SYNTHESIS OF SPEECH OF THE HEARING IMPAIRED

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This work is sincerely dedicated to Suri, Jaya and Mahesh for their everlasting love and understanding.

CERTIFICATE

This is to certify that the dissertation entitled

SYNTHESIS OF SPEECH OF THE HEARING IMPAIRED

is the bonafide work in part fulfilment for the degree of Master of Science [Speech & Hearing], of the student with Register No. M 8702

Director
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CERTIFICATE

This is to certify that this dissertation entitled

SYNTHESIS OF SPEECH OF THE **HEARING IMPAIRED**

has been prepared under my supervision and guidance.

DECLARATION

This dissertation is the result of my own study undertaken under the guidance of Dr. N.P. Nataraja, Reader and Head Of the Dept. of Speech Sciences, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any University for any other Diploma or Degree.

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CONTENTS

CHAPTER 1

INTRODUCTION

Speech has been for a long time the source of curiosity to human beings. This is because speech is always considered a powerful medium of communication. The ability to speak is closely related to one's ability to hear. One of the devastating effects of congenital hearing loss is that normal development of speech is often disturbed. According to Monsen (1978), though speech reading can compensate to a large extent for the loss of hearing in so far as speech reception is concerned, no comparable skill exists in the hearing world to compensate for an inability to produce ordinarily intelligible speech, many factors like residual hearing, segmental errors, suprasegmental errors have been correlated with impaired individuals.

The studies which try to correlate speech errors and intelligibility among hearing impaired can be divided into two main categories:

1. Studies in which hearing impaired children receive intensive training for the correction of errors and,
2. Studies in which the errors are corrected in hearing impaired children's recorded samples using modern signal processing techniques. The latter technique is also often referred to as speech synthesis.

Dorman and Hannley (1985) also suggests this as one of the major and recent development in the area of speech science which has some crucial advantages over the other methods of studying speech intelligibility among deaf speakers. According to them, in speech synthesis, speech signals can be created in which the spectral, temporal and intensity characteristics vary independently. This, in principle, allows investigators to separate the relative contribution of the various parameters to overall speech intelligibility.

A second attraction is, that speech signals can be varied on a particular physical dimension keeping other parameters constant.

There have been quite a few studies in the west using speech synthesis as a major tool. Some of them are by, Bernstein (1977), Dorman and Hannley (1985), Huggins (1978), Lang (1975), Massen and Povel (1979, 1985), Osberger and Levitt (1972).

Studies by Lang (1975), Osberger and Levitt (1979), Mason and Povel (1984), Oster (1985) and Sheela (1988) reveal that correction of some suprasegmental features brings about only a small increase in intelligibility. It has also been reported by Sheela (1988) that correction of pause and vowel duration decreases the intelligibility of speech of the hearing impaired.

In Indian context only one study by Sheela (1988) has been done. Her study was aimed to determine the relationship between some suprasegmental errors and intelligibility of the hearing impaired children's speech, by correcting the vowel duration, pauses and fundamental frequency. She found that there was improvement in intelligibility with correction. However, she found the intelligibility became poor when both vowel duration and pauses were corrected in the same speech sample, than when only one of them was corrected. Therefore it was considered interesting to explore the of variation in vowel duration on intelligibility along with correction of pauses in the speech of the hearing impaired.

AIM OF THE STUDY:

This study was aimed to investigate the relationship between the suprasegmental errors and speech intelligibility of the deaf speakers. Two aspects of suprasegmental errors which were considered here were:l. Presence of pause in the deaf speech and 2. Vowel duration in the deaf speech.

These were compared with normals and corrections were made wherever necessary and their effect on intelligibility was found out.

HYPOTHESIS 1 :

There is no significant differences in the normal hearing and hearing impaired children utterances in terms of, a) Vowel durationb) Intersyllabic pauses, and c) Total duration of words.

HYPOTHESIS 2 :

There is no significant difference between the intelligibility ratings of unaltered utterances and corrected utterances.

A) Correction of vowel duration : There is no significant differences between the intelligibility scores of unaltered utterances and the utterances where the vowel durations alone have been corrected.

B) Correction of pauses : There is no significant differences between the intelligibility scores of unaltered utterances and the utterances where the pause (intraword) have been corrected.

C) Correction of vowel duration and pauses : There is no significant differences between the intelligibility scores of unaltered utterances and the utterances where the vowel durations and pauses have been corrected.

D) Correction by varing vowel duration after correcting pauses: There is no significant differences between the intelligibility scores of utterances with different conditions of the vowel durations pauses being corrected.

Implications of the study :

1. The study would help in better understanding of speech of the hearing impaired.
2. The study would provide more information regarding the effects of correction of vowel duration and pauses on the intelligibility of the speech of hearing impaired.
3. The information so obtained from this study would help in planning and developing therapy which are directed towards improving the intelligibility of the speech of the hearing impaired.

CHAPTER - II

REVIEW OF LITERATURE

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

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

" 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 the 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 makes speech possible. Thus, hearing controls speech and without hearing speech fails" (Whetnall and Fry, 1964).

" The auditory pathway is the natural and most effective way to learn speech and language, in addition to providing all the other auditory information from our environment such as, music, doorbell, bird song and so on" (Pollack, 1971).

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

Several have reported the effect of hearing loss on acquisition and maintenance of speech. Hearing impairment has a marked effect on the child's ability to acquire speech. The orderly and seemingly natural development of speech language and communication is interfered by the presence of hearing loss (Stark, 1979; Chermaks, 1981).

The deaf is faced by a doubly severe communication handicap. Normal speech is unintelligible to him and as a result of lack of auditory feedback of his own speech production he has considerable difficulty in learning to speak correctly (Levitt et al., 1974; Cowie & Cowie, 1983).

One of the most recognized but probably least understood concomitants of deafness is a deficit of oral communication skills. The speech produced by many deaf persons is frequently unintelligible to even experienced listeners. Moreover, it is frequently difficult to determine the exact

nature of speech errors that reduce the speech intelligibility. Without a clear understanding of the underlying and nature of unintelligible speech of deaf, the development of effective clinical strategies is limited (Metz et al.,1982).

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

It is important to ensure that, hearing impaired children develop effective spoken language skills from early infancy (Ling, 1976).

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

It is clear from the results of diligent specialized teaching that the difficulty in the oral production skills, in principle, can be overcome. Levitt et al (1974) write that " however, only few deaf individuals attain a speech quality that is adequate for normal conversation. Many more deaf children could be trained to speak proficiently if we had greater insight into the essential problems. For example, much could be done to improve the efficiency of speech training programs if more was known about how errors occur or combination 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 et al, 1985) acoustic (Monsen, 1974, 1976a, 1976b, 1978, Angelocci et al, 1964; Gilbert, 1975; Mc Clumpha, 1966; Calvert, 1962; Shukla, 1985; Rajanikanth, 1986) and perceptual methods (Levitt, 1976; Stevens et al, 1983; Hudgins & Numbers, 1942; Mangan, 1961; Nober, 1961; 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 non-invasive, relatively basic with regard to instrumentation, may be used routinely depict changes in the physical characteristics of frequency, intensity and the duration of speech segments (Leeper.et.al.,1987). Acoustic analysis of speech of hearing impaired permits a finer grain consideration of some aspects of both correct and incorrect productions than would be possible using methods applied in the subjective procedures (Osberger & McGarr, 1982). It provides objective description 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 normal hearing children and the effect of the various errors and abnormal speech patterns on the intelligibility (Parkhurst & Levitt, 1978). Thus the analysis of the speech of hearing impaired becomes important.

Intelligibility of speech of the hearing impaired :

"Speech intelligibility refers to how much of what a child says can be understood by a listener" (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. (Boothroyd, 1985).

Inspite of the recent advances made in the areas of speech, education ands 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 speech is poor, only about one in every five words they say can be understood, by a listener who is unfamiliar with the speech of this group." On the other hand Metz et al (1982) are of the opinion that the speech produced by many deaf persons is frequently unintelligible to even experienced listeners.)

Recent studies (Brannon,1964; Maskids,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% if prelingually deaf children with hearing losses of 90dB or more have speech classified as "barely intelligible "or worse. The speech of hearing impaired children is usually less than 30% intelligible " (Ling,1976).

Hudgins & Numbers (1942) studied the speech intelligibility of 192 hearing impaired subjects of 8-19 years of age. A group of experienced listeners heard the speech samples (sentences) of the hearing impaired and wrote down whatever was understood by them, the mean score for the group was found to be 20%. Brannon (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 at least normal intelligence and had no known additional handicaps, he found only 20 - 25% of words in their practiced speech intelligible to listeners unfamiliar with hearing impaired children's 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.

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

According to smith (1972) who studied 40 hearing impaired children in the age groups 8-10 and 13-15 years word intelligibility, as assessed by 120 listeners unfamiliar with the speech of 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 Frisina 1961; Angelocci,1962; John and Howarth,1965; Montgomery, 1967; Toback, 1967; Braverman,1974; conrad, 1976; Kyele, 1977).

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

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 methodology employed and the heterology of the samples studied.

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

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

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

Several factors have been found to affect the intelligibility of speech. According to Subtelny (1977) the speech intelligibility is the single most practical index of hearing impaired persons oral communication abilities. But

she cautions that intelligibility assessment cannot be used with confidence for training purposes without the knowledge of the properties of speech that influences intelligibility. Stevens et al (1978,1983) reinforced this notion, who suggested that the fudamental 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; Nickson 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 residual hearing (Montgomery, 1967; Elliot, 1967; Boothroyd,1969; markides, 1970, Smith,1975; Kyle, 1977; Monsen,1978;stoker and lape, 1980, Ravishankar,1985)lip reading (Stoker & lapel980) and tactile perception (Stoker and Lape, 1980)abilities have been studied. The results have indicated that residual hearing ability shows the maximum correlation with the speech intelligibility.

On the production side speech intelligibility has been studied with relation to segmental and suprasegmental errors. Errors involving individual speech phonemes, i.e.,segmental errors have been studied in depth by number of researchers (Hudgins and Numbers, 1942; Nober, 1963; Mrakids, 1970; Smith, 1973,1975a; Monsen, 1977; Brannon,1966; Gold, 1978 McGarr, 1980; Ravishankar, 1985; Levitt et al., 1974;etc). According to these studies there is a high negetive corrilation 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 impaired have supported the findings of the above mentioned studies. (Calvert, 1961; Monsen, 1974; 1976 a,b,c; Rothman, 1976). Both consonant and vowel erros have long been recognised in the hearing impaired.

Consonant errors include :

- Voicing errors
- Substitution errors
- Omission errors

Vowel and dipthong errors include :

- Substitution errors
- Neutralisation 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 (1942), 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 consonant, voiced-voiceless cofusion, and errors involving compound consonants had most detrimental effect on speech intelligibility. Substitution errors, nasality errors, omission of final consonants and errors involving abutting 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), examined the relationship between intelligibility and four acoustically measured, variables of consonent production, three acoustic variables of vowel production and two measures of prosody. The three variables were highly correlated with intelligibility they were:

1. the differance in VOT between /t/ and /d/
2. the differance in 2nd formant location between /i/ and /I/ and 3. acoustic characteristics of the nasal and liquid consonants.

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

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 aspects include the contour of fundamental frequency versus time, the durations of certain of the speech events and pauses and the assignment of relative prominence or stress to different syllables. (Stevens.et.al., 1979).

Although much attention has been given to the segmental errors made by the deaf, it has long been recognised 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 (1942), reported that those utterances marked by faulty rhythm (55% of all utterences) accounted for only 26% of all of the intelligible sentences read by their deaf subgects. However, the remaining utterances which were charecterized by good use of rhythm, regardless of whether there were numerous articulatory errors accounted 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 factorslike 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 intelligibilty.

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 normal speakers. (Rawlings, 1935; 1936; Voelker, 1938; Calvert, 1962; Boone, 1966; Brannon, 1986; Hood, 1966; Martony, 1965; 1966; Calton and Cooker, 1968; Boothroyd.et. al., 1974; Wickerson.et.al., 1974).

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 166.4 words/minute for the 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; Voelker, 1935;1938).

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

According to Stathopolous, Duchan, Sonnenmeirer & Bruce (1988), intonation and timing in deaf speech have not been studied to the same extent as they have been in the speech of normal hearing persons, even though it is apparent that deaf speaker have abnormal intonation and timing patterns.

Some researchers emphasize on the duration of utterances in the speech of hearing impaired, as being longer in duration in comparison with that of normal hearing speakers. (Hood and Dixon, 1968; Voekler, 1938 and Dickerson, 1975). The increase in duration results from the lengthening of phonemes and therefore the syllables (Calert, 1962 ; Mason and Bright, 1937 ; Rothman, 1976, 1977 and Hood and Dixon 1969).

Other researchers view the speech timing of the deaf speakers as not merely slowing down of normal pattern but rather as qualitatively different. For example Audo and Canter (1969), found that deaf speakers produced only stressed syllables. Similarly, m the deaf speakers studied by Osberger and Levitt (1979), failed to adequately distinguish between stressed and unstressed syllables, and Mc Garr and Harris (1983), found considerable variability in intensity, f_o and duration of their deaf subjects production of both stressed and unstressed syllables. The existence of pauses between words also support the difference argument, since normal speakers do not typically exhibit such pauses (Rochester, 1972).

The study by stathopoulos. et.al., (1988) also confines the notion of longer duration of utterances among the hearing impaired as also the presence of pauses.

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 speech message.

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

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

Vowels are longer in the precence of voiced stops and continiuants (House and Fairbanks, 1953; Denes, 1955; Raphel, 1972; Peterson & Lehiste, 1960; Lindblom, 1968; Disimoni, 1974a,b). This lenthening of the vowel contribute to the perception of the consonants. Schwartz (1969) also noted that consonant duration was lengthened when the post consonant vowel was /i/ no matter what the proceeding vowel (in a VCV utterance). Unfortunately, however, the duration of phonemes 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 & Howrath, 1965; Hoone, 1966; Levitt et al.,1974; Parkhurst & Levitt, 1978). " The prolongation of speech segments such as phonemes, syllables and words are often present in the speech, of the hearing impaired " (Osberger & Levitt, 1979; Osberger & 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 rewsult of this study showed that hearing impaired speakers extended the duration of vowels, fricatives and the closure period of plosives upto five times the average durations for normal speakers.

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

Monsen (1976), studied twelve deaf and six normal hearing adolecents as they read fifty six CVCs containing the vowels /i/ or /I/. He found that the deaf subjects tended to create mutually exclusive durational classes for the two

vowels such that the duration of one vowel could not approximate that of the other even when they occured in the presence of different consonants. For the normal subjects, theduration of /i/ was always longer than /I/ for a particular consonant environment, but the absolute durations of the two vowels could overlap if the acompanying consonants differed. Thus, although the vowels produced by the deaf subjects were distinct in terms of duration, they were still less intelligible since the listener could not rely on normal decoding stategies to interpret the speech that was heard.

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

Whitehead and Johns (1979), noted that vowels were significantly longer in duration in a voiced than in a voiceless consonant environment and were longer in duration in a fricative than a plosive consonant environment. However, unlike normal speakers they found that, the hearing impaired speakers produced longer /s/ segments in the /a/ vowel environment than /i/ environment.

Osberger and Levitt (1979), observed that sylabble prolongaton in speech of the hearing impaired was primarily due to prolongation of vowels. Duration of vowels, glides and nasals were longer in speech of the deaf children. On the other hand the duration of fricatives, affricates and plosives were found to be shorter in deaf subjects.

" The hearing impaired fail to produce appropriate modification in the vowel duration as a function of the voicing charecterestics of the following consonants" (Calvert, 1961; Monsen, 1974). " Hence, the frequent voice-voiceless confusion observed in their speech may actually be due to vowel duration errors" (Calvert, 1961).

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 symmetrical(?) vowel /a/ - obstuent /p/ vowel /a/ formant. The stimuli were in three utterance contexts of increasing length ; i.e.,/apa/, /apa saw apa/, /apa saw apa with apa/.

The results showed that hearing impaired children took significantly longer time than their controls to produce syllables. In addition, there was a numerical trend for the

first word like utterance in the phrase to be shorter than 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 charecteristics of initials final vowel in the /apa/ utterences showed that the hearing impaired children had significantly larger durations on both positions of the syllable than did their controls for the normal hearing children the initial vowel in the VCV utterance was significantly shorter in the first word than in subsiquent initial vowels in the sentence like frames of increasing lenth 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 utterences for the normal hearing children. The hearing impaired children did not show a significant systematic shortening of the initial vowel in the syllabic productions for either three or five word like utterence length. The only trend that was noticeble for the hearing impaired children was for the length of the initial vowel in the sigle word repition event to be longer than all other initial vowels in the other utterence length task. Similarly, the hearing impaired children dmonstrated significantly longer durations of the final vowel in the /apa/ syllable during alterations of utterence lengtth, when compared with their normal controls.

"The hearing impaired children showed a significantly longer vowel duration, as compared with normals." Rajnikanth (1986), and Shukla (1987),compared vowel duration and consonent duration in thirty normal and hearing impaired individuals who were matched for age and sex. The results showed that -

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

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

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

d) In normally hearing speakers the mean duration of the vowels /a/, /i/ and /u/ in the final position, i.e., preceded by differen consonents were aaround 200msecs, 195msecs and 185msecs, respectively. In the hearing impaired speakers /i/ and /u/ tended to be longer than in normal speakers and the vowel /a/ tended to be either longer or shorter when compared to the length of the vowel /a/ in normal speakers.

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

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

g) There was a vowel lenthening phenomenon in Kannada language. (" vowel lenthening phenomenon is the final syllable vowel durational increment of 100 msec 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 preceding consonents.

i) In both the groups of subjects durations of consonants were longer in vowels /i/ and /u/ enviornments than in the vowel /a/ enviornment.

j) In both the groups velar sounds tended to be longer than bilabial consonents 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. Whereas, in the speech of the hearing imparied the durational difference between voiced and voiceless consonants was cosiderably reduced.

1) 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 hearting 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 showeda greater variation in controlling the length of all the consonants thn normally hearing speakers.

The factors leading to or related to particular difficulties with timing ofspeechevents, prolonging them and producing apparently high variability of timing in the speech of the hearing impaired are not known. However, one possibility is that tjey depend heavily upon vision and that vision simply does not operate in as rapid a time as audition (Carlson, 1977; Ganong, 1979). Another possibility is that auditory feedback us necessary for rapid smooth production of complex motoric sequences of speech (Lee, 1950) and that hearing impairement limits the necessary information too severly, 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 Englesh, changes in cotrastive stress have been found to produce systematic changes in vowel duration. When the same vowels are unstressed syllables, the proportional shortening is smaller,on the average in the speech of the hearing impaired than in the speech of the normal subjects (Osberger, Levitt, 1979; Stevens et al, 1978). In contast to this Reilly (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 pholnemes is that the hearing impaired speakers fail to make the difference between the durations of stressed and unstressed syllables sufficiently large (Angelocci, 1962; Nickerson et al, 1974). Although they prolong, the duration of both stressed and unstressed syllables, the increase tended to be proportionally greater for the unstressed sounds. Hearing speakers lengthen stressed syllables and syllables in word final and sentence final positions (Fry, 1958; Klatt, 1974).

Nickerson et al.,(1974) found that the deaf children fail 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 91962) reported that the durations of the unstressed vowels produced by deaf speakers were 4 to 5 times longer than those of normal sprakers. Durational increase for stressed syllables also has been reported (John & Howarth, 1965).

Osberger and Levitt (1979), found that the mean duration ratio for stressed 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 unstressed vowels is shorter than the duration of stressed vowels in the speech of the deaf children, the proportional shortening of unstressed vowels iss 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 unstressed 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 imprired 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 consonent vowel syllables. (Boone, 1966; John & Howarth, 1965). As a result, a lack of differentiation between the length of stressed and unstressed syllables contributes to the perception of improper accent in the speech of the hearing impaired. (Gold, 1980).

Several investigators have reported that the word duration itself has been found to be excessive in the speech of the hearing impaired. (John & Howarth, 1965; Osberger, 1978). Electromyographic data have supported these findings (Huntington et.al., 1968). 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 et. al., 1968).

The way in which the hearing impaired speakers use temporal manipulations to convey differnces in syllabic stress pattern is not clear. Mc Garr and Harris (1980), found that even though intended stressed vowels were always longer

than unstressed vowels in the speech of one profoundly hearing impraired speaker, the intended stress of 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 freqency would be a likely alternative, but McGarr and Harris (1980) also found that while the hearing impaired speaker produced the systematic changes in the fundamental frequncy associated with syllable stress, perceptual confution involving stress pattern were still observed. (Osberger & 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 movements or the rapid transition from one articulatory position to another 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. (Valvert, 1961; 1962; Angelocci, 1962; John & Howarth, 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, the deaf child intentionally omits sounds.

Other kinds of transitional problems reported include the timing of voice onset relative to the release of voiceless stops (Angelocci, 1962), defective timing during the onset of nasalization for nasal consonents (Stevens et. al., 1976) and during the end of nasalization of nasal consonents. (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 syntctic boundary, it is longer in duration than when it occurs in other positions in a phrase (klatt, 1975). It has been observed that hearing imaired speakers do not always lengthen the duration of the phrase final syllables relative to the duration of the other syllables in the phrase. (Osberger and McGarr, 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 differencees between the duration of syllables in the prepausal and nonprepausal position in the samples produced by the hearing impaired children.

Pauses:

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 et al., 1978).

Pauses may be inserted at syntactically inappropriate boundaries such as between two syllables in a bisyllabic word or within phrases. (Osberger & Mc Garr 1982).

Stark & Levitt (1974), reported that the deaf subjects tended to pause after every word and stress almost every word. Oral readings of sentences specially designed to test the use of pause and stress were analysed in this study. According to John & Howarth (1965), the silences between words seen in the speech of the 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 produce 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 & Levitt (1979), reported that there was no evidence of within phrase or within sentence pauses in the utterences produced by the normal hearing speakers. The deaf children paused frequently within a phrase and they often inserted pauses between syllables in bi-syllabic words. The mean number of pauses per sentence was 5.7 in the deaf children's 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 excessive and inappropriately placed pauses is that of poor rhythm. The inappropriate use of pauses along with the timing errors lead to the perception of improper grouping of syllables and thus contributes to the poor rhythm perceived in the speech of the hearing impaired (Hudgins, 1946; Nickerson et.al., 1974).

The results of the studying Hudgins (1934, 1937, 1946) suggested that the frequent pauses observed in the speech of the hearing impaired may be the result of poor respiratory control. The results showed that deaf children used short, irregular breath groups often with only one or two words and breath pauses that 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 & Hizon (1977) confirmed this from their study. THey found the muscle activity to be normal for deaf individuals during quiet breathing but noted that yhey do not take enough air while breathing for speech. Thus, hearing impaired children distort many temporal aspects of speech. These distortions, excessively prolonged speech segments and the insertion of 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 be a great 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 of the hearing impaired can be recognised easily. However, the charecteritics that contribute to this perceived deviation are difficult to characterize (Nickersory, 1975).

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 (Hundgins, 1937, Stevens, et. al., 1978).

Velar control:

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

Improper control of the velum has long been recognised 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 for the hearing impaired children because:

1. raising and lowering movements of the velum are not detectable via lipreading and
2. the activity of velum produces very little proprioceptive feed back (Nickson, 1975).

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; McClumpa, 1966; Stevens et.al.,1976), inappropriate timing of the opening and closure gestures of the velum (Stevens et,al.,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 for 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 the hearing impaired is due to the perceived resonance brought about in the pharengeal region by an inferiorly retracted tongue position during speech and not due to velopharengeal incompetency. Miller (1968), 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 (Marony, 1968; Miller, 1968; Carhart, 1970). Many of these studies have shown the occurrence of inappropriate loudness in the speech of the hearing impaired. Further abnormal variations in loudness have also been reported.

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

Ravishankar (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 segmantal errors and speech intelligibility:

Suprasegmental competence once acquired become 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; Geers 1978).

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

Suprasegmental errors also noted to be detrimental to speech intelligibility. Some investigators have attempted to correlate speech intelligibility with suprasegmental errors. (Hudgins and Nambers, 1942; John and Howarth, 1965; Levitt.et.al., 1974, Smith, 1975, Mc Garr. et.al., 1976, Parkhurst and Levitt, 1978 ; Monsen 1979 ; Ravishankar, 1986, Metz, et al., 1985).

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

1. Correlational studies.
2. Causal studies i.e., studies that attempted to determine the cause and effect relationship. These types of studies can be subdivided into two major categories :

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

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

Correctional 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 F_o. For (Osberger and Mc Garr, 1982). they found that sentences spoken with correct rhythm were substantially more intelligible than those that were not. The correlation between speech rhythm and intelligibility was 0.73. The other

correlational studies have shown a moderate negetive correlation between excessive prolongation of speech segments and intelligibility (Monsen and Leiter, 1975, Parkhurst and Levitt, 1978).

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

Reilly (1979), found that relative duration (stressed : unstressed syllable nuclii duration ration) 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 positive 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 intelligibility.

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, hyper 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 and Mc Garr, 1982).

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

Heddinger (1972), also reported similar result 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 corrected and the results of a similar study by Boothroyd, et.al., (1974) were equivocal.

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 is that the training may result in changes in the child's speech other than those of interest. In addition to this, the effect of phoneme production and of prosodic feature production upon intelligibility have not been separated sufficiently in these studies (Osberger and Mc Garr 1982).

Recent investigation have attempted to eliminate this confounding variables by using computer processing techniques. In such studies, speech is either synthesized with timing distortions, (Lang, 1975, Hudgins, 1977 ; Bernstein, 1977) or synthesized versions of the speech of the hearing impaired are modified so that the errors (timing or pitch and intonation errors) are corrected selectively. (Osberger and Levitt, 1979 Maassen and 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 such documentation

of the kinds of segmental 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 be able to identify those errors to occur most frequently in the speech of the deft, 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 improve speech production in the hearing impaired children".

During the last Years the studies have gradually been more concentrated on the relation between speech errors and the naturalness and intelligibility of speech with the aim to improve 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 that are seen in the training studies (Osberger and Levitt, 1979).

In digital manipulation techniques it is easy to correct errors in the time domain (suprasegmental) but more difficult to correct segmental errors (Hudgins,1977; Kruger 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 timing distortions in the samples of normal speakers. Minimal improvements intelligibility were observed for the speech of the hearing impaired, and minimal decrements in intelligibility were observed for the normal speakers.

Berstein (1977), found no reduction in the intelligibility of speech samples produced by a normal speaker when normal speech was synthesized with the durational relationship between stressed and unstressed syllables reversed there was 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

namely, relative timing, 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 deviant timing patterns in the speech of six deaf children. They were l. Original, unaltered sentences. 2. Correction of pauses only. 3. Correction of relative timing. 4. Correction of absolute syllable duration. 5. Correction of relative timing and pauses. 6. Correction of - absolute duration and pauses. An average improvement intelligibility was observed only when relative timing errors alone were corrected. The. second highest intelligibility score was obtained for the original, unaltered sentences. The intelligibility scores obtained for the other four forms of timing modification were poorer than those obtained for the original sentences, on the average. However, the improvement was very small(4%). Since the timing modification 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 detrimental effect on intelligibility" (Osberger & Mc Garr, 1982).

Maassen & Povel (1984), 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 30 sentences. Here, each phoneme got the same relative duration,as the corresponding phoneme in a normal utterances. Improvement in speech intelligibility was 11% to 17% when syllabic relative correction was done (for 8 sentences 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 & 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 sound, temporal structure, and intonation were carried out on 30 Dutch sentences spoken by ten deaf children. The transformed sentences were tested for intelligibility and acceptability by presenting them to inexperienced listeners. A complete segmental correction caused a dramatic increase in intelligibility from 24% to 72%, which for a major part, was due to correction of vowels. The correction of temporal structure and intonation caused only a small improvement from 24% to 34% combination of segmental and suprasegmental correction yielded almost perfectly understandable sentences, due to a more than additive effect of the two corrections. Quality judgements were in close agreement with the intelligibility measures. "The results show that, in order for these

speakers to become more intelligible improving their production temporal structure and intonation " (Maassen & Povel, 1985). Oster (1985) took speech samples from three deaf children and analyzed them individually to find errors in vowels, consonants and prosody. Based on this analysis, a phonetic system from 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 be used to establish the relative impact on intelligibility of different types of speech errors and to develop an individualized program for speech improvement. The individualized program suggested for the three deaf children imply that the segmental errors and then the suprasegmental errors. The segmental error correction will improve the intelligibility upto 66% to 97%.

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

Osberger & Levitt (1977), write "To this date, there have been studies of this nature (studies using computer processing techniques) 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".

In an earlier study conducted by sheela(1988), it was found that that the intelligibility decreased when both pauses and vowel durations were corrected, when compared to conditions where only pause or vowel duration was corrected. There is a relationship between the vowel duration and fundamental frequency i.e., as the fundamenal frequency varies the vowel duration has to be varied to keep the intelli gibility constant(Nataraja,1984). When the vowel duration is altered in the speech of hearing impaired, even though the intelligibility was expected to improve, it did not because of the interdependence and relationship between the same with fundamental frequnecy. An alteration in the vowel duration without variation in the fundamental frequency may not improve the intelligibility. Therefore, an attempt has been made here to find out the intelligibility by varying the vowel duration, after correction of pause, by 100 %,75 % 50% and 2 5 % towards the normal vowel duration. Thus the study is aimed at findingout the effect of correction of pauses and vowel duration, on in the speech of the hearing impaired,on intelligibility.

CHAPTER - III

METHODOLOGY

A. Subjects and test material:

Six children - three normal hearing and three hearing impaired - between 9 - 12 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 70 dB - ANSI 1969 in the better ear).
2. Had no additional handicap other than that directly related to the hearing impaired.
3. Were able to read simple bisyllabic (VCV combination) words in Kannada.

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

The test materials consisted of eight bisyllabic Kannada words (VCV). These words were chosen from the Kannada. Articulation Test (Bettageri, Rathna, Babu, 1972) which is used with the children of 3 years and above. Words were 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 using the tape recorder of the sound spectrograph (Voice Identification Icc.700 series) A National Panasonic taperecorder (Model RQ 2167) was used for perceptual judgement.

C. Recording procedure:

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 subjects mouth.

Acoustic Analysis:

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

The parameters which were taken for analysis were vowel duration, duration of the pauses (intraword - if any), total duration of the word. These were noted down for all the six children and for all the words [8 words each].

Statistical Analysis:

Descriptive statistics consisting of mean, standard deviations, minimum and maximum value, were obtained for all the 3 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 :

The parameters corrected were:

1) Vowel duration (both initial and final vowels)

2) Pauses, if any (intraword pauses)

All combinations of these three corrections were used. Thus, seven conditions of presentation were obtained altogether which included the unaltered speech samples of normal and hearing impaired group. They are listed as follows.

CONDITIONS OF SAMPLE PRESENTATION

Conditions	Samples
1.	Unaltered samples
2.	Samples with only pause eliminated
3.	Samples with altered vowel duration (100%)
4.	Samples with altered vowel duration (100%) with no pause
5.	Samples with altered vowel duration (75%) with no pause
6.	Samples with altered vowel duration (50%) with no pause
7.	Samples with altered vowel duration (25%) with no pause

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

Correction Procedures:

1. Correction of pauses only:

Since the normal hearing children did not show any within the word (inter syllabic) pauses, all the pauses were eliminated, from the hearing impaired children speech samples, if there were any. Care was taken to preserve the transition portions of the wave forms.

2. Correction of the vowel duration only:

Here, the vowel durations (both initials and 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 normal hearing group. Also the vowel durations of speech of hearing impaired were altered by 75%, 50% and 25% of the duration, so as to see their relative efffect on the intelligibility. For example, the 100 % duration which was excess for subject 1 when compared to the respective duration of the normal for vowel /a/, was 274.3 m.secs, therefore 75 %,50% and 25 % values which was altered were, 205.7, 137.15, 068.57 m.seconds respectively. Care was taken so that all the transition portions of the wave forms were not altered. The corrections was done only in the stable portions of the wave forms.

Thus a total of 176 words were obtained for perceptual judgement.

Re-recording the speech samples:

The unaltered and altered speech samples were recorded on a cassette tape. There were 47 unaltered utterances and 119 altered utterances. 10 utterances (consisting of both altered and unaltered samples) were added as check words to test the intra judge reliability. All the 176 words were randomized so as to eliminate practice effect.

Measures of speech Intelligibility:

Three listeners were asked to listen to the speech samples and to write down 'the words that they have heard. (Word Identification task). They were also requested to rate the intelligibility of the words on a 3 point interval scale (intelligibility rating), from 1, denoting unintelligible to 3, denoting highly intelligible.

All judges were native speakers of kannada language.

There were two conditions:

a) No clues were given regarding the words used in the study (open set)

b) After step (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 correct identification by each judge in each category was converted into percentage of scores, as follows ;

$$\frac{\text{number of correct identification}}{\text{total number of utterances}} X\ 100$$

b) The intelligibility rating:

The rating made by majority of the judges was considered to be the intelligibility rate of that particular word. This was done for both open set and close 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 significant differences between unaltered and each type of altered sets under both open and closed set.

Inter judge reliability was checked using Pearsons rank correlation method.

The results were also analysed 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 check the intrajudge reliability using the words which were included for the same purpose.

Figures 1 to 6 show the wave forms of unaltered and altered speech samples of a hearing impaired child.

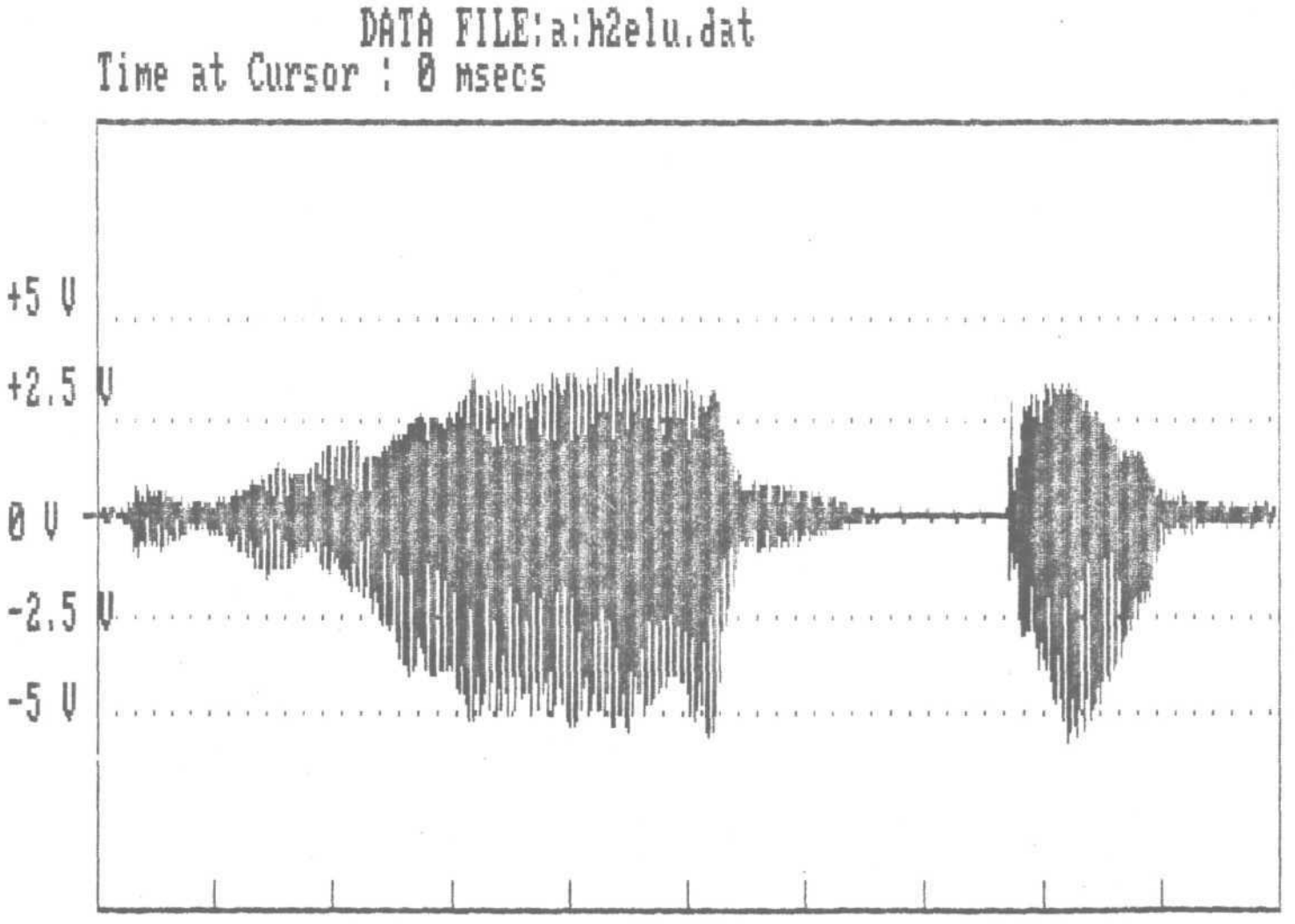

FIG 1 UNALTERED SPEECH SAMPLE OF HEARING IMPAIRED SUBJECT

WORD: /e:ɬu/

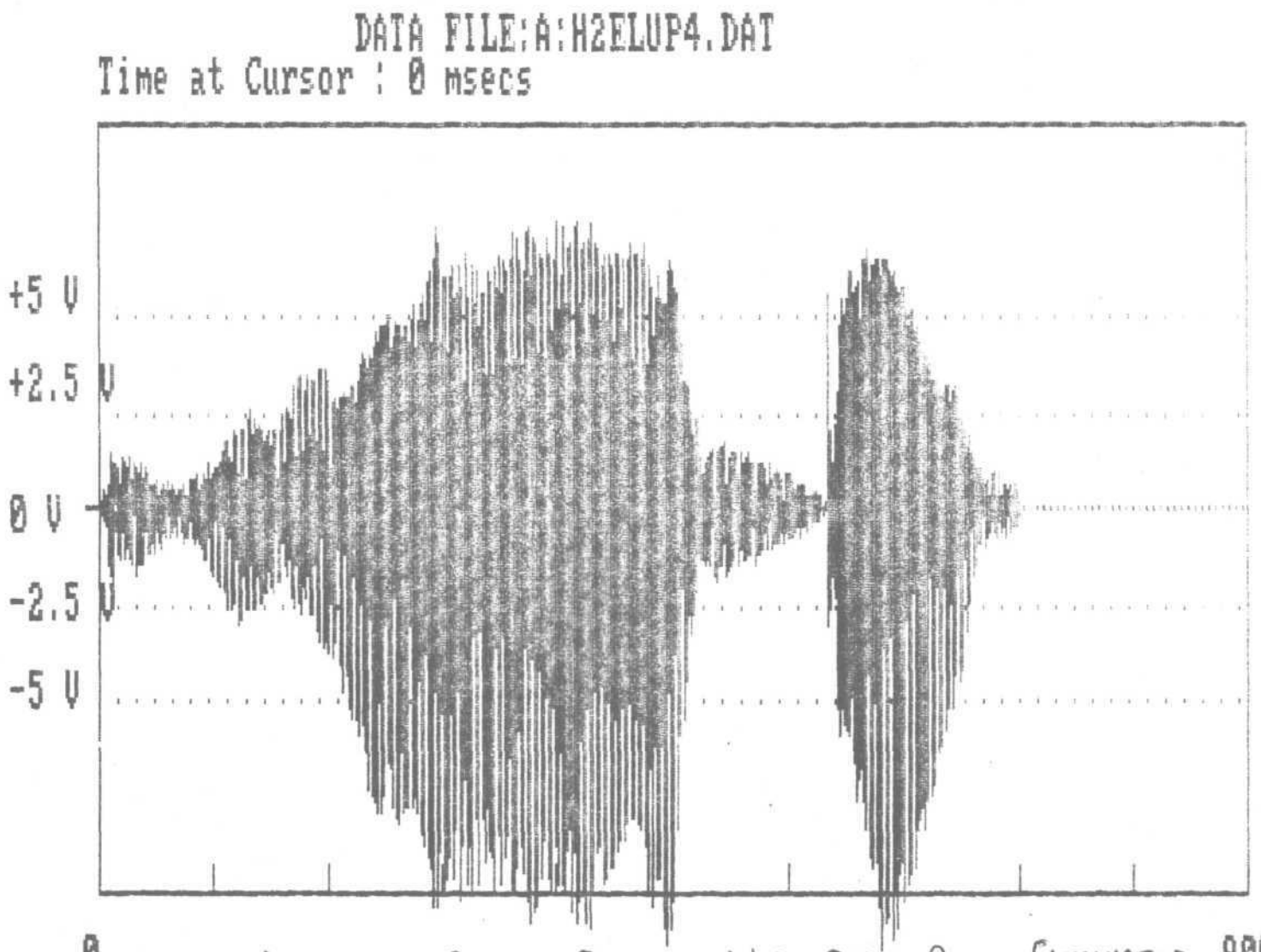

FIG 2 ALTERED SPEECH SAMPLE WITH ONLY PAUSE ELIMINATED.

WORDS /e:ɫu/

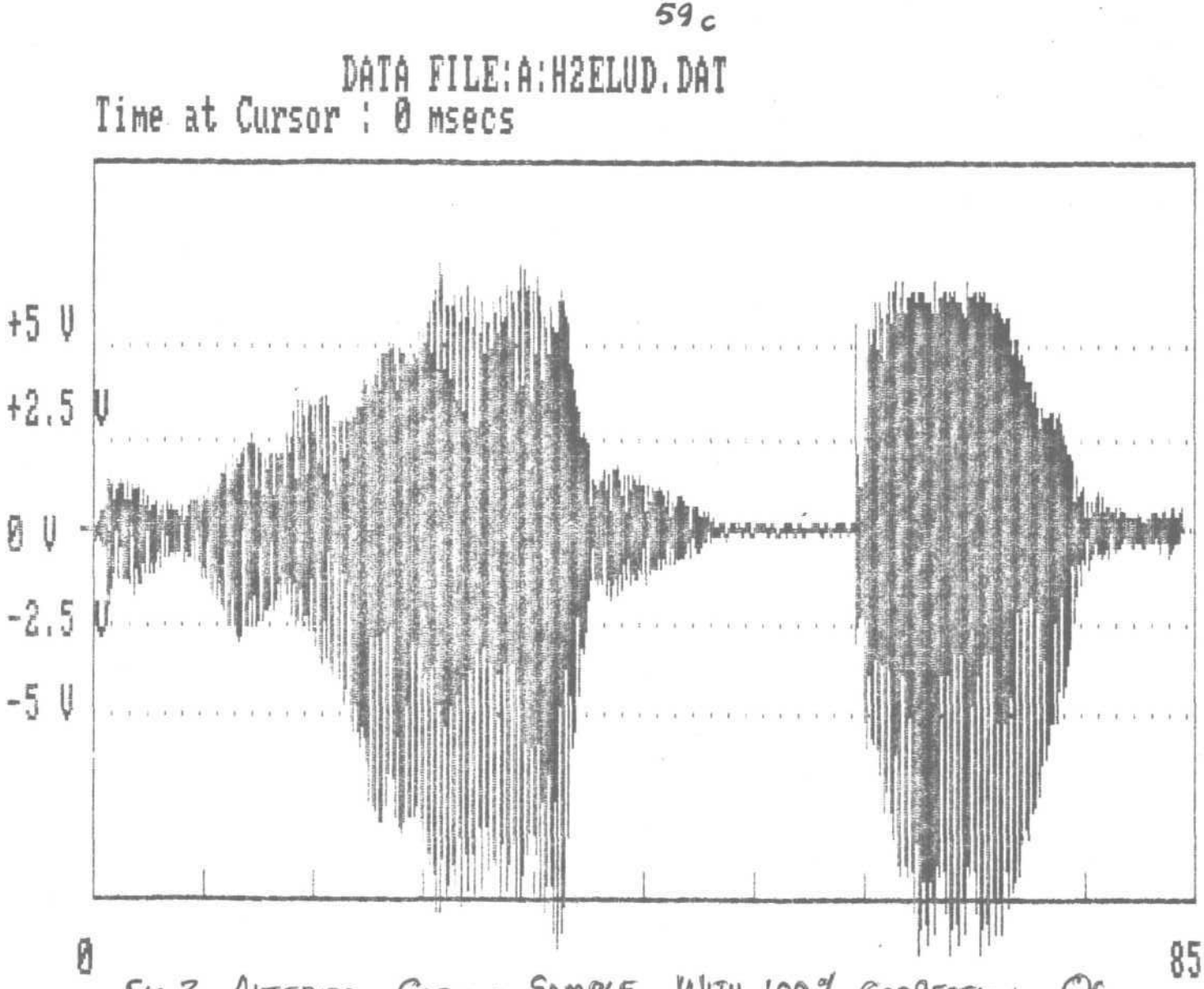

FIG 3 ALTERED SPEECH SAMPLE WITH 100% CORRECTION OF DURATION. WORD : /e:ɬu/

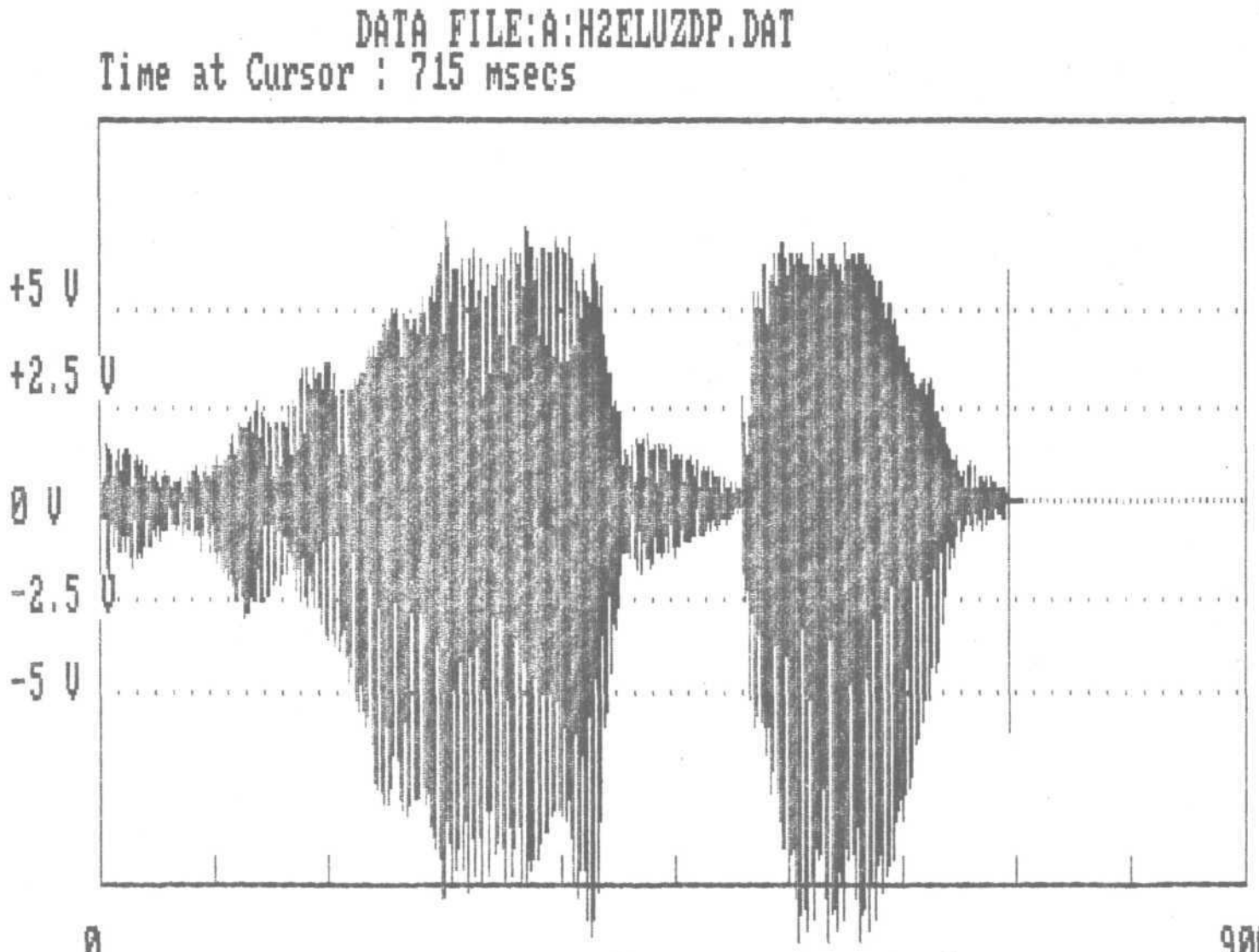

FIG 4 ALTERED SPEECH SAMPLE WITH 75% CORRECTION OF VOWEL DURATION AND ELIMINATION OF PAUSE WORD: /e:ɬu/

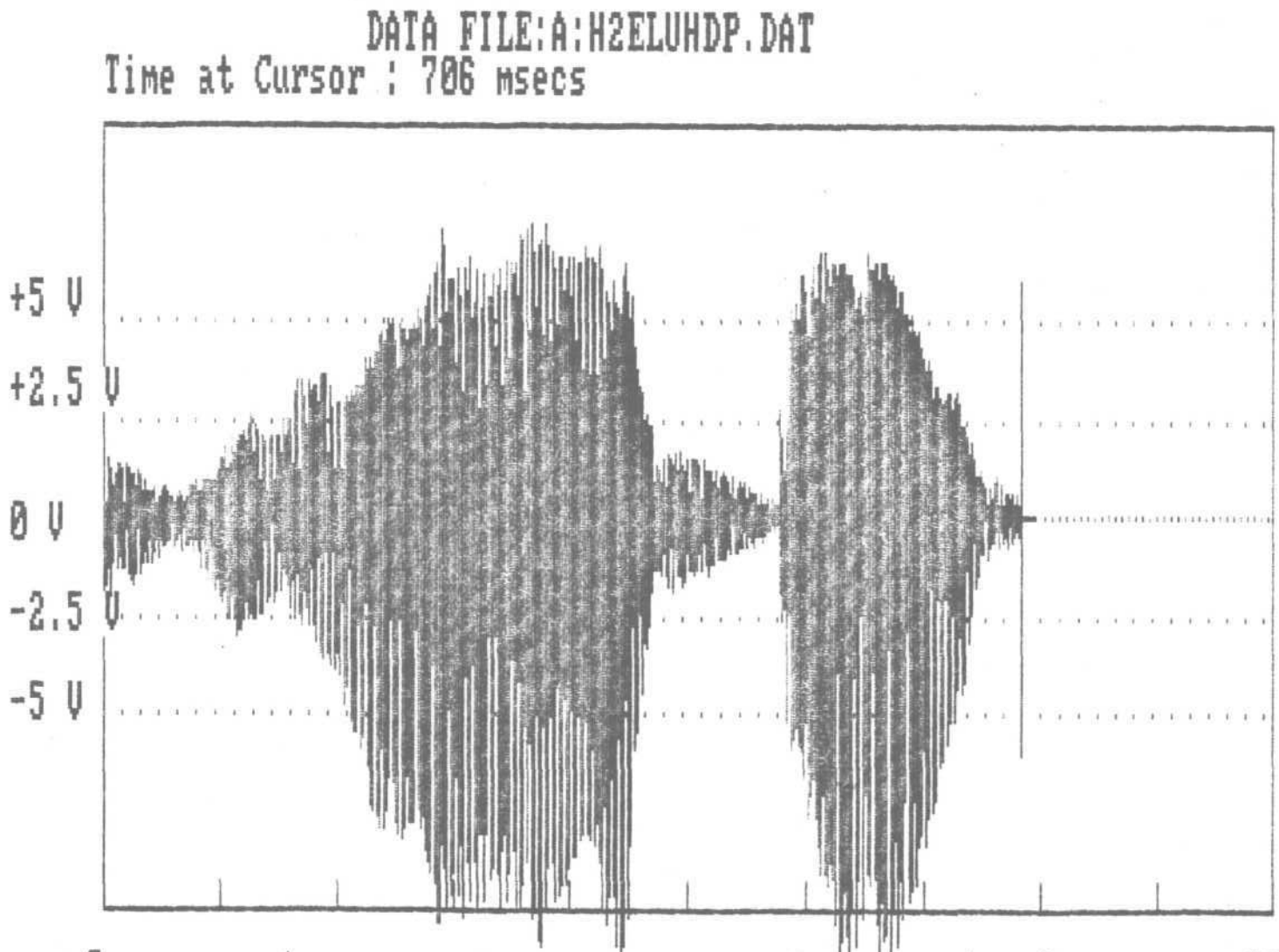

FIG 5 ALTERED VOWEL DURATION BY 50% AND ELIMINATION OF PAUSE. WORD: /ɛɫu/

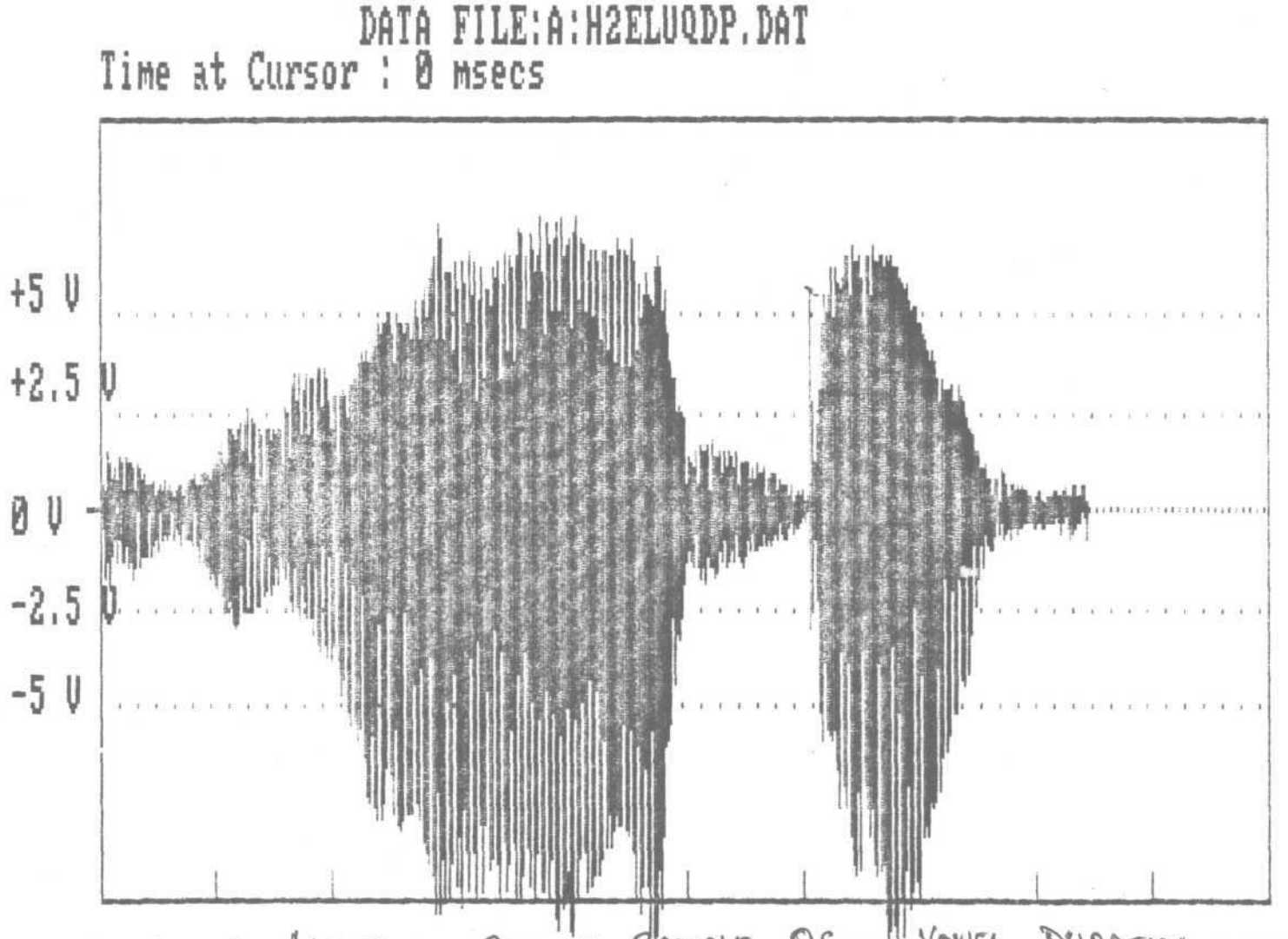

FIG 6 ALTERED SPEECH SAMPLE OF VOWEL DURATION CORRECTED BY 25% WITH ELIMINATION OF PAUSE. WORD : /ɛsɬu/

CHAPTER - IV

RESULTS AND DISCUSSION

The aim of the study was to investigate the relationship between suprasegmental errors and speech intelligibility of hearing impaired speakers. The study was carried out in three steps, viz., acoustic analysis, synthesis and perceptual judgement.

1. Acoustic analysis:

Here, the vowel duration (of initial and final vowels), pause duration (if any) and total duration of each vowel was analysis. The results of the acoustic analysis of vowel duration and pauses indicated the following:

Vowel duration:

On the average, the hearing impaired subjects had longer vowel durations when compared to normal hearing subjects. It was noticed that occasionally, in specific utterances, the vowel duration in the hearing impaired speakers were shorter than in normal hearing subjects. For example, / e:lu / of the hearing impaired subject 3 had a shorter final vowel (434.4 m.sec.) when compared to the corresponding normal hearing speakers utterance of / e:lu /. Tables 1 and 2 give the descriptive statistics of vowel durations in the initial and final position of words respectively for both normal and

hearing impaired subjects.

Table 1

Descriptive statistics of vowel duration in initial position.(For subjects of normal group)

Vowel	Mean	S.D	Range Minimum	Maximum
/ a:/	254.70	038.37	222.60	297.20
/ i /	114.23	044.30	082.70	165.00
/ u:/	234.46	055.67	198.50	298.60
/ e /	136.30	042.87	003.60	201.40
/ e:/	310.73	052.04	271.20	369.70
/ o /	273.06	263.14	113.70	576.80
/ o:/	343.90	105.30	229.30	436.40

(For hearing handicapped)

Vowel	Mean	S.D	Range Minimum	Maximum
/ a:/	357.60	232.80	108.60	571.50
/ i /	317.60	149.90	163.40	462.90
/ u:/	404.43	139.89	243.20	493.60
/ e /	167.50	056.19	08.80	241.10
/ e:/	414.30	141.34	254.60	523.50
/ o /	179.60	036.18	153.60	221.20
/ o:/	264.70	119.30	156.90	392.90

The inspection of the above table clearly indicates that the initial vowel in the speech of the hearing impaired had longer duration than the normals. Further the study of Table

-2, forces the conclusion that the duration of the final vowel in the utterances of the hearing impaired when compared to normals, was longer, similar to the initial vowel duration. The hearing impaired subjects have also greater variability of vowel duration, which is evident from Tables -1 & 2.

TABLE 2

Descriptive statistics of vowel duration in final position.(For subjects of normal group)

Vowel	Mean	S.D	Range	
			Minimum	Maximum
/ e /	218.17	037.92	183.10	278.80
/ i /	210.53	024.51	189.60	237.50
/ a /	171.90	037.65	130.00	202.90
/ u /	276.68	140.80	113.70	537.20

(For Hearing impaired)

Vowel	Mean	S.D	Range	
			Minimum	Maximum
/ e /	270.88	130.67	121.50	517.60
/ i /	330.80	153.49	228.50	507.30
/ a /	235.90	178.90	126.50	438.90
/ u /	227.90	122.05	122.50	434.40

Among the normal group /o:/ had the longest vowel duration in the initial position followed by /e:/, /o/, /a:/, /u:/, /e/ and /i/.

In the hearing impaired group, /e:/ had the longest vowel duration in the initial position followed by /u:/, /a:/, /i/, /o:/, /o/, and /e/. Similarly, the duration of final vowels when compared with normal, the hearing impaired subjects showed on an average /u/ as the longest final vowel followed by /e/, /i/ and /a/ than the normal hearing group.

For the hearing impaired group, /i/ had the longest final vowel followed by /e/, /a/, and /u/. It was also noticed that there was relatively a large variation in the duration of utterances of the hearing impaired when compared to normals, both in the initial and final vowels. The range of initial vowel duration in normals voice 82.70 m.secs. to 576.80 m.secs. In the hearing impaired group it was 108.30 to 571.50 m.secs. The values of final vowel duration ranged from 113.70 to 537.20 m.secs. in normals and 1 - 1.50 m.secs. to 517.6 m.secs in hearing impaired subjects.

Pause:

The utterances of normal hearing children did not show any inter syllabic pauses (or intra-word pauses). Out of three hearing impaired speakers, two showed intersyllabic pauses in almost all utterances. One subject showed pauses in /a:ne/, /ili/, /e:lu/, /o:le/ and /emme/, while the other showed in /a:ne/, /ele/, /e:lu/, /ondu/ and /emme/. The duration of pauses ranged from 18 m.secs. to 291.00 m.secs.

Total duration of words:

The words uttered by the hearing impaired subjects had longer word durations when compared to the normal hearing group. Table 3 gives a descriptive statistics of the total duration of words with their respective means and standard deviation. The finding that hearing impaired children had longer vowel duration when compared to the normal hearing group is in agreement with other studies by Angelocci (1962), Calvert (1962), John and Howarth (1965), Parkhust and Levitt (1978), Osberger and Levitt (1978), Rajanikanth, (1986), Sheela (1988), Shukla (1987) and Stathopoulous et.al., (1986).

According to Osberger and Lavitt (1979), the prolongation of syllables in hearing impaired speech was due to primarily the prolongation of vowels. The variability in duration in the speech of hearing impaired, which was found to be more when compared to normals has also been reported by Monsen (1974), Osberger (1978), Osberger and Levitt (1970), Rajanikanth (1979), Shukla (1987) and Sheela (1988). This study is also in accordance with them. The insertion of pauses by hearing impaired children which was found in this study has been reported by others also. (Boone, 1966 ; Boothroyd. et.al., 1974 ; Heidinger, 1972 ; Hood, 1966 ; John and Howarth, 1965 ; Stevens.et.al., 1978 ; Sheela, 1988). It has also been reported at the paused may be inserted at syntactically in appropriate places or boundaries such as

between two syllables in a bisyllabic word or within phrases (Osberger and Mc Garr, 1982). According to Hudgins (1946) the frequent pause which are observed in the speech of the hearing impaired could be due to poor respiratory control. Similarly to the findings of Leeper.et.al., (1987), it was found that the total duration of words were more in the speech of the hearing impaired when compared with normals. This could be natural, because of the increased vowel duration and presence of paused within a word.

TABLE 3 (a)

Descriptive statistics of total duration of words (For normals)

Words	Mean	S.D	Range	
			Minimum	Maximum
/ a:ne /	564.70	080.37	488.50	648.70
/ ili /	340.06	137.30	200.00	474.60
/ u:ta /	589.30	075.24	538.50	675.80
/ ele /	439.90	059.13	382.10	500.30
/ e:lu /	625.20	092.65	569.80	732.20
/ ondu /	632.10	079.32	577.20	723.10
/ o:le /	627.90	122.70	531.40	766.10
/ emme /	540.80	070.90	469.70	611.50

TABLE - 3 (b)

Descriptive statistics of total duration of words

(For Hearing impaired)

Words	Mean	S.D	Range	
			Minimum	Maximum
/ a:ne /	826.20	429.50	344.30	1168.80
/ ili /	724.06	248.40	449.00	932.10
/ u:ta /	793.70	314.78	451.10	1070.00
/ ele /	715.80	366.70	456.50	975.10
/ e:lu /	786.50	279.80	474.20	1014.50
/ ondu /	673.50	266.40	426.90	956.20
/ o:le /	684.10	205.90	446.50	810.70
/ emme /	692.00	197.80	483.20	876.80

The intelligibility of speech depends both upon segmental and suprasegmental aspects. It is a known fact that speech intelligibility in profoundly hearing impaired speakers is very poor. (Hudgins and Numbers, 1942; Goda, 1959; Guigley and Frisina, 1961; Angelocci, 1962; Srannon, 1964; John and Howarth, 1965; Hodgins, 1966; Montogomery, 1967; Nober, 1967; Toback, 1967; Markider, 1970; Heidinger, 1972; Braverman, 1974; Smith, 1975; Conrad, 1979; Mc Garr and Osberger, 1978; Ling, 1981; Ravishankar, 1985). The intelligibility of speech of the subjects of the present study was also poor, which may be partly due to the prolonged vowel duration and increased total duration of the words by

insertion of pauseses in between the syllables

2. Synthesis:

The errors of vowel duration and pause were corrected using synthetic procedures, in the second step. The correction was done in isolation and in various combinations which have already been discussed under methodology. A total of 119 words was obtained from the corrections which were then given for perceptual rating for intelligibility.

Studies on vowel duration production and perception in normals (Nooteboom, 1973) suggest that listeners are extremely sensitive to the duration that a vowel should have in a given context. It has been shown by Calvert (1961), that experienced listeners to deaf speech cannot identify speech as deaf unless they hear atleast 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).

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

Osberger and Levitt (1979), reported that the correction of absolute syllable duration had a detrimental effect 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 six sentences, whereas bisyllabic word have been used in this study.

Correction of pause had a detrimental effect on the speech intelligibility. There was a reduction in individual judges scores and in mean scores (in both conditions) when the pause alone were corrected.

Similar reports have been made in the literature (Parkhurst and Levitt, 1978; Osberger and Levitt, 1979; Maassen, 1986), but in all these cases, they were inter word or intraphrase paused, unlike in this study.

Parkhurst and 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.

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

3. Perceptual judgement:

A total of 176 samples (including unaltered samples) were randomised and given to three judges who were native speakers of Kannada language for word identification task and intelligibility ratings. The number of words correctly identified were converted into percentage scores. Ratings were done on both open and closed sets by all the three judges. Table - 4 gives the interjudge reliability scores as determined by the co-efficient of Pearson's correlation. All the scores were significant at 0.05 level.

TABLE - 4

Description of Inter-Judge reliability values

	J1 & J2	J1 & J3	J2 & J3
Open set	0.4	0.22	0.34
Close set	0.68	0.69	0.75

(Note : All values indicate Pearsons correlation R which are significantly correlated at 0.5 level).

A point to be noted is the rating also depends upon factors like, the type of judges selected and type of material used. This view is also supported by Ling (1976). The experience of judges, would yield better results when

compared to inexperienced judges and sentences tend to be more intelligible than words and those sentences which are spoken directly to a listener in a face to face situation than sentences which are taperecorded. Redundancy of words tend to decrease when utterances are taperecorded, which inturn, caused poor intelligibility scores.

The word identification scores in percentage are presented in Table 5 of all the three judges.

TABLE 5

Description of word identification scores (in terms of percentage) in both open and close set for different conditions.

Parameters correlated		J1	J2	J3	Average scores
1	0	12.00	12.00	12.00	12.00
	C	20.00	32.00	38.00	30.00
2	0	10.00	08.00	10.00	09.52
	C	10.00	10.00	10.00	10.00
3	0	08.70	08.70	26.08	14.49
	C	13.04	17.40	39.13	23.19
4	0	10.00	10.00	10.00	10.00
	C	10.00	10.00	30.00	16.66
5	0	17.40	13.04	13.04	14.49
	C	17.40	34.79	43.48	31.89
6	0	17.40	13.04	21.74	17.39
	C	17.40	26.09	47.82	30.43
7	0	13.04	13.04	13.04	13.04
	C	26.09	26.09	39.13	30.43

Note: 0 = open set of responses (without any clues)

C = closed set of responses (with clues)

Table 6 gives the correct identification scores (in terms of percentage) for different words by the three judges

TABLE 6

Description of the correct identification scores (in terms of percentage) for the words.

Words		J1	J2	J3	Average scores
/a:ne/	O	15.00	25.00	35.00	25.00
	C	30.00	35.00	45.00	36.66
	O	14.28	14.28	14.28	14.28
	C	14.28	33.33	23.80	23.80
/u:ta/	O	23.52	47.05	64.70	45.09
	C	47.05	76.47	29.41	50.97
/ele/	O	6.25	12.50	12.50	10.41
	C	12.50	12.50	12.50	12.50
/e:lu/	O	20.00	20.00	16.00	18.66
	C	24.00	28.00	20.00	24.00
/ondu/	O	15.78	15.78	15.78	15.78
	C	15.78	15.78	26.30	19.28
/o:le/	O	15.00	15.00	15.00	15.00
	C	15.00	20.00	45.00	26.66
/emme/	O	04.50	09.00	04.50	06.03
	C	31.88	27.27	27.27	39.43

Study of table 5 shows that there were no significant differences between the four conditions of vowel duration correction i.e., 100 %, 75 %, 50 % and 25 % conditions in terms of intelligibility. However, there was some improvement

in 75 % and 50 % conditions when compared to the 100% and 25% conditions. On the other hand all the four conditions had showed better intelligibility scores when compared with unaltered condition. Therefore it can be stated that altering the vowel duration has some effect on intelligi-bility of speech of the hearing impaired. Further, a change in vowel duration along with systematic variation in fundamental frequency would presenting intersting information But at present a definite and detailed information about the relationship between the fundamental frequency and vowel duration is not available. Thus the present results warrant further studies in these directions.

VERIFICATION OF_ HYPOTHESIS:

Hypothesis 1:

1. The hypothesis stating no significant difference in the utterances of children with normal hearing and hearing impaired children in terms of

a) Vowel duration is rejected.

b) Inter-syllabic pauses is rejected, and

c) Total duration of words is rejected.

Hypothesis 2:

a) Correction of vowel duration: The hypothesis stating no significant difference between the intelligibility scores of original, unaltered utterances and the utterances where vowel

duration alone has been corrected, is rejected.

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

b) Correction of pauses: The hypothesis stating no significant difference between the intelligibility scores of original, unaltered utterances and the utterances where the intersyllabic pauses alone have been corrected, is rejected.

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

C) Correction of vowel duration and pauses: The hypothesis stating no significant difference between the intelligibility scores of original, unaltered utterances and when the utterances where the vowel duration and pauses have been corrected, is rejected.

d) Correction of vowel duration after pauses: The hypothesis stating no significant difference between the intelligibility scores of utterances with different conditions of the vowel durations, pauses being corrected, is partly accepted and rejected.

Partly it is accepted because no significant difference between 100 % condition and 25 % condition were found and rejected because differences were found between 100 % & 25 % conditions and 50 % and 75 % conditions.

There was an improvement in the intelligibility scores when vowel durations were altered by 75, 60 and 25 percent with correction of pause at each of these levels.

Thus the results of the present study indicates that the speech of the hearing impaired can be improved by correcting the pauses and vowel durations using synthesis programmes.

CHAPTER V

SUMMARY AND CONCLUSION

It is beyond doubt that deafness is one of the most serious problems faced by individuals who are effected by it. It is probably one of the most recognised problems. One of the major and often seen effects of hearing loss is a deficit in oral communication skills. According to Conrad (1979), the magnitude of the problem illustrated by recent studies suggests that about 75% of the prelingually deaf children with hearing loss of 90 dB or more are classified to be "barely intelligible" or "worse".

This low achievement of the hearing impaired has led to several investigations of the receptive and productive variables of speech.

Attempts have been made by Lang (1975), Osberger and Levitt (1979), Maassen and Povel (1984,1985), Oster (1985) and Sheela (1988) to study the direct effect of segmental and suprasegmental error corrections on speech of hearing impaired using modern computer processing techniques.

Three congenitally deaf children in the range of 9 to 12 years were selected for the study. All these children had

severe to profound bilateral sensorineural hearing loss with no other problem. All could read simple bisyllabic words in Kannada.

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

The speech samples of all the three children were recorded as they read the words. Recordings were also obtained of a matched group (for age and sex) of three normal hearing children reading the same set of words.

1 Step

The samples were analysed using a PC-XT computer and values for the following parameters obtained.

1. Initial and final vowel duration.
2. Duration of pause (if any) and
3. Total word duration.

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

The following Conclusions were drawn from the results.

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

2. Normal hearing children did not show any intersyllabic pauses (intraword) whereas two out of three children in the hearing impaired group inserted intersyllabic pauses.

3. The total duration of the words uttered by the hearing impaired children were significantly longer than that of normal hearing group. In all instances, the hearing impaired children exhibited greater variability than normal children.

II step

Vowel duration and Pauses (if any) were modified using synthesis programs towards normal values of the respective counter parts of the control groups.

The measures corrected were both in isolation and in combination with each other. Thus,

1. Correction of pause alone.
2. Correction of vowel duration alone by 100%.
3. Correction of vowel duration by 100% and elimination of pause (if any).
4. Correction of vowel duration by 75% and elimination of pause (if any).
5. Correction of vowel duration by 50% and elimination of pause (if any).
6. Correction of vowel duration by 25% and elimination of pause (if any) were made.

III Step

A total of 176 samples (47 uncorrected + 119 corrected and 10 from both groups for reliability check) were presented randomly using a tape recorder to the three judges for intelligibility rating and word identification under both open and close set conditions. The number of words identified correctly were converted into percentage scores. The judges had to rate the intelligibility on a three point interval scale, ranging from "1" (unintelligible) to "3" (highly intelligible).

The intra and inter judge correlation were high. The results indicated that correlation of correction of vowel duration by 75, 50, and 25 percent elimination of pause had positive effect on intelligibility, while all the other types of corrections had detrimental effect on intelligibility. The correction of vowel duration by 75, 50, and 25 percent with elimination of pause showed an average improvement in intelligibility by 2.05%.

The word which was correctly identified by most of the judges for most of the time was /u:ta/ followed by /emme/, /a:ne/, /o:le/, /e:lu/, /ili/, /ondu/ and /ele/.

The performance of rating improved in the closed set as

compared with the open set responses.

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

a) **Improved** when vowel duration (both initial and final) were altered by 75, 50, and 25 percent with elimination of pauses (if any).

b) **Decreased**

i) When pause alone was altered.

ii) When duration alone was altered.

iii) When duration was altered by 100% with elimination of pause (if any).

Thus it was observed correction of some of the supra-segmental aspects of speech caused only a small increase in the intelligibility. It was also seen that correction of a part of vowel duration with elimination of pause had bene-ficial effects on the speech intelligibility.

On the basis of the present study and on those which were carried out by Osberger and Levitt (1979), Maassen and Povel (1984), Oster (1985) and Sheela (1988), it can be concluded that improvement in intelligibility can be expected if one succeeds in training the hearing impaired children for better control over the suprasegmental aspects of speech.

This implies that correction of segmental errors along with suprasegmental errors bring about more improvement in

the intelligibility.

Recommendations :

1. Similar studies can be carried out for segmental corrections.
2. Similar studies can be carried out for both segmental and suprasegmental corrections in various corrections.
3. Similar studies can be carried out using sentences as speech materials.
4. A study to establish the relative impact on intelligibility of different types of speech errors and to develop an individualised program for speech improvement would be interesting.

BIBLIOGRAPHY

Adams, M.E (1914) "The intelligibility of speech of the deaf", American Annals of the Deaf, 59.

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

Angelocci et.al., (1964) "The vowel formants of Deaf and normal hearing 11 to 14 years old boys" J.Sp.Hear.Dis, 156-170 .

Asp, C.W (1975) "Measurement of aural speech perception and oral speech production of the hearing impaired", In Singh S (Ed.) "Measurement procedures in Speech, Hearing and Language", Baltimore, University Park Press.

* Bernstein, J. (1977) "Intelligibility and simulated deaf - like speech. Conference Record (IEEE International Conference on Acoustics, Speech and Signal Processing", Hartford, Connn), as cited by Osberger, M.J. & McGarr, N.S (1982)

Black,J.W (1971) "Speech pathology for the deaf speech for the Deaf children knowledge and use" Ed. LE Connor. Washington DC A.G. Bell Association for the deaf, 154-169.

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

Boothroyd, A (1985) "Evaluation of speech production of the hearing impaired and some benefits of forced - choice testing", J.Sp.Hear.Res, 28, 185-196.

* Boothroyd,A.et.al., (1974) "Temporal patterns in the speech of the deaf - A study in remedial training", Nothampton Mas: C.V.Hudgins Diagnostic and research Centre, Clark school for the deaf., as cited by Osberger, M.J. & Mc Garr, N.S (1982)

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

* Brannon,J.B (1966) "The speech production and spoken language of the deaf", Language and speech, 9, as cited by Ling, D (1976), 127-136.

Bristow,Geoff (1984) "Electronic Speech Synthesis, GRANADA, London.

* Bush,M (1981) "Vowel articulation and laryngeal control in the speech of the deaf", Unpublished doctoral dissertation, Masachusetts Institute of Technology, as cited by Osberger, MJ, and Mc Garr, NS. (1982).

* Calvert,D.R (1961) "Some acoustic characteristics of the speech of profoundly deaf individuals" Ph.D., thesis, Stanford University, as cited by Harris, K.S., E Mc Garr, NS. (1980).

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

Chermak,G.D (1981) "Handbook of audiological rehabilitation" Illinois, Charles C Thomas, 9-7.

Cotton,R.H & Cooker,H.S (1968) "Perceived nasality in the Speech of the deaf" J.Sp.Hear.Res, 11, 553-559.

Conover.W.J (1971) "Practical non-parametric statistics" John Wiley & Sons Inc, New York

Cowie,R.I.D & Cowie,E.D (1983) "Speech Production in profound post lingual deafness", In M.E.Lutman and M.P. Haggard (eds), "Hearing Science & Hearing Disorders" , Academic Press, London 183-231.

* Decarlo,L.M (1964) "The Deaf", Prentice Hall Inc., Englewood Cliffs, N.J., as cited by Ravishankar.K.C (1985).

Denes, P (1955) "Effect of duration on the perception of voicing" J.Acous.Soc.Amer, 27, 769-773.

Dorman.M.F and Hannley,Maureen.T (1985) "Materials and methods for studying speech intelligibility" in Raymond.G.Daniloffs Speech Science. Taylor and Francis, London, 112.

Doyleg,J (1987) "Reliability of Audiologists" ratings of the intelligibility of hearing impaired children's speech" Ear and Hearing, 8(3), 170-174.

* Erovik.D.A (1965) "A Spectrographic analysis for comparison of connected speech of deaf subjects and hearing subjects", Master thesis, University of Kansas, as cited by Shukla,R.S (1987).

Forner, L & Hixon, T (1977) "Respiratory Kinematics in profoundly hearing impaired speakers' J.Sp.Hear. Res, 20, 373-408.

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

Gold, T (1980) "Speech production in hearing impaired children" J.C.D., 13, 397-418.

* Greenwald, B.E (1966) "A comparison between vocal characteristics of deaf and normal hearing individuals' Unpublished Doctoral Dissertation, University of Kansas.

Harris,K.S & McGarr,N.S (1980) "Relationships between speech perception and speech production in normal Hearing and hearing impaired subjects", Status report on Speech Research, Haskins Laboratories, New Haven, Connecticut, Jan -March 1980, 23-46.

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

* Hood, R.B (1966) "Some physical concomitant of the perception of speech rhythm of the deaf" Ph.D., thesis, Stanford University.

* Houde,R (1973) "Instantaneous visual feedback in speech training for the deaf" Paper presented at the ASHA Convention, Detroil. as cited by M.J.Osberger & N.S.Mc Garr (1982).

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

* Hudgins,C.V & Numbers,F.C (1942) "An investigation of the intelligibility of the speech of the deaf" Genetic Psychology Monographs, 25, 289-392., as cited by M.J.Osberger & N.S.Mc Garr (1982).

Huggins,A.W.F (1977) "Timing and speech intelligibility" in (ed. J.Requin) Attention and performance, VII.

Huntington,D (1868) "An electromyographic study of consonant articulation in hearing impaired and normal speakers" Journal of speech and hearing Research. 11, 147-158.

* Howrath,N.John (1965) "The effect of time distortions on the intelligibility of deaf children's speech; Language and Speech, 3, 127-134 as cited by M.J.Osberger & N.S.McGarr (1982).

Klatt,D.H (1974) Cited in R.S.Nickerson "Characteristics of the speech of deaf persons. The Volta Review, 1975, 77, 342-362.

* Kruger, F (1972) "Synthetic speech as a diagnostic tool, CSL research report, No.2. June.

*lang,H.G (1975) "A computer based analysis of the effects of rhythm modification on the intelligibility of the speech of hearing and deaf subjects" Unpublished master's thesis, Rochester Institute of Technology as cited by M.J.Osberger & N.S.Mc Garr, (1982).

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

Levitt,H, Smith,R (1972) "Errors of articulation in the speech of profoundly hearing impaired children", J.Acous.Soc.Amer, 51, 102.

Levitt H, Smith C.R & Stromberg, H (1975) "Acoustic, articulatory and perceptual characteristics of the speech of the deaf children" In G.Fant(ed). Speech Communication Proceedings of the speech communication seminar, Stockholm, Vol.4, Stockholm, Almquist, & Witsell International, 121-139.

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

Ling,D (1981) "Early speech development" in Mencher GT & Gerber, IE, (eds.) "Early management of hearing loss, 1st Edition, New York, Grune & Stratton, 319-334.

Linggard,R (1985) "Electronic synthesis of speech" , Cambridge University Press, London.

Lyberg,B (1981) "Some observations on the vowel duration and the fundamental contour in Swedish utterances" Journal; of Phonetics, 9, 261-273.

Maassen.B (1986) "Marking word boundaries to improve the intelligibility of the speech of the deaf" J.Sp.Hear.Res., 29, 229-230.

* Maassen,B & Povel,D.J (1984) "The effect of correcting temporal structure on the intelligibility of deaf speech", Speech Communication, 3, as cited by D.J.Maassen & Povel, (1984b), 123-135.

Maassen.B & Povel,D.J (1985) "The effect of segmental and suprasegmental corrections on the intelligibility of deaf speech", J.Acous.Soc.Amer., 78 (3), 126-140.

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

Mencher,G.I & Gerber,S.E (1981) "Early management of hearing loss New York, Grune & Stratton.

Metz,D.E, Whitehead,R.L, Mahshie.J.J (1982) "Physiological correlates of the speech of the Deaf" A preliminary view" In D.G.Sims, G.G.Walter, R.L.Whitehead (eds.) "Deafness and communication: Assessment and training" 1st Edition, Baltimore, Williams & Wilkins, 75-89.

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

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

Monsen,R.B (1976) "Durational aspects of vowel production in the speech of deaf children", J.Sp.Hear.Res., 17, 386-398.

Monsen.R.B (1976) "The production of English stop consonants in the speech of deaf children" Journal of Phonetics, 4, 29-41.

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

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

Monsen.R.B (1983) "The oral speech intelligibility of hearing impaired talkers' J.Sp.Hear.Dis., 48, 286-296.

Monsen.R.B, Leiter, E (1975) "Comparison of intelligibility with duration and pitch control in the speech of deaf children", J.Acous.Soc.Amer., Suppl. 1, 57, (569a).

Nataraja,N.P * Jagadish, A (1984) "Vowel duration and fundamental frequency", J.A.I.I.S.H., Vol.15, (57-63).

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

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

* Nober,E.H (1967) "Articulation of the deaf" Exceptional Child, 33, (611-621) as cited by Ling, D (1976).

Nooteboom.S.C (1973) "The perceptual reality of some prosodic durations", Journal of Phonetics, 1, (24-45).

* Osberger,M.J (1978) "The effect of timing errors on the intelligibility of deaf children's speech", Unpublished doctoral dissertation, City University of New York.

Osberger,M.J & Levitt, H (1979) "The effect of timing errors on the intelligibility of deaf children's speech", J.Acous.Soc.Amer., 66, (1316-1324).

Osberger,M.J & McGarr, NS (1982) "Speech production characteristics of the hearing impaired" Status report on Speech Research, Jan-Mar. Haskins Laboratories New Haven, Conn. (227-290).

Oster,A.M (1985) "The use of a sysnthesis-by rule system in a study of deaf speech", Quarterly progress and status report, Speech Transmission Laboratory, QPSR 1/1985, Royal Institute of Technology (KTH) Stockholm, Sweden.

Parkhurst,B & Levitt, H (1978) "The effect of selected prosodic errors on the intelligibility of deaf speech" J.C.D., 11, (249-256).

Penn,J.P (1955) "Voice and speech patterns of the hard of hearing", Acta Otolaryngologica, Supplement, 124.

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

Pollack, D (1981) "Acoupedics: An approach to early management", In Menclur, GI & Gerber SC (Editors) "Early Management of hearing loss" 1st edition, New York, Grune & Stratton (301-318).

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

Raphael,L.J (1972) "Proceeding vowel duration as a cue to the perception of the voicing characteristics of word-final consonants in American English. J.Acous.Soc.Amer., 51, (1296-1303).

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

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

Ross, M & Giolas, TG (1978) "Auditory management of hearing impaired children" University Park Press (1-14).

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

Siegel, S (1956) "Non-parametric statistics for the behaviour sciences' Tokyo, Mc-Graw Hill, Kogakusha, Ltd.

Sheela,K (1988) "Analysis and synthesis of speech of hearing impaired" Unpublished Master's Dissertation, University of Mysore, Mysore.

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

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

Smith,C.R (1975) "Residual hearing and speech production in deaf children" J.Sp.Hear.Res., 18, (795-811).

Stark,R.E (1979) "Speech of the hearing impaired child" In Bradford, LJ & Hardy WG (editors) "Hearing and Hearing impairment" 1st edition, New York, Grune & Stratton (229-248).

Stark,R.E & Levitt, H (1974) "Prosodic feature reception and production in deaf children" J.Acous.Soc.Amer., 55, 363 (Abstract).

Stathopoulos,E.T.,Duchan,J.F.,Sonnenmeirer,R.M and Bruce,N.V (1986) "Intonation and pausing in deaf speech", Folia Phoniatrica, 38, 1-12.

* Sussman & Hernandez (1979) "A spectrographic analysis of the suprasegmental aspects of the speech of the hearing impaired adolescents' Audiology, Hearing and Education, 5 (12-16).

* Thomas,W.G 91964) "Intelligibility of the speech of deaf children Proc. Int. Corgr On Education of the deaf, Washington, D.C. US Government Printing Office, (245-261). as cited by Ling, D (1976).

* Thornton, A (1964) "A spectrographic comparison of connected speech of deaf subjects and hearing subjects" Unpublished Master's Thesis, Lawrence (as quoted by Gulbert, HR, 1978).

* Voelker,C.H (1935) "A preliminary strobophotoscopic study of the speech of the deaf" American Annals for the Deaf, 80, (243-259).

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

Willemain,T.R & Lee,F.F (1971) "Tactile pitch feedback for deaf speakers' The Volta Review, 73, (541-554).

Whernall, E & Fry, D.B (1964) "The deaf child" 1st edition, London, William Heinemann Medical books Limited.

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

Zimmerman G & Rettaliata, P (1981) "Articulatory patterns of an adventiously deaf speaker: Implications for the role of auditory information in speech production" J.Sp.Hear.Res, 24, (169-178).

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APPENDIX - I

The eight bisyllabic words (VCV combinations) used in the study were :

1. / a:ne /
2. / ill /
3. /u:ta /
4. / ele /
5. / e:lu /
6. / ondu /
7. / o:le /
8. / emme /