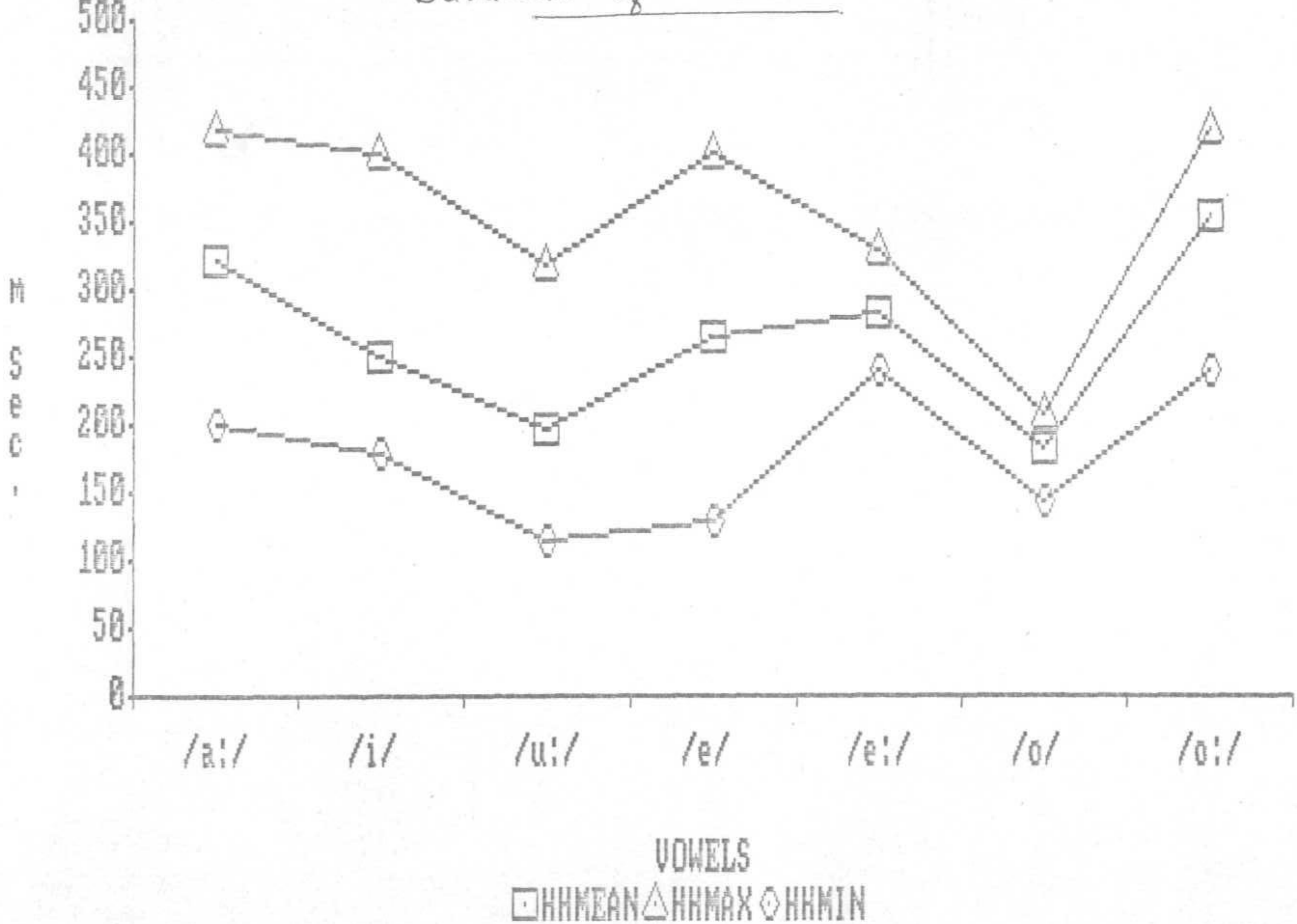
Note: N = normal
HH = Hearing Impaired.

4.4

Duration of Initial vowels

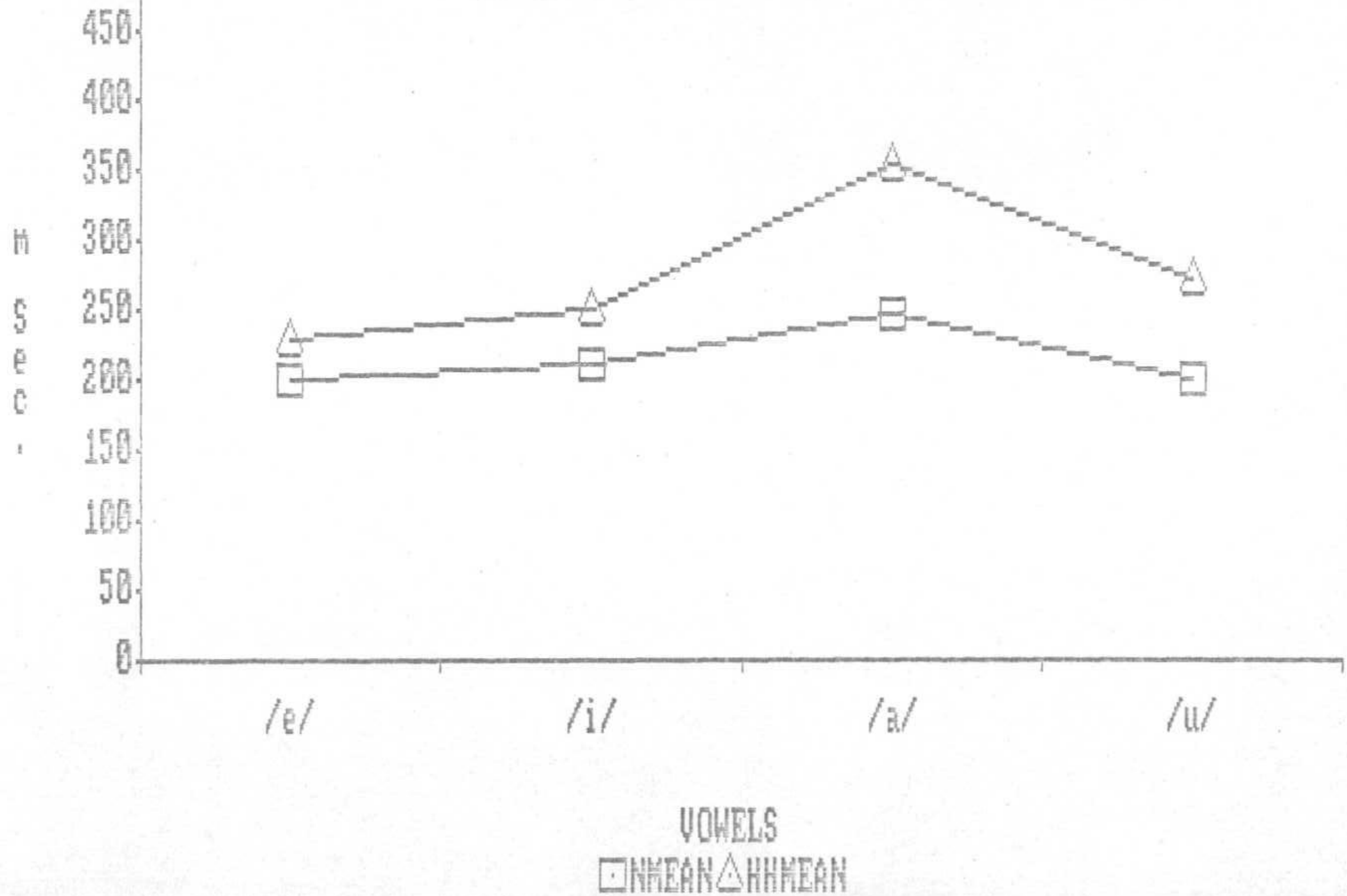


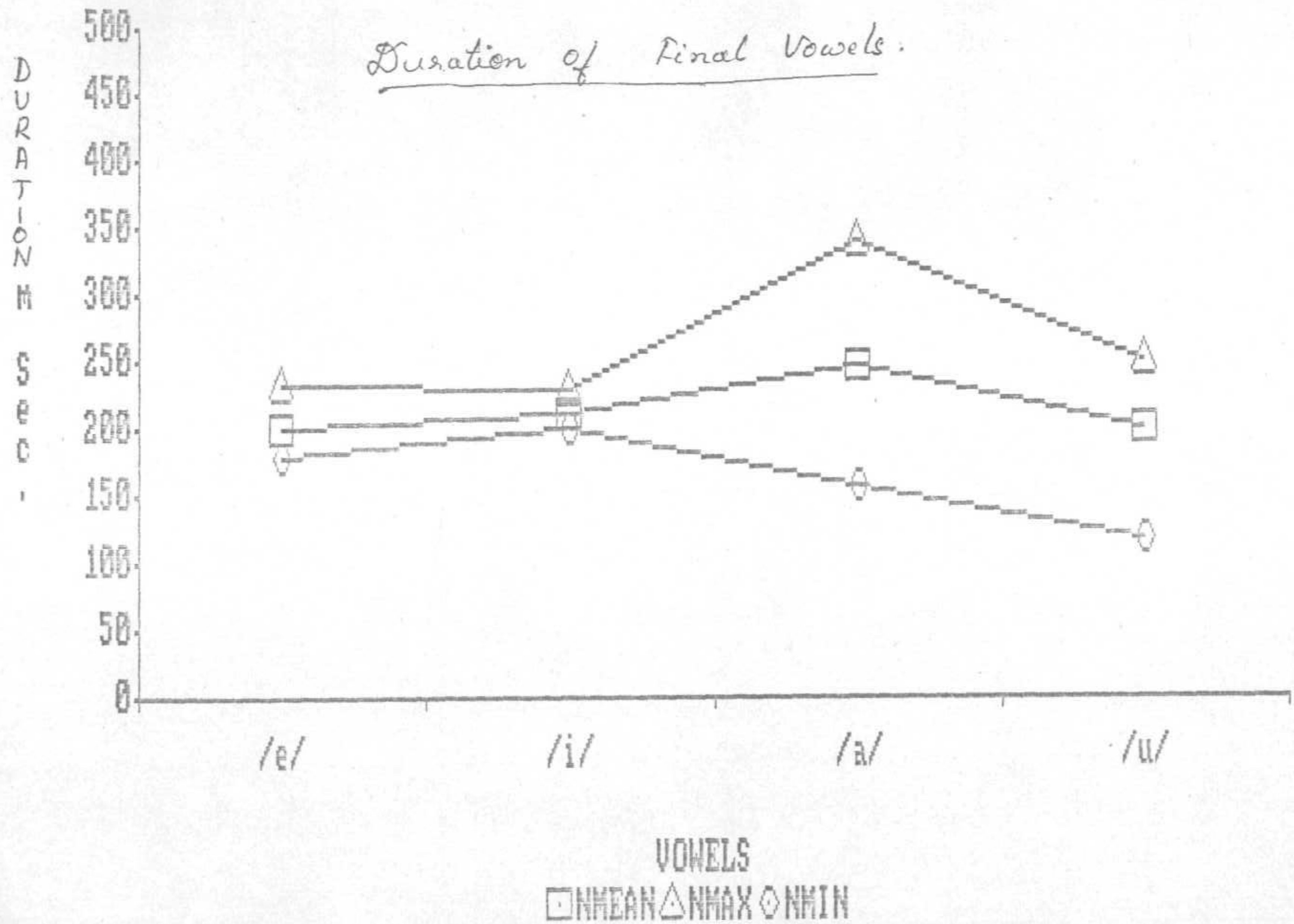
Duration of Initial Vowels.



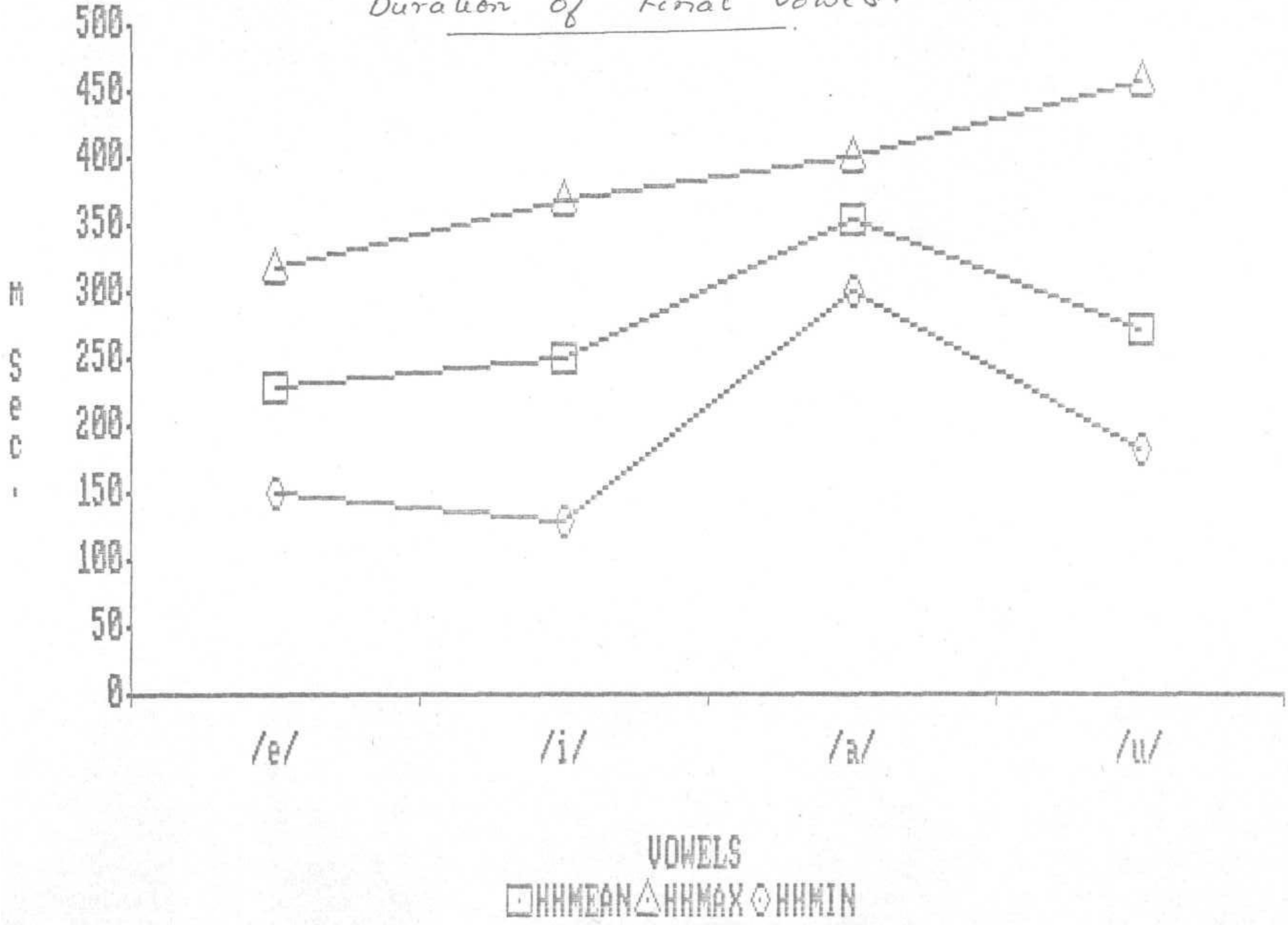
4.6

Duration of final Vowels.




Duration of Final Vowels.
DURATION M SEC.
500
450
400
350
300
250
200
150
100
50
0
/e/
/i/
/a/
/u/
VOWELS
NMEAN NMAX NMIN

Duration of Final Vowels.



8.2

to the normal hearing subjects. When the intended vowels were long vowels (Eg. /a:/, /u:/, /o:/). Sometimes, this trend was seen in the final vowels also. (Eg: /e/ in 'a:ne', /e/ in 'ele').

Out of the seven vowels measured in the initial position, five vowels (a:, i, e, o, o:) had longer vowel durations than normal hearing group and two /u: & e:/ had shorter vowel durations than that of normals.

All the four vowels measured in the final position had longger vowel duration in the hearing impaired group that that of normals.

In the normal group; among the seven vowels of initial position the vowel /o:/ had the longest vowel duration (316.25 m.sec.) followed by /e:/ (310 msec), /a:/ (275 m.sec) /u:/ (227.25 m.sec) & /e/ (125 m.sec). In case of hearing impaired group also the vowel /o:/ showed the longest vowel duration (355 m.secs) to was followed by /a:/ (323.75 m.secs) /e:/ (265 msec), /a/ (266.25 m.sec.), /i/ (250 m.sec) /u:/ (190.75 m.sec), and /o/ (183.75 m.sec).

Among the vowels in final position /a/ was longest in the normal group (247.5 m.sec. long) The next positions were taken by /i/ (212.5 m.sec) /c/ (201.25 m.sec), and /u/ (200 m.sec.

In case of hearing impaired group, also /a/ was longest (355 m.sec.) followed by /u/ (273.75 m.secs), /i/ (251.2 m.sec), and /e/ (231.25 m.sec.).

The hearing impaired group had greater variabition than that of the normal group exception in_________cases. (Please see the Table 1 & 2 for the values).

There was an overlap between the ranges of the values of two groups. For normal group minimum valve varied from 90 - 260 m.secs for initial vowels and 120 - 280 m.secs. for final voweles. The maximum values ranged from 140 - 400 m.secs. for the initial vowels and 230 - 340 m.secs for the final vowels.

In the hearing impaired group the minimum values for the initial vowels ranged from 115 - 240. m.secs, and for final vowels 130 - 300 m.secs. the maximum valeus ranged from 210 - 420 m.secs for initial vowels and from 320 - 420 m.secs for the final vowels.

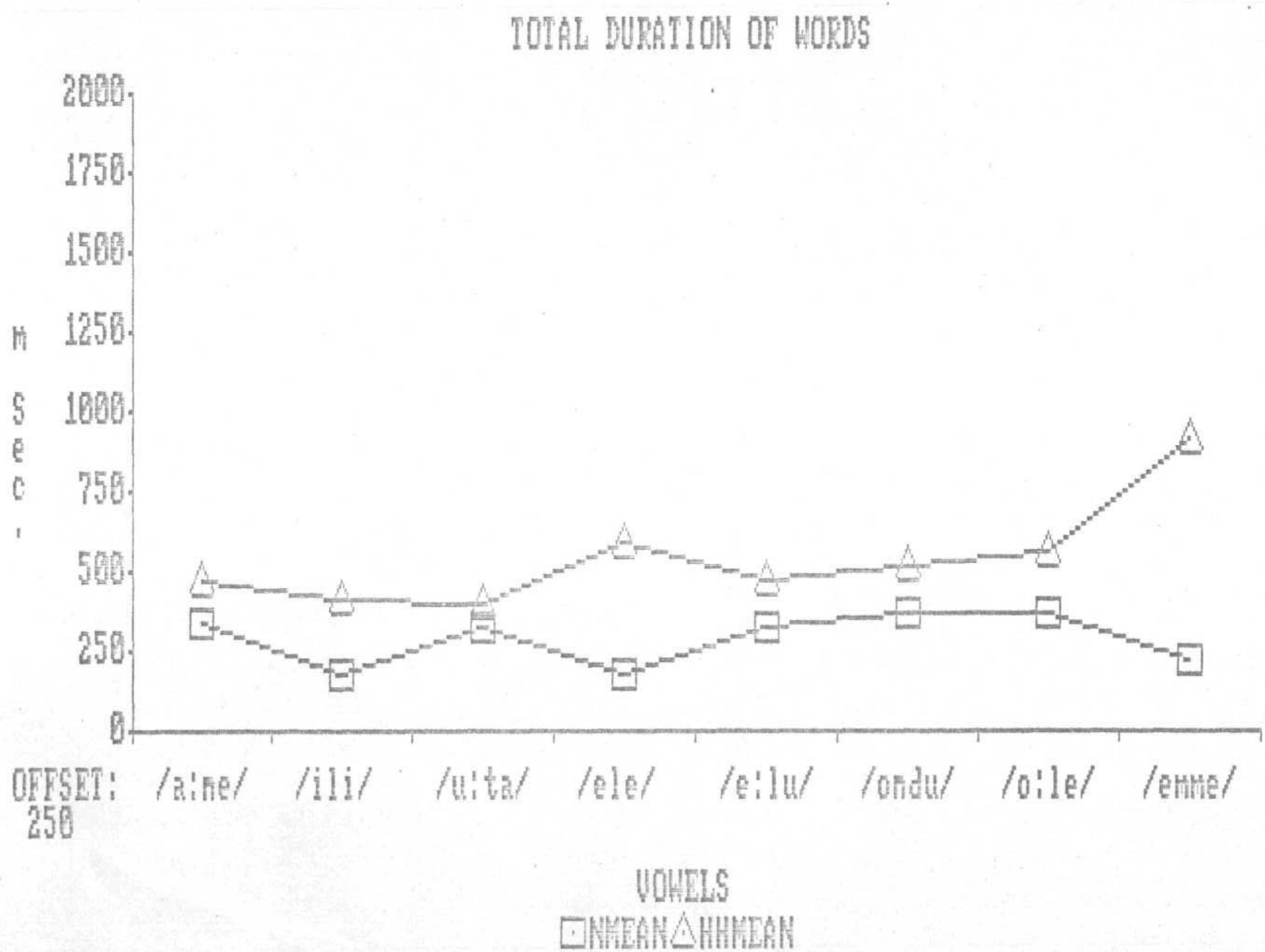
Pauses: The normal hearing children did not show any intersyllabic (or intraword) pauses. Pauses were observed in the utterances of three hearing impaired Children. One subject in the hearing impaird group did not introduce any pauses). The pauses were not observed in the /u: ta/ & /ondu/. One subject showed pauses in six words and the other two showed pauses in two words and one word respectively.

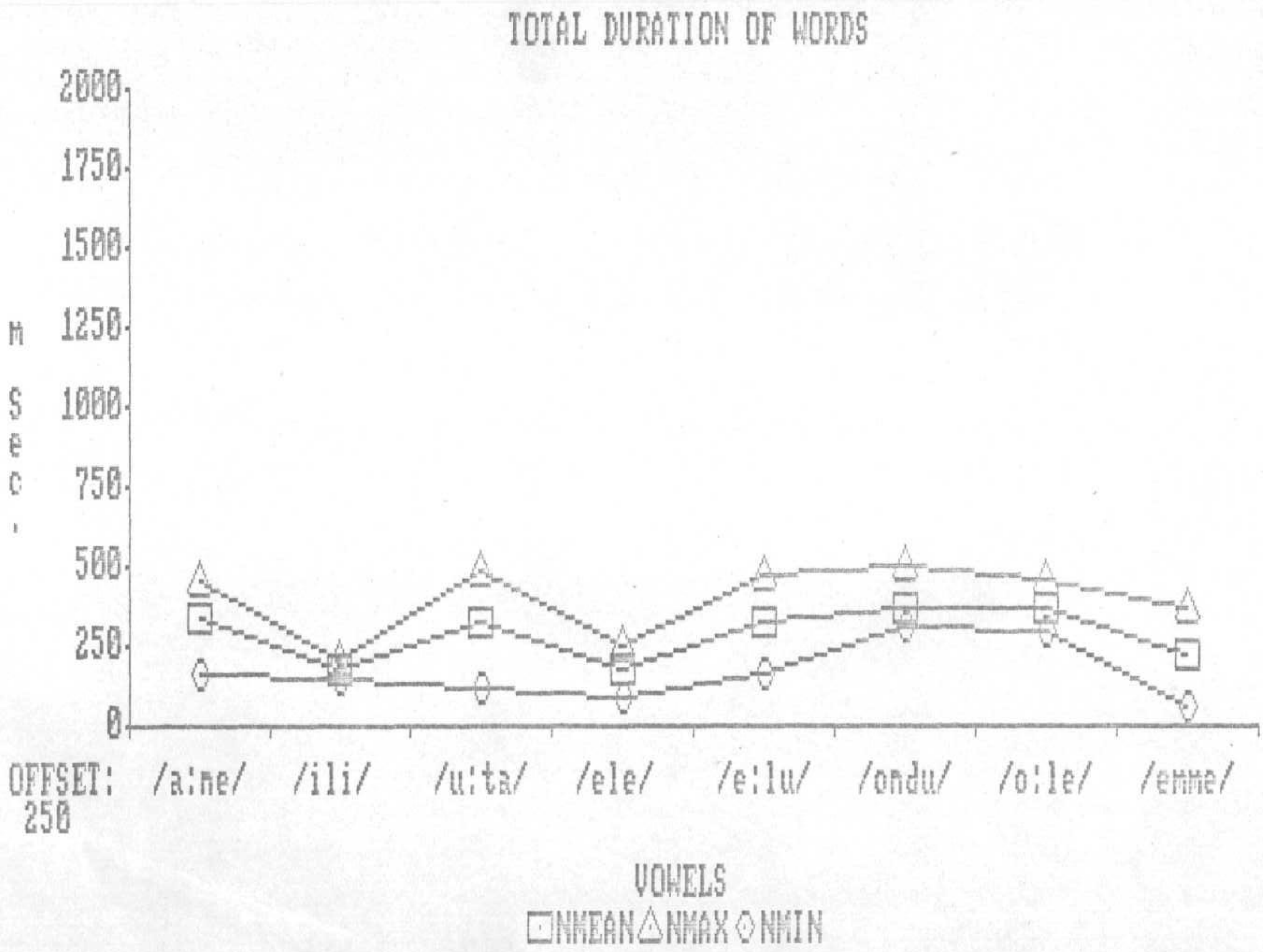
The durations of pauses ranged from 100 m.secs. to 1190 m.sec:

Total duration of the words: The words utttered by the hearing impaired subjects had longer durations, in general, when compared to the normal hearing group.

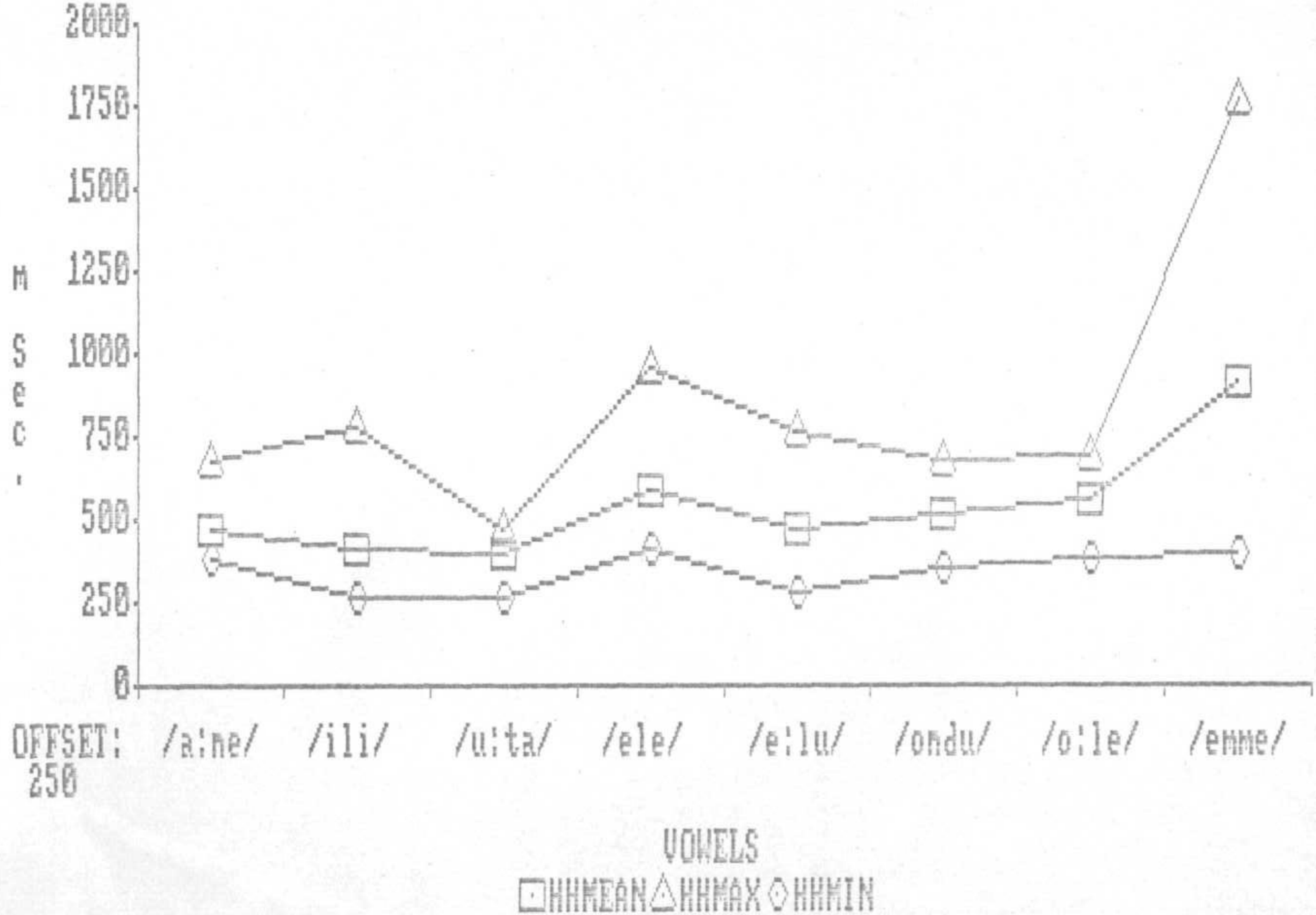
Table-III Showing descriptive statistics of total duration of words.

Subjects	Words	Mean	S.D.	Min.	Max.
NORMALS	/a:ne/	602.5	127.12	420	710
	/ili/	432.5	32.02	400	460
	/u:ta/	575	148.21	380	740
	/ele/	432.5	74.11	340	510
	/e:lu/	587.5	136.47	420	730
	/ondu/	627.5	90.32	570	760
	/o:le/	627.5	84.21	550	710
	/emme/	472.5	133.51	320	620
HEARING IMPAIRED	/a:ne/	722.5	145.69	640	940
	/ili/	675	239.79	520	1030
	/u:ta/	657.5	96.74	520	730
	/ele/	850	250.20	670	1220
	/e:lu/	732.5	217.77	540	1020
	/ondu/	772.5	149.75	610	940
	/o:le/	820	147.20	640	950
	/emme/	1167.5	594.55	650	2020


TOTAL DURATION OF WORDS
m Sec -
2000
1750
1500
1250
1000
750
500
250
0
OFFSET: 250
/a:me/
/ili/
/u:ta/
/ele/
/e:lu/
/ondu/
/o:le/
/emme/
VOWELS
NMEAN HHMEAN


TOTAL DURATION OF WORDS
M Sec.
2000
1750
1500
1250
1000
750
500
250
0
OFFSET: 250
/a:me/
/ili/
/u:ta/
/ele/
/e:lu/
/ondu/
/o:le/
/emme/
VOWELS
NMEAN NMAX NMIN

TOTAL DURATION OF WORDS



The words /e:le/ and /ondu/ had longest mena total duration (627.5 m.secs) followed by /a:ne/ (602.5 m.sec). /e:lu/ (587.5 m.secs)/u:ta/ (575 m.secs), /emme/ (432.5 m.secs) in the normal hearing groups.

In case of hearing impaired group the word /emme/ had longest mean total duration (1167.5 m.secs) followed by, /ele/ (850 m.secs), /o:le/ (820 m.secs)/ondu/ (272.5 m.secs)/e:lu/ (732.5 m.secs) /a:ne/ (722.5 m.secs) /ili/ (675 m.secs) & /u:ta/ (657.5 m.secs).

Overall, the hearing impaired group had longer variation then that of the normal hearing group. (Please see the table 3 for the values).

The minimum values for the words ranged from 320-570 m.secs for normals and the maximum values ranged from 460-760 m.secs.

In case of hearing impaired, the minimum values ranged from 520 - 650 m.secs. and the maximum values from 730 to 2020 m.secs.

Average fo:

The hearing impaired children had higher to than that of normal hearing children and had greter variability.

In the normal group -

1. The final vowel /a/ in the word /ele/ had highest fo of 323 Hz.
2. Among the initial vowels, the vowels /u:/ had the highest for (301 Hz) followed by / i / (285 Hz) /o:/ (282.75 Hz), /a:/ (272 Hz), /e:/ (271.5 Hz), /e/ in /ele/) (266.25 Hz),

/e/ (261.5Hz) and /e/ (in emme) (255.75 Hz).

3. Among the final vowels, the vowel /a/ (in ele) had the highest to (323 Hz) followed by /e/ (in o:le) (321.5 Hz), / i / (320.25 Hz), /u/ (311 Hz) (in e:lu) /u/ (in ondu) (308 Hz), /a/ (301.5 Hz), /e/ (in a:ne), 293.75 Hz), /a/ (in emme),. (273.25 Hz).

4. Among the consonants /l/ (in e:lu) had the highest fo (294.25 Hz)followed by /l/ (in ole) 293.25 Hz), /d/ (290.25 Hz) /l/ (in ele) (287.25 Hz), /l/(in its), (285 Hz) /n/ (in a:ne) (280 Hz), /n/ (in ondu) 279 Hz), and /m/ (256.75 Hz)

5. The minimum values ranged from 232 Hz to 296 Hz and the maximum values from 296 to 400 Hz.

In case of hearing impaired children:

1. The initial vowel /i/ in (ili) had highest fo value (359.75 Hz).

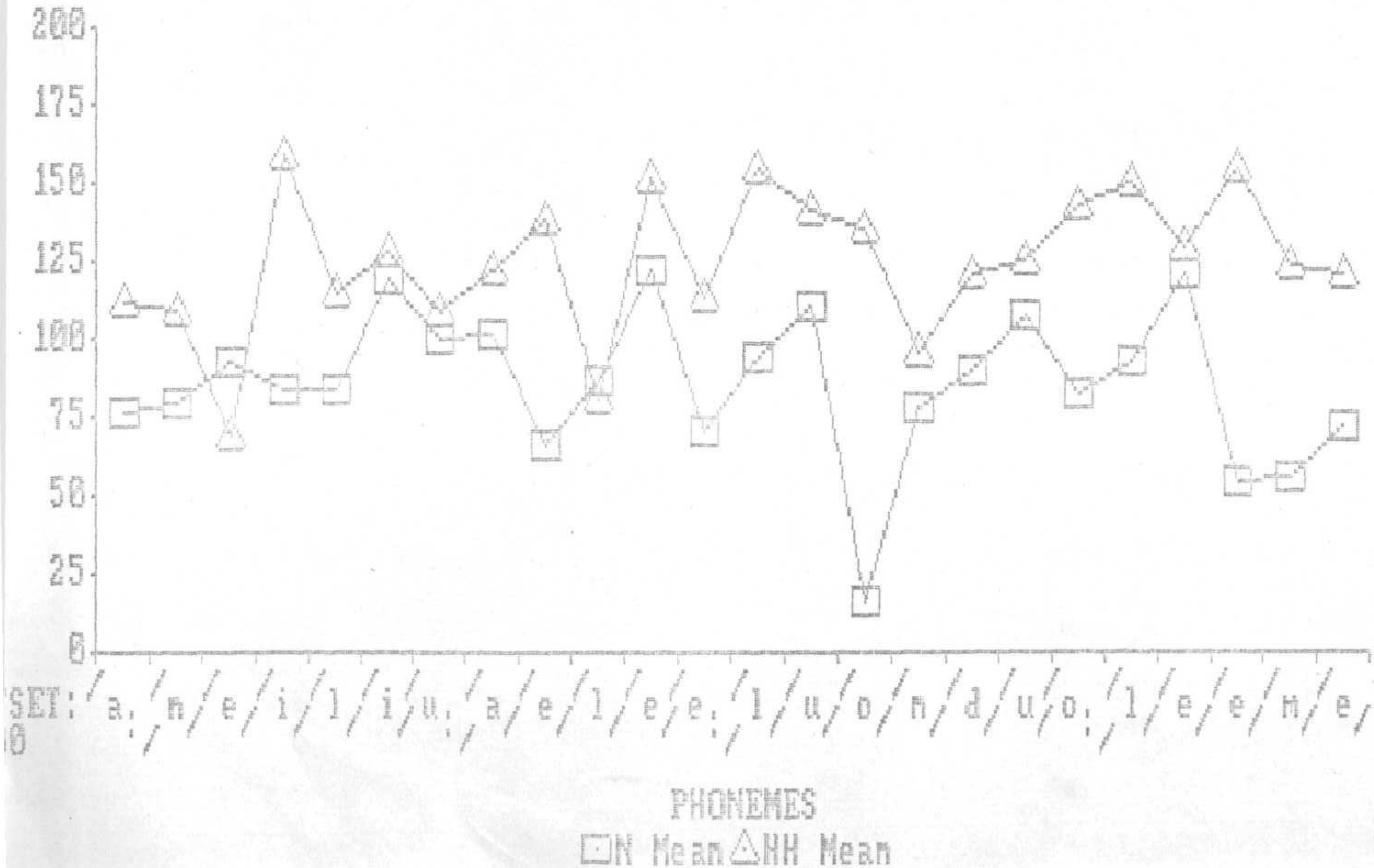
2. Among the initial vowels the values were as follows:- /i/ (359.75 Hz), /e/ (in emme) (355.25 Hz), /o:/ (344 Hz), /e/ (in ele), (338.25 Hz), /o/ (335.75 Hz), /e:/ (314 Hz), /a:/ (312.5 Hz) and /u/ (310.25 Hz).

3. Among the final vowels the vowel /e/(of ele) had the highest value (352.5 Hz) followed by /u/ (in elu) (342.25 Hz), /e/ (in o:le) (329.5 Hz), /i/ (in ili) (329.25 Hz) /u/ (in ondu) (325.5 Hz), /a/ (in u:ta) (322.75 Hz), /e/ (in emme) (321.25 Hz), /e/ (in a:ne) (269.75 Hz).

Table IV: Showing descriptive statistics of average fo of each phoneme in the word.

	Normals				Hearing Impaired			
Phoneme	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.
/a:/	277.25	49.21	235	348	312.5	43.83	258	348
/n/	280	40.22	235	333	309.25	79.86	222	400
/e/	293.75	66.03	222	381	269.75	59.85	205	348
/i/	285	25.01	250	308	359.75	68.42	258	400
/l/	285	25.01	250	308	316	88.85	216	400
/i/	320.25	40.89	296	381	329.25	52.62	276	400
/u:/	301	27.41	267	333	310.25	77.19	235	400
/t/	0	0	0	0	0	0	0	0
/a/	301.5	32.06	276	348	322.75	50.22	276	381
/e/	266.25	25.98	235	296	338.25	58.09	258	381
/l/	287.25	23.17	267	320	282.25	64.64	211	364
/e/	323	53.78	286	400	352.5	57	267	381
/e:/	271.5	32.55	250	320	314	69.94	235	381
/l/	294.25	50.23	250	364	355.25	54.84	276	400
/u/	311	52.1	269	381	342.25	46.18	276	381
/o/	261.5	23.91	242	296	335.75	46.45	267	364
/n/	279	36.25	258	333	295.75	88.93	216	381
/d/	290.5	44.34	242	348	322	86.72	211	400
/u/	308	38.51	276	364	325.5	78.28	235	400
/o:/	282.75	43.71	258	348	344	51.96	267	381
/l/	293.25	43.87	250	348	350.75	63.56	258	400
/e/	321.5	59.23	267	400	329.5	48.26	258	364
/e/	255.75	27.52	235	296	355.25	54.84	276	364
/m/	256.75	34.33	235	308	324.75	72.52	229	381
/e/	273.25	50.63	222	333	321.25	23.57	296	348

AVERAGE F0 OF PHONEMES



4. Among the consonants /l/ (in e:lu) had highest Fo 355.25 Hz), follwed by /l/ (in O:le) (350.75 Hz), /n/ (324.75 Hz). /d/ (322 Hz), /l/ (in ili) 316 Hz), /n/ (in a:ne) (309.25 Hz), /n/ (in ondu) (295.75 Hz), /l/ (in ele) (282.25 Hz).

5. The minimum values ranged 205 - 296 Hz and the maximum values ranged from 348 - 400 Hz.

Formant freqeuncies: 3 formant freqeuncy namely F_1, F_2, F_3 were calculated for each phoneme of all the words.

On the average, the hearing impaired chidlren had higher F_1 & F_2 and smaller F_3 values than those of the normal hearing group, the hearing impaired group showed higher variabiliy.

Bandwidths: 3 bandwidths, B1, B2, B3 were cauculated for each phoneme of all the words.

The hearing impaired children had smaller values of band widths.

The standard deviation values did not show any consistant pattern here.

Wilcoxon singed ranks test was performed to check whether there was any significant difference between the two groups for all the measures.

A significant differnece was seen between the 2 groups at 0.05 level of significance for the -

1. Vowel duration -both initial and final position
2. Total duration of the words
3. Average fo (of the vowels in the)
4. F_1, F_3 (initial position)

5. F_1 & F_3 (of vowels in the final position)
6. B_2 (of vowels in the final position)

There was so significant difference at 0.05 level of significance between the 2 groups for the following measures.

1. F_2 of both initial and final vowels
2. Bandwiths (B_1 B_2 B_3) of initial vowels.
3. B_1 & B_3 of final vowels.

Step 2: Correction of erros by synthesis:

In the second stange, the digitized data of hearing impaired subjects speech was corrected. Only three measures were consisdered for the correction purpose due to limitation of equipment and time. Only these three were considered as these parameters had shown maximum difference and also easy to correct. They are:

1. Correction of pauses
2. Correction of vowel duration
3. Correction of average fo

These measures were corrected in isolation and in combinations. Thus, altoghether seven types of corrections were made as described in methodology.

Step 3:

All the corrected utterances were mixed with the unaltered utterances and thus, to 256 utterances were obtained totally. These utterances were randomized and given to 5 judge for word identification task & intelligibility rating.

The number of words identified correctly were converted into percentage scores.

The scores obtained for both closed set and open set are given in the table V.

Interjudge reliability, was determined using correction method. The values exhibited high correlation between the judgments made by different judges.

The values are given in Table VI.

There was poor corelation between J_1 & J_5. Once but as it was not seen in the second set of reponses. J_5 was included in the study. Judge five was a layman who had no exposue to the speech of deaf.

Intra judge reliability was also found to be high. The unaltered words and the words which were included in the pause corrected group were compared (23 words of this group had no intersyllable pauses hanece they were used) to find out intrajudge reliability. Thee was high percentage of agreement between the identified words of unaltered words group and the identfied words of pause corrected group (Scores varied from 56% - 65%). Therefore it was considered there was high of intrajudge reliability.

From the table V it is clear that the judges identified the words better when an additional clue about the words were provided. An overall increase of 25.3% was observed i.e. the identification of close set presetnation were better.

Table V : Showing the word identification scores (interms of percentage) in both open set and closed set for different conditions.

Parameters Corrected		J1	J2	J3	J4	J5	MEAN
Nil (Unaltered)	O	6.8	3.4	15.3	13.6	3.4	8.5
	C	49.1	45.8	27.1	37.3	42.4	40.34
Pause	O	0	0	0	0	0	0
	C	11.1	44.4	0	22.2	11.1	17.76
Vowel Duration (V.D)	0	3.9	3.9	17.6	23.5	7.8	11.34
	C	62.7	52.9	37.3	37.3	58.8	49.8
Fundamental Frequency (Fo)	0	3.4	0	1.7	0	0	1.02
	C	33.9	15.3	15.3	13.6	25.4	20.7
Pause + Vowel Duration	0	0	0	0		11.1	2.22
	C	22.2	44.4	0	0	22.2	17.76
V.D. + Fo	0	2	0	3.9	2	0	1.58
	C	25.5	25.5	15.7	11.8	27.5	21.2
Pause + Fo	0	0	0	0	0	0	0
	C	22.2	11.1	0	0	22.2	11.1
Pause + V.D. + Fo	0	0	0	0	0	0	0
	C	11.1	11.1	0	22.2	0	8.88
TOTAL	0	3.52	1.56	8.2	8.2	2.73	4.84
	C	39.06	33.59	20.31	23.05	34.77	30.18

[Note: 0 = open set of responses(without clues)
C = closed set of responses(with clues)]

Table VI :- Showing the inter judge reliability values.

Judges	Values of Pearson's "r" Open Set	Closed Set
J1 & J2	0.79	0.62
J1 & J3	0.84	0.95
Jl & J4	0.70	0.61
J1 & J5	0.11	0.97
J2 & J3	0.98	0.69
J2 & J4	0.97	0.81
J2 & J5	0.42	0.65
J3 & J4	0.97	0.73
J3 & J5	0.37	0.91
J4 & J5	0.45	0.49

When on open set was given, the total correct identification scores varied from 1.56% to 8.20% with a mean value of 4.84% and the mean scores indicate that the highest scores obtained were for the vowel duration correction only (11.34% which is followed by scores for unalterd utterances (8.5%), pause and vowel duration correction (2.22%) V. duration and fo correction (1.58%)and fox correction (1.02%). None of the judges had identified the words when pauses, pause and f and pauses, vowel duration and fo were corrected (0%).

When an additional clue was provided (closed set) the judge performed better. The range of correct identification was from 20.13% to 39.06% with a mean vaule of 30.16%. Here also, the average value for word identification was best when vowel duration alone was corrected (49.8%) followed by unaltered words (40.3%), V. duration + fo correction (21.2%) to correction alone, (20.7%), pause correction only and P+V D correction (17.76%), pause and fo correction (11.1%) and P + V duration + fo correction (8.88%).

The vowel duration correction yielded around 3% in (open set) and 9.5% (in closed set) improvement in intelligibility. Thus both the sets/ that the correction / indicate of vowel duration itesel has positive effect on speech intelligibility and all the other corrections have a dctrimental effect on speech intelligibility.

Wilcoxon signed ranks test was applied to check whether the improveemnt shown when the vowel duration was corrected was significant or not.

The results showed that the improvement observed was statisticallysignificant at 0.05 level significance.

The results were further analysed to find out which of the eight words have been identified correctly most of the time. It was seen that the wordd was identified most frequently was followed by /ane/ and /ondu/. The details are given in table VII.

Besides word identification task, the judges werealso requesited to rate the intelligibility of each word on 5 point interval scale as follows: -

0 - unintelligible
1 - poorly intelligible
2 - fairly intelligible
3 - quite intelligible
4 - highly intelligible

The analysis of intelligibility ratings revealed the follwing:

The judges rated better intelligibility for the words when a closed set was provided.

In the open set the ratings were:-

64.45% as unintelligible (rating 0)
31.25% as poorly intelligible (rating No.1)
4.3% as fairly intelligible (rating No.2)
None of the words rated as quite or highlyintelligible.

Table VII :- Showing the correct identification scores (interms of percentage) for the words.

WORDS		J1	J2	J3	J4	J5	MEAN
/u:ta/	O	18.75	9.38	43.75	46.88	3.13	24.38
	C	75.0	68.75	46.88	43.75	46.88	56.25
/a:ne/	O	3.13	3.13	18.75	12.5	15.63	10.63
	C	56.25	59.38	43.75	50.0	43.75	50.63
/ondu/	O	— 6.25	0.0	3.13	6.25	3.13	3.75
	C	43.75	31.25	50.0	34.38	34.38	38.75
/ili/	O	0.0	0.0	0.0	0.0	0.0	0.0
	C	34.37	31.21	0.0	12.5	37.5	23.12
/e:lu/	O	0	0	0	0	0	0
	C	31.25	21.88	12.5	9.38	28.13	20.63
/emme/	O	0	0	0	0	0	0
	C	34.38	21.88	3.13	12.5	18.75	18.13
/ele/	O	0	0	0	0	0	0
	C	12.5	12.5	3.13	15.63	43.75	17.50
/o:le/	O	0	0	0	0	0	0
	C	25	21.88	3.13	6.25	28.13	16.88

When a closed set was provided the ratings are:

55.86% as poorly intelligible (0)

24.61% as unintelligible (1)

12.5% as fairly intelligible (2)

5.47% as quite intelligible and (3)

1.56% as highly intelligible (4)

The details are presented in Table VIII .

Table VIII: Showing the scores and percentage of scores of intelligibility ratings.

Sets	Intelligibility Ratings 0	1	2	3	4
Open	165 64.45%	80 31.25%	11 4.3%	0 0%	0 0%
Closed	63 24.61%	143 55.86%	32 12.5%	14 5.47%	4 1.56%

Thus, In Hypothesis (1) stating that there is no significant difference in the utterances of children with normal hearing and hearing impaired children in terms of

a) Vowel duration is REJECTED.

b) Intersyllabic pauses is REJECTED.

c) Total duration of the words is REJECTED.

d) Average Fo of the phonemes in the words is REJECTED.

e) Formant frequencies (F_1, F_2, F_3)

(i) first formant(F_1) and third formant (F_3) of the vowels in the initial position and final position is REJECTED.

(ii) Second formant of the vowels (both in initial and final position) and the formant frequencies (F_1, F_2, F_3) of consonants is ACCEPTED.

f) Bandwidths (B_1 B_2 B_3)

(i) B_2 of the vowels in the final position is REJECTED.

(ii) Bandwidths of the vowels in the initial position, Bandwidths of consonants, B_1 & B_3 of the vowels in the final position is ACCEPTED.

Hypothesis (2):

A. Correction of vowel duration:

The Hypothesis stating that there is no significant difference between the intelligibility scores of original, unaltered utterances and the utterances where the vowel duration alone has been corrected, 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 pauses alone have beencorrected, is REJECTED.

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

C. Correction of average Fo of the phonemes:

The hypothesis stating that there is no significant differences between the scores of original, unaltered utterances and the utterances where the average Fo has been corrected is REJECTED.

There was s decrement in the intelligibility scores when the average Fo was corrected.

D. Correction of vowel duration and pauses:

The hypothesis stating that there is no significant difference between the intelligibility socres of origninal, unaltered utteranced and the utterances where the vowel duration and pauses have been corrected is REJECTED.

There was decrement in the intelligibiliy scores when the vowel duratin and pauses were corrected.

E. Correction of vowel duration and Fo:

The hypothesis stating that there is no significant difference between the intelligibility scores of original, unaltered utterances and the utterances where the vowel duration and fo have been corrected, is REJECTED.

There was a decreemnt in the intelligibility scores.

F.Correction of pauses and Fo:

The hypothesis stating that there is no signifcant difference between the intelligibility scores or original, unaltered utterances and the utterances where the pauses and Fo have been correctd is REJECTED.

There was a decrement in the intelligibility scores.

G. Correction of vowel duration, pauses and Fo:

The hypothesis stating that there is no significant difference between the intelligibility scores of original unaltered utterances and the utterances where the pauses, vowel duration and Fo have been corrected is REJECTED.

There was a decrement in the intelligibility scores when all these three measures were corrected.

Discussion

The hearing impaired children had longer vowel durations when compered to the normal hearing group. This finding is in agreement with the studies of Angelocci, 1962; Calvirt,(1962); John & Howarth, 1965; Boone, 1966; Levitt et al, 1974; Monsen, 1974; Parkhust & Levitt, 1978; Osberger & Levitt, 1979; Rajanikanth, 1986; Leeper et al, 1987; Shukla, 1987. These studies reported that a general tendency towards lengthening of vowels and consonants in the speech of hearing impaired.

Osberger & Levitt (1979) observed that syllable prolongation in the speech of the hearing impaired was due primarily to prolongation of vowels.

In the present study it was also observed that the hearing impaired children showed more variability when compared to the normall hearing children. These findings are in agreement with the reports of Monsen (1974), Osberger (1978), Osberger & Levitt (1979), Rajanikanth (1985), Shukla (1987). Similar findings have been reported by physiological studies also. (Rothman,1977; Zimmerman & Rettaliata, 1981). Rothman (1977) states that the deaf, as a group, were more variable in their articulatory behaviour than ware normal speakers.

Lyberg (1981) reported that there was a strong relationship between vowel duration and fundamental frequency. Nataraja & Jagadish (1984) found that vowel duration of / i / and /u/ were longer at higher and lower fundamental frequencies than that of natural fundamental frequencies (or normal pitch).

The longer vowel durations seen in case of hearing impaired children may be attributed to this factor as it was also seen that on the average, these Children had higher fo than that of normal hearing children.

It has been observed that the profoundly hearing impaired speakers typically insert more pauses and pauses of longer durations than do speakers with normal hearing. (Boone, 1966; Boothroyd et el, 1974; Heidinger, 1972; Hood, l966; John & Howarth, 1965; Stevens et al, 1978). Osberger & Mc Gara (1982) while considering the speech of hearing impaired state that "pauses" may be inserted at syntactically inappropriate boundaries such as between two syllables in a bisyllabic word or within phrases".

In this study, it was found that three out of four hearing impaired children inserted pauses between two syllables and one subject did not.

Pauses were present in six of the a utterances in one subject, 2 in the another and the 3rd subject had pause in only one word.

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

(Hudgins, 1934, 1937, 1946). Hudgins reported that the deaf children used short, irregular breath groups often with only one or two words and breath pauses that interrupted the flow of speech at inappropriate places. Also,there was excessive expenditure of breath on single syllables, false grouping of syllables and misplacement of accents. Forner & Hixoa (1977) found that the muscle activity to be normal for deaf individuals during quiet breathing but noted that they do not take enough air while breathing for speech.

The total durations of words were also longer in case of hearing impaired group than normal hearing children in this study. Similar findings have been reported by Leeper et al (1987).

It was expected that the total duration of the words would be more in case of hearing impairad children as they prolong the speech segments.

Osberger & McGars (1982) also note that "prolongation of speech segments may be present in the production of phonemes, syllables and words."

"If there is a problem with a hearing impaired speaker's average fo, more often the voice pitch is characterized as too high rather than too low." (Angelocci, 1962; Angelocci, et al, 1964; Boone, 1966; Calvert, 1962; Engelberg, 1962; Kopp & Holbrook, l964; martony,l968; Meckfessel, 1964; Thornton, 1964; Gilbert & Camp bell, 1980; Rajanikanth, 1986; shukla, 1987).

The findings of this study were in agreement to the findings reported earlier. In general, the hearing impaired children showed higher fo than that of normals. Also, the hearing impaired children showed greater variability when compared to the normals.

There have been a few explnations put forward in order to explain the higher fo in case of hearing impaired.

Angelocci, et al (1964) suggested that the hearing impaired subjects attempted to differentiate vowels by excesive laryngeal variation rather than with articulatory maneuvers as done by normal hearing speakers.

willemain & Lee (1971) hypothesized that the deaf speaker uaes extra vocal effort to give him an awareness of the onset and progress of voicing and this becomes the cause for the high pitch observed in their speech.

Pickatt (1968) had suggested that the increase in pitch was due to increased subglottal pressure and tension of the vocal cords. Thus the general opinion has been that the increased vocal effort ia directed at the laryageal mechanisms for kinesthetic feedback.

Bush (1981) has not support this view. Greater fo variability was observed for the hearing impaired speakers who produced a wide range of vowel sounds. She attributed age related factors such as laryngeal growth accompanied.

by adolescent voice change, which are not auditorily detected to the pitch deviation.

Martony (1968), Honda (1981) opined that the laryngeal tension is a side effect of the extra effort put in the articulators. 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 a change of position in the laryngeal structures. This would cause a change in pitch.

In summary it may be stated that the high fo indicates lack of laryngeal control due to the absence of auditory feedback.

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

"Speech intelligibility is the single most practical index of hearing impaired person's oral commuication abilities." (subtelny, 1977).

On the average, the intelligibility of profoundly hearing impaired childrens' speech is very poor. (Hudgins & Numbers, 1942; Goda, 1959; Quigley & Frisina, 196l; Angelcocci, 1962; Branaon, 1964; John & Howarth, 1965; Hood, 1966; Montcgomery. 1967; Nober, 1967; Toback, 1967, Markider, 1970; Heidinger, 1972; Braverman, 1974; Smith, 1975; Conarad, 1979; Mc Gars & Osberger, 1978; Ling, 1981; Ravishankar, 1985).

In the present study, two kinds of responses were studied, i.e., (1) one with open set. In this condition, the judges were asked to identify the words. They were not informed about the words presented to than.

The response of the judges for unaltered, original utterances ranged from 3.4% to 15.3% with a mean score of 8.5%.

These results indicates that the speech intelligibility was very poor. This can be attributed to the condition and the type of material used. As Ling (1976), Puts it, 'intelligibility ratings vary not only with the type of judge employed (experienced vs inexperienced), 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 listner in a face-to-face situation are mare intelligible than sentences which are tape recorded.'

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

When an additional clue regarding the words was provided to the judges i.e., when the judges were provided with the list of words used, they could identify the words better. The scores obtained for original, unaltered utterances ranged in this condition from 27.1% to 49.1% with a mean score of

40.34%.

The results of some of the previous studies are:

Investigator	Average speech intelligibility
Hudgins & Numbers (1942)	29%
Brannon (1964)	20-25%
Nober (1967)	Less than 4 year level (3-15 yaara children)
Markides (1970)	19-31%
Heidinger (1972)	20%
Smith (1975)	18.7%
Monsen (1978)	76% (attributed to the use of very simple speech materials)
Ravishankar (1985)	42.43%

A comparatively high scores (40.34%) obtained here may be attributed to the clues given to the judges regarding the speech materials used. In the natural speaking situations also, the listeners are provided with contextual cues, sentences are used which are more redundant and there is a face-to-face situation. so, this condition (closed set) may be near natural conditions than the open set condition. Therefore improvement intelligibility might have been seen.

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

Subtelny (1977) cautioned that speech intelligibility assessment can't be used with confidence for training purposes without Knowledge of the properties of speech that can influence intelligibility. Stevens et al (1978, 1983) supported this notion by stating that the fundamental problem of speech assessment with hearing impaired persons is to identify those properties of speech that determine its intelligibility. Mets et al (1980) & Nickerson & Slevens (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) has opined that although there was much decoumentation 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 type* on overall speech intelligibility. Having knowledge in this regard will help in planning suitable training program for each hearing impaired child for improving the speech production ability.

Manipulation of deaf speech by means of digital speech processing or 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 a few studies in this regard so far. (Kruger et al, 1972; Lang, 1975; Osberger & Levitt, 1979; Maassen & Povel, 1984a, 1984b, 1985; öster, 1985; Maassen,1986). The present study is also similar to these studies and aimed at checking the effect of some timing errors and the average fo correction on the speech intelligibility of the hearing impaired children's speech.

The following conclusions have been drawn from the presetn study:

(1) the correction of timing errors and average fo did effect the intelligibility of the hearing impaired children's speech.

(2) the correction of different types of errors, either in isolation or in combinations, had differential effect on the intelligibility.

Oat of 7 types of corrections, (1) elimination of pauses, (2) vowel duration correction, (3) Fo correction, (4) correction of pause & vowel duration, (5) correction of vowel duration & fo (6) correction of pauses and fo, (7) correction of pauses, vowel durations and fo), performed maximum improvement in intelligibility was observed when the vowel duration alone was corrected. The improvement was observed both in open set (8.5 to 11.34%) and closed set (40.34% to 49.8%)of responses and was statistically significant at 0.05 level of significance.

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

Studies on vowel duratonproduction and perception in normal (Ncoteboom, 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 liateners to deaf speech can net identify speech as deaf unless they hear at leaat syllable length productions. "This shows that the effect of the characteristic deaf syllable prolongation were to make the deaf Conspicuous and tedious to listen to". (Harris & Mc Garr, 1980).

The vowels have been compared to the day and the consonants to the night. The consonants have been considered as pearls in the string of vowels, parhapa due to the superior perception of thevowelsin normal speech. vowels play a very important role at different levels in a language i.e., semantic, syntactic and) paralinguistic or prosodic. This suggest that the durational information is used by liateners in decoding speech. The vowel duration seems to be important factor in speech perception. It is obvious from the fact that the judges identified the words better whan the vowel durations were modified i.e., the duration was equal to that of normals.

Osberger & Levitt (1979) reported that the correction of absolute syllable duration had a detrimental affect on intelligibility. They attributed this to a reduction in processing time. According to them, the longer durations may provide the listeners with additional time with which to process the numerous distortions which occur in the speech of the deaf. Also, the speech materials they used were 6 sentences, whereas bisyllabic words have been uaed in this study.

Maassen & Povel (1984 a, b, 1985) Changed syllable and pnonema durations such that they ware either absolutely or relatively aqual to durations of the correaponding segments in the normal utterance. 5% improvement in intelligibility was seen when a phonemic relative correction was performed in 16 of 30 sentences. 6% improvement was seen in 8 (out of 30) sentences when the syllable was the unit of transformation. For 5 sentences largeat increase resulted from a phonemic absolute correction (7%). Maassen & Povel (1985) reported that they had found that (in 1984a study) phonemic absolute correction deteriorated the sentence intelligibility.

Correction of pauses had a detrimental effect on the speech intelligibility. There was a reduction in individual judge's scores and in mean scores (in both conditions) when the pauses alone ware corrected.

Similar reports have been made in the literature (Parkhurat & Levitt, 1978; Caberger & Levitt, 1979; Maassen, 1986), but in all these casaa, thay were inter word or intra-phrase pauses, unlike in this study.

Parkhurst & Levitt (1978) observed that the insertion of short pauses at syntactically appropriate boundaries had a positive effect on intelligibility. They added that excessive or prolonged pauses appeared to have a secondary effect in reducing the intelligibility.

Osberger & 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 & Levitt stated that "thus, it appears that the presense of long pauses may actually provide the listner with additional time with which to process the numerous distortion which occur in the speech of the deaf". They also cautioned that attempts should be made to correct those pauses which occur at syntactically inappropriate boundaries, such as those which are inserted between bisyllabic words.

Maassen (1986) inserted pauses at syntactically appropriate boundaries, in the speech of deaf children and found that there was small but significant improvement in the intelligibility.

The above mentioned studies have used sentences as speech materials.

In the study by osberger (1977), it was found that the elimination of inappropriate pauses sometimes reduced, rather than improved, intelligibility.

The correction of fundamental frequency, either alone or in combination with pauses, vowel duration, pauses & vowel duration also showed a detrimental effect on intelli- gibility.

This might be partly due to the synthetic speech. After changing the average fo values of the phonemes the data was synthesized. It has been observed that the synthetic speech sounds 'monotonous' or 'unnatural'. Also, all the judges in the present study were unfamiliar with the synthetic speech. The reduced intelligibility of synthesized words may also due to limitations of the programs used here for synthesis.

Maassen & povel (1984b, 1985), have reported that the correction of fo contours had slight positive effect on intelligibility. They corrected the intonation either in isolation or in combination with temporal measures.

The correction of pauses and vowel duration simultaneously showed a negative effect on intelligibility, strangely. This might be because the correction of pauses had more dominating effect on the intelligibility than that of vowel duration correction. It ohowa that there was an interaction between timing corrections whan 3 types of timing errors were corrected simultaneously.

Osberger & Levitt (1979) observed that the correction of relative timing errors alone improved intelligibility, whereas the concomitant correction of relative timing errors and pauses simultaneously reduced intelligibility. According to them, this might be because the effect of pause corrections exerted a greater influence on intelligibility than did the correction of relative timing errors. They also observed that the correction of absolute syllable duration and pauses also had a detrimental effect on speech intelligibility.

An analysis of intelligibility rating revealed that most of the utterances got rating 'o' meaning that the words were unintelligible. This was observed in the open set response.

When a clue regarding the words used in the study was provided to the judges, most of the words got rating 1 meaning, poorly intelligible (55.86%). 24.61% of the words (out of 256) were rated as unintelligible. A few (1.56% as highly intelligible & 5.47% as quite intelligible) were rated as highly & quite intelligible, which was not present (0% for both) in the previous condition (open set condition).

This result once again supports the view that the intelligibility of speech of the hearing impaired will be much better when the contextual clues are provided (which is the case in the natural or face to face conditions).

In summary, the present study is in agreement with the previous studies (Kruger et al, 1972; Lang, 1975; Huggins, 1977; Bernstein, 1977,Osberger & Levitt, 1979; Maassen & Povel, 1984a, b, 1985; Oster, 1985) in telling that the correction of suprasegmental aspects does not improve intelligibility of the speech of hearing impaired children drastically. However, a small but significant improvement will be observed if one corrects the suprasegmental aspects such as temporal errors and pitch and intonation patterns.

The following conclusions were drawn:

(1) On the average,the hearing impaired group had significantly longer durations for vowels than that of normal hearing group.

(3) Normal hearing children did net show any inter syllabic pauses (intraword) whereas 3 out of 4 children in the hearing impaired group inserted interayllabic pauses at least once.

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

(4) On the whole, the hearing impaired children exhibited higher average fo than that of the normal hearing group.

(5) The hearing impaired children had higher first formant (F_1) and second formant (F_2) values and smaller third formant (F_3) values than that of normal hearing group.

(6) The hearing impaired children had smaller values of band widths when compared to their normal counterparts, which was not significant statistically.

In all instances, the hearing impaired children exhibited greater variability than the normal children.

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

(a) improved

1) when the vowel durations (both in initial and final positions) were corrected.

(b) decreased

1) when the intersyllabic pauses were corrected.

3) when the average fo of the phonemes were corrected.

3) when the pause & vowel durations were corrected.

4) when the pause and fo were correcte.

5) when the vowel duration and fo were corrected.

6) when the pauses, vowel duration and fo were corrected.

CHAPTER - V

SUMMARY AND CONCLUSIONS

"One of the most recognized but probably least understood concomitants of deafness is a deficit of oral communication skills". (Metz etal., 1982).

"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 uggesting that of prelingually deaf children, hearing losses of 90 dB or more, about 75% have speech classified as "barely intelligible" or corse, (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". (öster,1985).

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

Speech intelligibility is correlated with segmental and supr-segmental errors an the porduction side. And there is such documentation of the kinds of errors seen in the speech of the hearing impaired.

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

No such studies have been reported on Indian population and that too in Kannada speaking deaf speakers. Hence, 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.

Four congenitally deaf children in the age range of 8-10 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 realted to the hearing impairment. All could read simple bisyllabic words in Kannada.

Eight simple bisyllabic Kannada words with VCV combination were selected from the test developed by Babu, Rathna and Bettegari (1972).

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 normal hearing children reading the same set of words.

1. Stage: The samples were then analyzed using a PC-XT computer. The following six parameters were obtained.

1. Voval duration (both initial and final);
2. Duration of pauses, if any;
3. Total duration of the words;
4. Average fo:
5. Formant freqeuncy (F_1, F_2, F_3)
6. Bandwidth (B_1, B_2, B_3)

The obtained data was subjected to statistical analysis, in order to determine the mean, standard deviation and significance of differences.

The following conclusions were drawn:

1. On the average, the impaired group had significantly longer duration for vowels than that of normal hearing group.

2. Normal hearing children did not show any intersyllbic pauses (intraword) whereas 3 out of 4 chidlren in the hearing impaired group insergted intersyllabic pauses atleast once.

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

4. On tha whole, higher average fo than that of the normal hearing group was exhibited by the hearing impaired children.

5. The heating impaired chidlren had higher first formant (F_1) and second formant (F_2) and smaller third formant (F_3) values than that of normal hearing group.

6. The hearing impaired chidlren had smaller values of band widths when compared to their normal counterparts; which was not significant statistically.

In all the instances, the hearing impaired chidlren exhibited greater variability than normal children.

<u>II Stage:</u> Some aspects of the suprasegmental errors in the digitized data of hearing impaired children's speech were modified in the next stage. Three Measures were considered. Those were: (1) Correction of pauses, if any,

(2) Correction of vowel duration

(3) Correction of average Fo

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

These three measures uere corrected, either in isolation or in combination. Thus altogether, seven types of corrections were performed.

1. Correction of pauses alone
2. " vowel duration only
3. " average fo only
4. " pauses and vowel duration
5. " Vowel duration & fo
6. " pause & Fo
7. " pause and vowel duration.

Whenever the Fo values uere edited, the data was synthesized using cascading synthesizing program.

III. Stage: The unaltered Utterances and the corrected utterances (total 256 utterances) were mixes together and randomized. These 256 words were recorded into 6 casettes five judges (2 speech and hearing professionals, 2 speech and hearing students and one listener who had not been exposed to deaf speech such before) were given those cassettes for word identification task and intelligibility rating.

The number of words identified correctly were converted into percent scores using a formula,

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

in the word identification task. Separate scores were found out under each category.

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

The judges had to judge the speech samples provided to thes under the conditions.

1. At first they had to listen to the words and write down whatever they heard and rate the intelligibility (open set of responses).
2. In the second step, they were informed regarding the words used in the study.

Knowing this, they had to rapeat the 1st step (closed set of responses).

The Pearson's correlation method was pplied to find out the interjudge reliability. It showed good correlation between the judges. The intrajudge correlation was high too.

The results showed that the correction of vowel duration had a significant positive affect on intelligibility, while all the other types of corrections had detrimental effect on intelligibility. This was reflected in both the kinds of response criterion.

The correction of vowel duration showed 3% improvement (approximately) in open set of responses and 9.5 % improvement in closed set of responses.

The overall correct identification for original utterances ranged from 3.4 % to 15.3 % (with a mean of 8.5 %) and 27.1 % to 49.1 % (with a mean score of 40.3% for open and closed set of responses respectively.

The results were also analysed to find out which of the 8 words has bean identified correctly most of the time. The word topped the list in both the conditions followed by /a:ne/, /ondu/, /ili/, /e:lu/, /emme/,/ele/, and /o:le/.

Analysis of the intelligibility ratings revealed that in the open set of response most of the words (64.48 %) were rates as unintelligible. When the additional clue was provided regarding the words used to the judges, the performance was improved here also like in the word identification task. Here 55.86 % words were rated as poorly intelligible, 24.5 % as unintelligible, 12.5 % as fairly intelligible, 5.47 % as quite intelligible and 1.56 % as highly intelligible.

The synthesis of speech of the hearing impaired children showed that the intelligibility,

a) <u>improved</u>

1. when the word durations (both in initial and final positions)were corrected

b) <u>decreased</u>

1. When the intersyllabic pauses were corrected.
2. When the average fo of the phonemes were corrected
3. When the pause and vowel durations were corrected.
4. When the pause and fo were corrected.
5. When the vowel duration and fo were corrected
6. When the pauses, vowel duration and fo were corrected.

Thus, it was seen that the correction of some of the suprasegmental aspects of the speech of hearing impaired only caused a samll increased in intelligibility. It was also observed that only correction of vowel duration alone was a beneficial effect on the speech intelligibility.

The present study is in agreement with the results of provious studies quoted in the literature (Lang, 1975, Osberger & Levitt, 1979; Maassen & Povel, 1984 a, b, 1985; Oster, 1985). These studies reported that artificial correction of temporal aspects and intonation contour of deaf speech only caused a small increase in intelligibility. Maasen & Poval (1985) and öster (1985) reported that correction of segmental errors alone caused a dramatic increase in intelligibility. (Intelligibility increased upto 66 % to 97 %).

Thus, on the basis of the results presented here, combined with those of some ealier studies (Obserger & Levitt, 1979; Maassen & Povel; 1984, a, b, 1985; Oster, 1985), we can conclude that no dramatic gain in intelligibility may be expected, if speech pathologiste succeed in training the heating impaired children to have better control over the suprasegmental aspects of the speech.

We can also suggest that the segmental corrections may be started first in the training programm 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 result, that is, how and to what extent these suggestions can be applied in practical speech training, aspecially in view of the high correlation between sgemental and surasegmental aspects in speech production, is a question that cand only be solved in practice". (Maassens & Povel,1985).

RECOMMENDATIONS

1. Similar study may be carried out for segmental corrections.
2. Similar study using sentences as speech materials may be carried out.
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 the relative impact on intelligibility of different types of speech errors and to develop an individualized program for speech improvement would be interesting.
5. A study of larger population with suggested modifications will be useful.

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* Original article has not been referred to.

APPENDIX -I

The eight bisyllabic words (VCV combination) used in the study :-

1. /a:ne/ ಆನೆ
2. /ill/ ಇಲಿ
3. /u:ta/ ಊಟ
4. /ele/ ಎಲೆ
5. /e:lu/ ಏಳು
6. /ondu/ ಒಂದು
7. /o:le/ ಓಲೆ
8. /emme/ ಎಮ್ಮೆ