Journal of the All India Institute of Speech and Hearing , 1990, Vot XXI

Speech Characteristics of the Hearing Impaired : A Tutorial Review

R.S.Shukla
Lecturer in Speech Pathology
All India Institute of Speech and Hearing, Mysore - 570 006

Introduction

Speech is such a natural by product of maturation process that it's development is always taken for granted. And it is hearing, the main channel through which we learn to speak. Hearing impairment either at birth or soon after birth and during early childhood results in a concomitant deficiency in comprehension and usage of speech. All the studies on the Speech of the hearing impaired that have been conducted so far have just revealed the fact that, the hearing impaired individuals do not produce speech as well as those who hear. Although speech reading can compensate to a large extent for the loss of hearing insofar as speech reception is concerned, still majority of the hearing impaired individuals do not develop intelligible speech. This underlines the role of hearing in the development of normal speech.

The speech of the hearing impaired differs from normals in both segmental and suprasegmental aspects. Speech characteristics which have been described as typical of hearing impaired individuals can therefore be grouped into two categories, viz., scgmcnlal errors which include misarticulations and suprascgmental errors which include abnormal voice quality, slow rale, faulty rhythm and faulty intonation patterns.

Also, speech whether normal or abnormal can be described at three levels, viz., the physiological, the acoustical and the perceptual level. Naturally researchers have attempted to describe the speech of the hearing impaired individuals at all the three levels.

Descriptions of the speech at the perceptual level is a subjective method, where the clinician listens 10 the recorded speech and categories it as cither segmental errors or supra segmental errors. In this method clinicians may also measure the overall intelligibility of the speech of the hearing impaired. Descriptions of the speech of the hearing impaired individuals have, for the most part, been based on such subjective evaluations. Recently with the advancement in technology and instrumentation several researchers have attempted to describe the speech of the hearing impaired both at the acoustical and at the physiological level. These two methods involve sophisticated instruments as tools of measurements while describing the speech and are considered as objective evaluations. Any such objective evaluations, however, must be verified with the subjective evaluations, as speech is basically a perceptual phenomenon.

In this review an attempt has been made to present the information on the speech problems of the hearing impaired, wherever possible, at all the three levels. As the objective of this paper is to provide an overview of the speech problems encountered by the hearing impaired individuals, this approach is would be more appropriate for a better understanding of the speech problems of the hearing impaired individuals. Hearing impaired individuals, in this article, are referred as those who have hearing loss greater than 71 dB in the better ear since birth or from pre - lingual period. Table 1 shows the speech problems encountered by the hearing impaired individuals in a nutshell.

A Segmental Errors

Failure to develop certain phonemes, failure to differentiate between phonemes, substitution of one sound for another, use of the neutral vowel schwa /o / as a general purpose vowel and other distortions are all articulatory difficulties that are encountered in the speech of the hearing impaired persons. The discussion on the articulatory problems of the hearing impaired will be grouped under two subheadings :- vowel articulation and consonant articulation.

A.I. Vowel Articulation

Good vowel articulation is important in speech since they are the basic building blocks of words, they help in identifying adjacent consonants and carry the prosodic information (Monsen and Shaughnessy, 1978). Monsen (1976c) has shown that the accurate control of vowel articulation by the hearing impaired speakers is highly correlated with the overall intelligibility of the speech they produce. Several researchers (Hudgins and Numbers 1942 ; Angelocci, Kopp and Holbrook 1964 ; Boone 1966 ; Nober 1967 ; Markides 1970 ; Smith 1975 and Gcffner 1980) have reported that the hearing impaired individuals fail to produce appropriate vowel sounds.

Hudgins and Numbers (1942) reported the first quantitative study of the speech production of the hearing impaired children. Their findings showed that the major vowel errors were substitutions, errors in the production of diphthongs and neutralization. Markides (1970) grouped the vowel errors of the hearing impaired children into four categories. They were vowel substitution, neutralization, prolongation, nasalization and diphthongization. Markides (1970) reported that the deaf children misarticulatcd nearly 56% of all vowels and diphthongs attempted.

Table 1 : Showing the method of organization employed in the article to describe ihe speech problems of the hearing impaired individuals.

INTRODUCTION :

A : Segmental Errors :

A. I. Vowel Articulation

Perceptual Evaluation :	Objective Evaluation :
Vowel Substitution and Neutralization	Formal Frequency studies
Vowel Prolongation	F / F Plots
Vowel Dipthogization	Reduced Phonological Space
	Durational Studies
	Abnormal Lengthening
	Abnormal Shortening
	Greater Variation
	Physiological Studies
	LMG Study

A. II. Consonantal Articulation :

Perceptual Evaluations :	Objective Evaluations :
Substitutions	VOT Studies
Distortions	Shorter Positive VOT
Omissions	Fewer Negative VOT
Voiced - Voiceless	
Distinction Problem	Duraiional Studies
Misanicutation of Blends	Abnormal Lengthening
Aniculatory errors in terms of :	Abnormal Shortening
	Greater Variation
Place	
Manner	Physiological Studies
Position	Reduced Oral Pressure
	I.aryngea! incoordination

A. HI. Vowel Errors Vs. Consonantal Errors

B. Suprasegmental Errors :

B. I. Abnormal Voice Quality

B.I. 1. Poor Phonatory Control:

- a) High Pitched Voice
- b) Reduced Breath Control
- c) Other Acoustic Correlates
- d) Abnormal Resonance
  - Improper Control of the velum
  - Reduced Speaking Tempo

B. II. 2. Inappropriate Intonation :

- a) Lack of Fundamental Frequency Variation
- b) Excessive Fundamental Frequency Variation

BIII. Inappropriate Rhythm :

- a) Reduced Rate of Speech
- b) Inappropriate Pauses
- c) Abnormal Duration of Phonemes
- d) Poor Diadochokinetic Rate

C. Speech Intelligibility

Degree of Intelligibility

Factors contributing to Speech Intelligibility

A.1.1. Vowel Substitution and Neutralization

Perceptual evaluation

Smith (1970) found that the low central vowels were produced correctly most often and that there was a tendency for all vowels to drop to a more neutral position. Geffner (1980) while describing spontaneous speech production of sixty five, six-year old deaf children showed that the vowels with low tongue position were correct more often than those produced with mid or high tongue position.

Acoustic and Physiological evaluation

It is generally accepted that the frequencies of the first two form ants are the most important features in the recognition of vowels. Though the first two formants determine the phonemic quality of the vowels, the individual vowels are not identifiable with absolute formanl frequency values as they are dependent on the speaker's age and sex. The formant frequencies of children are higher than those of adults and those of female adults are higher than male adults. Thus measurement of formant frequencies as such docs not yield any useful information because it does not necessarily indicate the vowel articulation accuracy. Levitt (1978) suggested that the vowels are differentiated by the ratio of the first and second formant frequencies, i.e., the F2/F1 ratio.

Angelocci et. al., (1964) measured the mean values of the first 3 formants of 10 English vowels uttered by two groups of eighteen deaf and eighteen normal male adolescents, and coordinate plots of Fl and F2 were drawn. The plots showed considerable overlapping of the vowel areas. This overlapping of the vowel areas suggest a high degree of inaccuracy in the placement of articulators when producing the vowels. They also noted that the deaf occupy a far more limited range of frequency than do the normal hearing ; hence the vowels said by the deaf appeared to be in general more centralized or schwa-like than the normal. Angelocci et. al., concluded that the deaf did not have "clearly defined articulatory vowel target areas". Levitt (1978) while studying the acoustic and perceptual characteristics of the speech of deaf children concluded that formant frequencies during vowel sounds are similar to those for normal children, but were biased towards values typical of the schwa vowel. Boone (1966) found that the second formant frequency tended to be lower for the deaf than, for the hearing children. He suggested that this is because the tongue is held too far back toward the pharyngeal wall.

Another approach to study the articulatory behaviour of vowels at the acoustical level is to measure the phonlogical space or the vowel space. Thevowel space in phonetic literature represents tongue height on the ordinate and tongue backing on the abscissa. In English language, vowels /i/, /u/, /oc/ and /a/ form the four comers of a vowel space (Ladefoged, 1975). The traditional vowel charts grossly reflect tongue position. Monsen (1976c) defined the vowel space acoustically as the differ0 ence between maximum and minimum frequencies of the first two formants of vowel sounds of particular language. Monsen (1976c) instead of measuring form ant frequencies of all vowels, measured the dimensions of phonological space itself by plotting the most extreme points for hearing impaired individual subjects.

The phonological space was found to be reduced for many of the hearing im0 paired subjects. Monsen concluded that this reduction of phonological space was due primarily to a relative immobility of the second formant and secondarily to a restricted range of the first formant. Similar findings have been reported by Mctz et. at., (1985) and Shukla (1990). This reduced phonological space can be explained in two ways. Firstly, the frequency sensitivity of the deaf child is usually worse in the region of the second rather than the first format. The study of Van Tassel (1980) demonstrated that the hearing impaired children cannot clearly discriminate the second formant frequency region of vowel sounds, supports this explanation. Secondly, the articulatory gestures of tongue movement which exert a strong influence on the movement of the second form ant, are among the most difficult for the deaf child to see. Zimmerman and Rettaliata (1981) in their recent study of movement kinematics found that deaf speaker showed less distinctive tongue shapes for vowels than expected suggesting that the deaf speaker rely more heavily on jaw displacement to distinguish between vowels than do normal hearing speakers who display greater flexibility in tongue shaping and movement.

A.I.2. vowel prolongation

Perceptual evaluation

Several investigators (Hudgins and Numbers, 1942; John and Howarth, 1965 ; Hood, 1966) have considered poor liming of vowels and consonants to be a major cause of the poor intelligibility of the speech of the deaf. Nickerson (1975) opined that precise specification of timing deficiencies is not possible because not much is known about the temporal characteristics of normal speech. Research results do, however, suggest ways in which the speech of the deaf individuals may differ in the aggregate than lhalof the hearing speakers with respect to temporal (liming) aspects.

Acoustic **and Physiological Evaluation**

"During the process of speech production, phonemes arc acted upon by elaborate sets of rules and arc converted into phonetic units which do manifest duralional values and temporal variability" (Smith, 1978). Segmentat durations in adult production are influenced by perceptual variables and intrinsic variables. Perceptual variables are due to linguistic influence that are results of language specific variables and learning processes. Intrinsic variable are due to physical properties of the speaker's production mechanism. While perceptual variables are learnt, intrinsic variables are not learnt and are universal in nature. For example, in English the vowel /l/ is shorter than /i/, / / and / /. But only the I/i difference is traditionally recognized as linguistically significant. That is something the speaker "knows" and has control over. The differences between 1/ , I/ however, are usually attributed to constraints of the speech production mechanism.

Vowel prolongation in the speech of the hearing impaired is just one aspect of poor timing of vowels. Vowel prolongation-just refers to the abnormal lengthening of the vowels. That,is, the hearing impaired speaker simply increases the length of the vowels he utters and this has been reported by several investigators (Calvert, 1961; Monsen, 1974 ; Osbergerand Levitt, 1979 and Shukla, 1988). In Monsen's (1974) study the deaf subjects produced vowels which were longer by one and half times when compared to the normally hearing speakers. Osberger and Levitt (1979) observed that the syllabic prolongation in the speech of the hearing impaired subjects was due primarily to prolongation of the vowels. Shukla (1988) in his spectrographic analysis of speech of the hearing impaired subjects observed an abnormal increase in the durations of the vowels /a/, /i/ and /u/ both in the medial and final positions. Not only the durations of the vowels /a/, /i/ and /u/ were significantly longer in comparison to the speech of the normally hearing, but the hearing impaired subjects varied greatly in controlling the length of the vowels as indicated by their standard deviation scores. Shukla (1988) also observed that a few hearing impaired subjects tend to shorten the final vowel especially the vowel /a/.

Another vowel durational abnormality noticed in the speech of the hearing impaired subjects is the absence of the modifying influence of the following consonant on the duration of the vowel. For example, Monsen (1974) showed that the normal pattern of durational modification according to the following consonant was not evident, although the variation was different from normal speech, in any one subject, it appears systematic to a consider able extent. Similar observation has been reported by Shukla (1988).

Another abnormality of vowel duration in the speech of the hearing impaired is related to the issue which has received a considerable amount of attention in recent research is the conditioning of the vowel length by voicing of a following consonant. Several investigators (House and Fairbanks, 1953; Peterson and Lehiste, 1960; Monsen, 1974 ; Whitehcad and Jones, 1976 ; and Mitleb, 1984) have reported that vowels preceding voiced consonants in English are of greater duration than those preceding voiceless consonants. For example, in Monsen's study (1974) the vowel /i/ was 174 and 238 msec, longer when following by voiced stop and voiced fricative consonants respectively than when followed by their voiceless counterparts. Thus, vowels are typically about 100 msec, longer before voiced than before voiceless final consonants in English.

Similar findings have been reported by physiological studies as well (Rothman, 1977 ; Zimmerman and Rettaliata, 1981) Rothman (1977) who measured EMG activity associated with the vowel/ / followed by /t/, /k/ and /s/ reported that the deaf group extended the duration of the vowel A)/ Further, a comparison of the standard dc viations of the normal and deaf groups indicated that there is more variation between talkers within the deaf group than in the normal group. He concluded that "the deaf, as a group are more variable in their articulatory behaviour than are normal speakers". Zimmerman and Rettaliata (1981) in their cineflourographic study demonstrated that the deaf subjecthad longer utterance durations. However, Shukla (1988) observed that though the majority of the hearing impaired speakers tend to lengthen the duration of a vowel some of them do decrease the duration of a vowel, specially the duration of the vowel in finai position.

A.II. Consonant Articulation

A.II.l. Perceptual evaluations

Hudgins and Numbers (1942). studied 142 subjects between the age range o! 8 to 20 years, whose hearing loss ranged from moderate to profound. The most common error types observed were : 1) confusion of voiced-voiceless distinction 2) substitution of one consonant for another 3) added nasality 4) misarticulaiion of blends 5.) misarticulation of abutting consonants 6) omission of word-initial or word final consonants.

The errors when analyzed according to the place of articulation, there is a general agreement that phonemes produced in front of the mouth are often produced correctly lhan are phonemes produced in back of the mouth. For example, Nober (1967) rank ordered the correctly articulated consonants according to the place of articulation as follows : bilabials 59%, labiodentals 48%, linguadentals 32%, linguaalveolars 23%, linguapalatals 18% and linguavclars 12%. More recently Geffner (1990) studied the spontaneous speech of 65 deaf children, ranging in age from 6 to 11 years. Herrcsults revealed that labiodental and bilabial consonants were produced correctly than velar consonants. More errors in the sounds produced in the back of the oral cavity is because, the ariculatory movements for these sounds are visually obscure and therefore these Sounds are difficult to lip read. Consonants that are easy to lip read are most often produced correctly (Ravishankar, 1985).

The errors when analyzed according to the manner of production, showed that lateral and glide phonemes were elicited more accurately than the other categoreported that in terms of correctness of production glides and laterals with 30%, nasals with 28% and fricatives with 26%.

When the errors were analyzed according to the type of misarticulalion, by far the single most frequently reported error in the speech production of the hearing impaired is omission of a phoneme (Hudgins and Numbers, 1942: Markides, 1970 and Smith, 1975). The omission of consonants may occur in word initial and or in the final position of words. The initial consonants were produced more correctly than those in the medial position, which were produced more correctly than those in the final position. Hudgins and Numbers (1942) reported that omission of initial consonants was more common than the omission of the final consonants. The consonants that are more frequently omitted from the initial position of a word included /h, 1, r, y, th, s/ . Patterns of error of the final consonants are : omission of consonants, releasing of consonants in to the following syllable, or incomplete production whereby the phoneme loses it's dynamic properties and merely retains passive gestures. Among the final consonants that are frequently omitted were /I, s, z, d, g, k/. However, the-study of Markides (1970) showed that the final consonantal errors were more numerous than errors involving the initial and medial positions. Smith (1975) found the omission of consonants to be the commonest error in the speech of the hearing impaired individuals. In her study, an analysis of position of errors indicated that there was no difference in mean proportion of errors in initial and medial position, however a marked increase of errors in the final position existed. However, Ravishankar (1985) found that the errors in initial position were most frequent than the errors in the medial position. This could be because of the non - occurence of consonants in the final position in Kannada. Next frequent type of error in the speech production of the hearing impaired individuals is the substitution of voiceless consonants for voiced consonants or vice versa. The average voiceless /voiced errors is 61.31% (Ravishankar, 1985).

The result of the studies by Hudgins and Numbers, 1942; Nober, 1967; Markides, 1970; Smith, 1975; and Geffner, 1980; Ravishankar, 1985 generally agree in that the most frequent consonant errors are incorrect productions of the palatal and alveolar fricatives, the affricates, and the velar nasal. In addition, the results also indicate a better production of bilabials, glides, and labiodental fricatives. The most common error types are omission, voiced and voiceless distinction. Omission of the final consonant is more frequent than that of the initial consonant. From these data Geffner (1980) hypothesized that a "phonological system for the deaf does exist, governed by features of intensity, visibility and frequency."

In all these studies, normal listeners listened to the speech of the hearing impaired individuals, and described it as they heard it. However, by listening to the specc h of hearing impaired individuals, it is not always possible "to extract the source of a speech error, that is, the 'real acoustic reason' and its articulatory counterpart, because speech is a complicated, coarticulalcd code rather than a simple linear string of symbols." (Monsen, 1978). Recently there have been several attempts to measure ihc acoustic characteristics of speech of the hearing impaired individuals.

A. II.2. Acoustic and Physiological evaluation

A. II. 2. a. VOT Studies

Normal hearing people distinguish between different kinds of oral stop consonants produced at the same place of articulation as voiced and voiceless whereas hearing impaired individuals fail to distinguish between voiced and voiceless consonants (Hudgins and Number, 1942; Calvert, 1962; and Smith, 1975). Indeed it was found that one of the most common errors in the speech of deaf children is confusion of voiced and voiceless cognates. The nature and direction of the confusion is not always agreed upon. For example, Hudgins and Numbers (1942) reported thatthe three most frequently misarticulatcd sounds were /b/, /d/ and /g/, and these were substituted by voiceless counterparts. On the contrary, Smith (1973) found that /b/ was produced correctly more often than all other English consonants.

Calvert (1962) suggested that this is essentially a durational problem. That is, when a plosive was intended to be unvoiced (/p/, /t/) and was heard as voiced (/b/, /d/*)* the duration of the release period was about the same as that of voiced consonants when produced by hearing speaker. Perm (1955) reported another form of voiced "voiced-voiceless problem, that is, 'continuous phonation' in the speech of the hearing impaired population. Recently, Millin (1971) observed this problem in a fairly large number of hearing impaired individuals and concluded that "continuous voicing destroys perception o (the separation between words, thus making word identification very difficult."

Lisker and Abramson (1964,1967) who defined voice onset time (VOT) as the time difference between the release of a complete articulatory constriction and the onsctof phonalion, suggested that measurement of VOT, would provide an useful acoustic objective measure of the various phonemic categories such as "voiced plosive", ":voicclcss plosive" and ":voiceless aspirated plosive". Voiced plosives in English normally have a short VOT (less than 20 - 30 msec.) and voiceless plosives on the other hand have relatively long VOT values (greater than 50 msccs.)

Monscn (1975, 1976a) spectrographically measured the VOT of word initial stop consonants (/p/, /t/, /k/) and (/b/, /d/, /g/) in the speech of thirty seven deaf and six normally hearing adolescents. In eleven of the deaf children, VOT values for voiced and voiceless stop consonants were similar to those in the normal hearing, i.e., these individuals could produce all the stops in a normal manner. The remaining deaf individuals deviated systematically from the normal in their failure to produce a distinction between the voiced and voiceless stop at a given place of articulation. Those who failed to produce "voiced-voiceless distinction" tended to produce (p-b) and /t-d/ as unaspiratcd stops, and to produce either aspirated or unaspi rated stops for /k-g/. He concluded that 'while the speech production of a deaf child may deviate from normal, it is by no means phonetically or phonologically inconsistent in itself.

Gilbert and Campbell (1978), in their study, observed differences in VOT, though the stop consonants produced by both the normally hearing and the hearing impaired individuals were perceived as being produced correctly. VOT values for hearing impaired speakers were shorter than those values for normally hearing speakers. Gilbert and Campbell (1978) have given 2 explanations for the short VOT values observed in the speech of the hearing impaired. 1) Gilbert (1975) reported that airflow during the production of stop consonants was less for the hearing impaired subjects than for normally hearing subjects. Short VOT values observed possibly is due to this reduced intra-oral airpressureduring the production of stop consonants. 2) And the other explanation for the short VOT values obtained for voiceless stops may be the inability of the hearing impaired individuals to coordinate the phonatory and articulatory mechanism. Another difference was that the hearing impaired speakers exhibited fewer negative VOT values for the prevocalic voiced components, than did the normally hearing subjects. Shukla (1988) also observed that shorter VOT values for voiceless stop consonants and absence of negative VOT values for voiced stop consonants in the majority of the hearing impaired subjects. According to Gilbert and Campbell (1978) the reduced number of negative VOT values obtained from hearing impaired speakers indicated that they did not make as great a distinction in the production of stop consonants cognates.

At the physiological level, Hutchinson and Smith, 1976 ; Whitehead and Barefoot, 1980; and Whitehead, 1982, have shown that the hearing impaired speakers have difficulty in coordinating the events of respiration and laryngeal valving. This observation provides the physiological reason for the failure to correctly produce voiced and voiceless distinction. Mahshie (1980) and McGarr and Lofquist (1982) showed that during pauses between vowels the hearing impaired speakers inappropriately opened the glottis, a pattern never observed in the production of the normally hearing speakers. They opined that hearing impaired speakers have difficulty in coordinating the temporal and spatial demands of different articulators resulting in voiced and voiceless confusion. Studies of McGarr and Harris (1980), Rothman (1977) and Zimmerman and Rettaliata (1981) also demonstrated hearing impaired speakers inability to coordinate inter-articulalor movements. However, Hutchinson and Smith (1976), Whitehead and Barefoot (1980) and Whitehead (1982) have shown that some hearing impaired speakers do produce plosives with normal air flow palterns, that is, voiceless plosives was produced, with grater peak air flow than their voiced cognates, suggesting that at least some hearing impaired speakers are relatively successful in coordinating respiration and laryngeal valving.

A.II.2.b. Durational Studies

Durations of consonants perform different functions in different languages. In American English, variations in consonant durations are phonetic in nature. Duration serves as a primary perceptual cue in the distinctions between voiced versus voiceless sounds, presence or absence of emphasis, phrase final versus non-final syllables and etc. Mdns;en, Moullcrand Umcda (1972) and Lehiste(1973)listedsomeof the language specific duration factors, which modify phoneme duration. They are phonetic environment, consonantal voicing, place of articulation, mariner of articulalion, presence of lexical stress, the number o! syllables in the word and the degree of sentence stress. Investigators have attempted to find out whether ihere arc similar consonantal durational modification in the speech of the hearing impaired as in the case of normally hearing subjects.

1) The effect of vowel environment on duration of consonants

The effect of vowel environment on the duration of consonants has been described by various authors (Schwartz, 1969 ; Di Simoni, 1974 and Whitehead and Jones, 1978). To explain the differential effect ol vowel environment on the duration ol consonants, Schwartz (1969) posed the following rationale: a scanning mechanism looks ahead and considers the relative magnitudes of arliculatory adjustment required lor she transition from the consonant to the vowel, and uses this information to time the arrival of the neural commands that initiate the movement away from the turbulence producing constriction.

There appears to be only one study (Whitchcad and Jones, 1978). investigating the phenomenon of "forward scanning" in the speech of the hearing impaired. Their subjects were ten normal hearing, ten hearing impaired and ten deaf adult male speakers. The results indicated that for the normal hearing and hearing impaired subjects, the consonants /s/and / / were significantly longer in duration in/i/vowel environment when compared to the /a/ vowel environment. However, for the deaf subjects the consonants /s/ and/ / were significantly longer in duration in the /a/ vowel environment when compared to the /i/ vowel environment. Thus, it appears that the deaf do not learn the process of "forward scanning" as does a normal hearing or hearing impaired population. Whitehead and Jones (1978) concluded that "the deaf fail to learn to combine phonemes using some of the learned principles of coarticulation and thus may view speech in terms of distinct individual phoneme units rather than as a dynamic coarticulatory event". Failure to learn the various segments ofcoarticulation would disrupt the normal timing of speech and thus, may account in part, for the poor overall speech intelligibility.

2) Consonant duration and consonantal voicing

Evidences from physiological and acoustical 'Studies suggest that durational differences exist between the voiced and the voiceless consonants, voiceless consonants being longer than voiced consonants.

Calvert (1961,1962) found that the misarticulation of voiced and voiceless consonants was principally a durational error, in which intended voiced plosives were perceived as voiceless plosives or vice verse. Shukla (1988) studied the duration of/p vs b/, A vs g/ and /c vs j/ in thirty normally hearing and thirty hearing impaired sujects. The results indicated that the durational difference between voiced and voiceless consonants, on the average, is considerably reduced in the speech of the hearing impaired subjects. However, the individual analysis of the data revealed the following. 1) Some hearing impaired subjects showed durational differences between voiced and voiceless consonants comparable to that of normals. 2) In some hearing impaired subjects the duration of the voiceless consonants (p, t, k, c) was longer than their voiced counterparts, but the difference was less than JND for duration. 3) In .some subjects, voiced consonants exhibited slightly longer duration than their voiceless counterparts. 4) In the remaining subjects the durational difference between the voiced and voiceless consonants was very small or there was no difference at all.

3) Consonant duration and Manner of articulation

The manner of articulation also seems to affect the duration of the consonants (Falchun, 1951 ; Elert, 1964 ; Savithri, 1983; Shukla, 1988). Shukla (1988) showed that within the voiced category the affricate /j/ is the longest in duration and within voiceless category affricate *Id* is the longest in duration. Shukla also showed that lateral/I/and the fricative /s/ are the shortest within the voiced and voiceless categories respectively.

However, the hearing impaired subject's temporal structures were different. The dental plosives /d/ and /t/ were longest and within the voiced and voiceless categories respectively. Also the lateral /I/ and the dental fricative /s/ were shortest. One prominent feature in the speech of the hearing impaired was that the all the eleven consonants studied were longer when compared to those of normally hearing subjects.

Another prominent feature was that, in the majority of the hearing impaired speakers durations of the dental nasal /n/ and the lateral /I/ were greatly elongated than any other consonants in all the three vowel environments. However, a few hearing impaired speakers showed excessively shortened durations for nasal /n/ and lateral /l/ as well.

Rothman (1977) with an electromyographic investigation of articulation and phonatory patterns in the hearing impaired subjects reported that the hearing impaired speakers extended the durations of speech segments. Further, he reported that the articulatory patterns of the hearing impaired group, as indicated by EMG activity, showed greater variance than did that of normal group, that is, the deaf speakers not only behaved differently from normal speakers, but they were also different from eacholhcr.

A.III. Vowel errors versus consonant errors

Hudgins and Numbers (1942) and Nober (1967) reported that their subjects made twice as many consonant as vowel errors. Geffner (1980) also found that the vowels were produced correctly more than the consonants. Geffner (1980) attributed this logrealcr phonetic power and visibility of vowels and to high frequency components and inherently weaker intensity of consonants. This is further substantiated by the fact that voiced consonants were produced more accurately than voiceless consonants. On the contrary a few investigators (Huntinglon et. al., 1968 ; Jones. 1967) have claimed that as a rule deaf speakers produce consonant sounds more clearly than vowel sounds.

B. Supra-Segmental Errors

In the speech of the hearing impaired, several investigators (Nickcrson, 1975; Levitt et. al., 1976; Monsen, 1978; Monsen, 1979) have noted supra - segmenlal errors, such as, abnormal voice quality, inappropriate intonation, abnormal rhythm and stress. Levitt et. al., (1974) noted that children with approximately the same frequency of segmental errors had speech intelligibility scores differing by as much as 30%. This observation clearly indicates the contribution of supra - segmental errors to the low intelligibility of the speech of the hearing impaired individuals.

B.I. Abnormal Voice quality

Calvert (1962) found that the terms must commonly selected by teachers of the deaf as descriptive of the voices of deaf children were "tense", "flat", "breathy", "throaty", and "harsh". The two major sources of abnormal voice quality, in the speech of the hearing impaired individuals are 1) poor phonatory control and 2) abnormal resonance.

B.I. 1. Poor phonatory control

Boothroyd and Decker (1972) and McGarr and Osberger (1978) opined that poor phonatory control contributes to the low intelligibility of the speech of the hearing impaired individuals. The poor phonatory control present in the speech of the hearing impaired individuals may be divided into three major types :

1) Excessively high fundamental frequency
2) Reduced phonation duration and
3) Other acoustic correlates of voice

B.I. l.a. Voice quality and fundamental frequency

The auditory feedback system is a main channel for appropriate establishment and production of fundamental frequency. Fundamental frequency, the perceptual correlate of which is called as pilch, has been a particularly difficult properly of speech for deaf children to learn to control (Boothroyd, 1970). Martony (1968) suggests that this is because deaf children may lack a conceptual appreciation of what pitch is.

Several investigators (Angelocci, Kopp and Holbrook, 1964; Boone, 1966; and Martony, 1968) have noted that deaf individuals arc apt to have a relatively higher pitch. Angelocci et. al., (1964) found that mean fundamental frequency of the hearing impaired adolescents between 11 to 14 years was 43 Hz higher than that of the normally hearing subjects. Boone (1966) reported that this problem was greater for teenagers than for prc - adolescents and that it was particularly troublesome for adolescent boys. Angclocci et. al., (1964) not only noted that the fundamental frequencies of hearing impaired individuals was highest among those of normal hearing individuals, but also that the average fundamental frequency for different individuals spanned a wider range. Thornton (1964) has reported essentially normal speaking frequencies for hearing impaired speakers Whitehead and Maki (1977) found that while the speaking fundamental frequency was higher for deaf adults than for normally hearing adults on the average, a majority of the deaf adults in their study had speaking fundamental frequency values which fell within a normal range.

Monsen (1979), in a group of 24 hearing impaired children, found that fun--damental frequency was 297 Hz. This was with in the range of normal hearing children. Monsen et. al., (1979) observed similar findings in deaf adolescents. These studies make it clear that mean fundamental frequency range among hearing subjects is quite broad, and the hearing impaired subjects appear in most cases to fall within it. In the cases where they do not, the mean fundamental frequency is higher than normal. Monsen (1978) measured mean fundamental frequency and mean amount of change of fundamental frequency in 37 hearing impaired individuals. He found no correlation between speech intelligibility of hearing impaired adolescents and either mean fundamental frequency or mean amount of change of fundamental frequency. According to Monsen (1979), the correlation between mean fundamental and voice quality was 0.52

B. 1.1. b. Reduced phonation duration

Phonation duration is defined as the maximum amount of time an individual can sustain phonation after taking a maximum inhalation. Inability to sustain phonation indicates excessive breathiness, inadequate intensity or incomplete word grouping. Inadequate breath control in the speech of the hearing impaired individuals was reported by Hudgins (1934), Rawlings (1935). These authors concluded that the hearing impaired speakers have shorter breath control and consequently they are likely to interrupt the speech flow more frequently in order to permit the intake of air. Scuri (1935a) reported that deaf speakers tend to use more breath while speaking than when not speaking. Asp (1975) and Nickerson (1975) opined that the breath duration is an important factor in speech intelligibility. Stoker and Lape (1980) included breath duration as an important variable in their study of "Analysis of some non - articulatory aspects of the speech of hearing impaired children". They found a positive correlation between breath duration and speech intelligibility.

Shukla (1988) also, reported reduced phonation duration in thirty hearing impaired subjects he studied when compared to the normally hearing speakers. Not only the aberrant respiratory patterns in the speech of the hearing impaired (Whitehead, 1982 ; Itoh and Horii, 1985), will directly affect the duration of phonalion, but also the control of the expiratory cycle particularly the coordination between the respiratory system and the laryngeal system is very crucial for sustained phonation As Borden and Harris (1980) put in the problem of respiration common to some speech pathologisls are not a matter of needing more energy since, only one fourth of vitalcapacity is usually used to conversational levels, but more likely are problems in control and modification of the air stream.

Monsen et. al., 1979 ; Metz et. al., 1982 have demonstrated abnormal laryngeal function in the hearing impaired subjects. Monsen et. al., (1979) who observed differences between hearing impaired and hearing subjects for successive changes of the glottal waveforms from one period to another, showed evidences of diplophonia in the waveforms of the hearing impaired, hypothesized that hearing impaired speakers have difficulty in controlling overall tension of the vocal folds and subglottal pressure. Metz et. al., (1982) provided evidences of abnormal laryngeal function, that is, inappropriate positioning of the vocal folds prior to the onset of phonation and subsequent patterns of abnormal vocal fold vibration in the hearing impaired speakers.

Thus, the shorter phonation duration indicates abnormal respiratory patterns, abnormal laryngeal and inadequate breath control in the speech of the hearing impaired.

B. 1.1. c. Voice quality and other acoustic correlates

Monsen et. al., (1979) noted that in some of the hearing impaired subjects the variability of fundamental frequency from period (Jitter) and the variability of intensity from period to period (Shimmer) may be greaterthan in the normals, and concluded that "it is possible that large amounts of jitter and shimmer constitute an incipient form of diplophonia, or atleast are related to it in cause". However he observed no differences in glottal wave form shape and spectrum between the voice of normally hearing subjects and hearing impaired subjects.

While studying the control of the glottal wave over time, he noted that many of the hearing impaired subjects produced patterns of frequency and intensity changes which were different in various degrees from normal patterns. He reasoned that these deviant patterns of phonation were necessarily caused by a deviant pattern of control of sub - glottal air pressure and vocal fold tension.

With these observations Monsen et. al., (1979) concluded that "the effect of deafness upon phonation is one which extends beyond the \ limits of an individual glottal pulse ; deafness affects instead the way in which the speaker controls the changing qualities of phonation by the degree of tension of the vocal folds, the amount of subglottal air pressure, and the extent of glottal closure."

Wirz, Subtleny and Whitehead (1981) in a spectrographic investigation indicate that the tense vowels of the hearing impaired speakers consistently had more spectra] energy than their relaxed counterparts. By visual inspection of spectrograms they suggested that deaf speakers were using a variety of physiological and acoustic bases for this vocal tension.

B. I. 2. Voice quality and abnormal resonance

Abnormal resonance in the speech of the deaf has long been recognised (Hudgins and Numbers, 1942). However they found it to be a rare phenomenon. Colton and Cooker (1968) reported thai virtually all hearing impaired individuals have excessive nasality. The term nasalilv is referred to designate the perceptual impression of nasal quality.

Fletcher and Daly (1976) reported that nasalance was significantly higher in the hearing impaired speakers than in the control group. Rutherford (1967) has suggested that individuals are forced to rely heavily on the auditory feedback mechanism to establish and maintain the oral / nasal distinction, since there are a few tactile / kinesthetic sensory receptors in the velum as compared to the structures found in the anterior portion of the oral cavity. In addition he also noted the loss of the nasality feature in phonemes /m/, /n/ and /ng/ when normal subjects were deprived of their auditory feedback by use of masking. This indicates the importance of auditory feedback system in perceiving the perceptual cues for oral and nasal distinction. However, Seaver et. al., (1980) found a non - significant rho of 0.3 between the degree of hypcrnasality and the severity of hearing loss.

Excessive nasality in the speech of the hearing impaired individuals has been attributed to two reasons. They arc: 1) Improper control of the velum (McClumpha, 1966; Gilbert, 1975). 2) Speaking tempo (Colton and Cooker, 1968).

B. I. 2. a. Improper control of the velum

The improper control of the velum has long been recognised as a source of difficulty in the speech of the deaf (Brehm, 1922; Hudgins,1934). McClumpha (1966) compared the palatopharyngeal valving patterns of normally hearing and hearing impaired individuals through cineflourographic observations, and reported that all five normal speakers achieved and maintained contact of the palate with the pharyngeal wall while four of the five hearing impaired speakers never achieved closure. Gilbert (1975) studied the simultaneous nasal and oral air - flow in the speech of the hearing impaired children and observed thai the hearing impaired speakers were unable to co - ordinatc velopharyngeal function with the activity of the other speech articulalors. The nasal air - How profiles obtained by him clearly indicated that hearing impaired speakers represented a heterogenous population with regard to vclopharyngeal function, supporting the findings of McClumpha (1966). Stevens et. al., (1976) using a nasal accelerometer found that a number of deaf children exhibited inadequate velopharyngeal control. By comparing listener's judgements with accelerometer, they speculated that nasality may reflect an inappropriate timing of the opening and closing of the velum. Seaver, Andrews and Granata (1980) obtained several types of measures of 26 hearing impaired young adults. These measures included manomclric ratios, listener's judgements of nasality and degree of velar contact and opening as measured on still X - rays. Nineteen of the 26 subjects were judged to have speech characterized by hypernasality and nasal air emission was present only in live subjects. Lock and Seaver(1984) compared cincradiographic observations of velopharyngcal functioning and listener's judgements of hypernasality in the speech of five hearing impaired adults. In this study, while all the five hearing impaired subjects were perceived to have hypcrnasality in their speech, but only two speakers exhibited any velo-pharyngeal opening. The authors suggested that "the frequent reports of the presence of excessive nasality in the speech of this population are most likely due to a combination and interaction of a variety of factors. These might include mechanical inter connections within the speech production mechanism and the effect of a variety of other deviations."

Improper velar control has been described as both a "quality" problem and an "articulalory" problem. A quality problem because nasality due to improper velar control can give the speech a characteristic sound. It is an articulalory problem because improper velar control leads to a confusion between /m/, /n/, /ng/ and /b/, */d/* and /g/.

B.I. 2. b. Reduced speaking tempo

The excessive nasality judged to be present in the utterances of hearing impaired speakers may be due to the reduced speaking tempo as suggested by Collon and Cooker (1968). This view gets the support of Bzoch (1968) who found discontinuities in the palatopharyngeal contact as a subject reduced his speaking rate. Bzoch (1968) used cinefluorography to study the effects of speaking rate on velopharyngcal function in normally hearing speakers. He found that at habitual speaking rates no velopharyngcal opening was observed for the production of non - nasal phonemes. At slowed rates, some degrees of velo - pharyngeal opening was observed. Bzoch (1968) and Thompson and Hixon (1979), Gilbert and Hoodin(1984) found that speech tempo has an effect on velopharyngeal function. In their study nasal air - flow rates were greater at the slower speaking rates than the faster rates.

Objective and subjective assessment of nasality has been done in the speech of the hearing impaired persons. Judging nasality is difficult, in part because the perceptual features of nasalization have not been clearly defined and in part because the perception of nasality may be affected by factors like misarliculation, pitch variation and speech tempo. Because of these reasons objective measures that correlate with the nasality are of considerable advantage for assessment of nasality. Fujimura(1960) and House (1961) reported that shifted and split formant characterizes nasal sounds. Delattre (1955) suggested that nasality is indicated by enhanced amplitude of the lowest harmonics. Apart from spectrographic measurement to detect nasality, measurement of the (low of air through the nose (Quigley et. al., 1964; Lubker and Moll, 1965; and Gilbert, 1975), and me--surement of the vibration on the surface of the nose (Holbrook and Crawford, 1970; Stevens ct. al., 1974) have also been reported.

B. II. Inappropriate intonation

Inappropriate fundamental frequency variation (intonation) is another problem of voice that the deaf individuals have. Two major types of fundamental frequency variation in the speech of the hearing impaired are 1) Lack of variation of fundamental frequency and 2) Excessive or erratic fundamental frequency variation.

B. II. 1. Lack of variation of fundamental frequency

Several investigators (Calvert, 1962; Hood, 1966; Martony, 1968; Hood and Dixon, 1969; and Nandyal, 1961) noted that the hearing impaired individuals often tend to vary the fundamental frequency much less than do normally hearing individuals. Monsen 0978) measured the extent of variation of fundamental frequency variation and correlated it with intelligibility of speech A low correlation of 0.22 was obtained between the amount of fundamenlal frequency variation and speech intelliglbility. He reasoned that "some relatively unintelligible talkers may use extremely large degrees of variation in fundamental frequency over a smaller range. . . . .and measurement of the change of fundamental frequency docs not take into account whether that change is in an appropriate direction.

Monsen (1979), while studying the manner in which fundamental frequency changes over time, using spectrographic technique observed four types of fundamental frequency contours in the speech of the hearing impaired individuals. They are: (1) falling contour(in which the fundamental frequency declines smoothly at an average rate greater than 10 Hz per msec); (2) short falling contour (in which the duralion of the word is extremely short - less than 150 msec); (3) falling 11 at contour (in which there is rapid change of frequency at the beginning of the word, followed by a relatively unchanging flat (portion); and (4) flat contour (in which there may be a decline in fundamental frequency over the course of the word, it is less than 10'Hz per 100 msec).

The correlation coefficient between voice quality and the scores based on quantification of the intonation contours was 0.88, which indicated thai approximately 77% of the variation in the voice quality scores was due to this single variable. Thus, the type of fundamental frequency contour appears to be the most general acoustic characteristic which differentiates the better from the poorer voices.

B. II. 2. Excessive or erratic fundamental frequency variation

Excessive variation of fundamental frequency has also been reported in the speech of the hearing impaired individuals. Nickerson (1975) opines that such variations are not simply normal variations that have been somewhat exaggerated but, rather pitch breaks and erratic changes that do not serve the purpose of intonation.

B. **III. Inappropriate Rhythm**

It has long been recognized that inappropriate rhythm contribute to the problems of poorintclligibility in the speech of the hearing impaired. Hudgins and Numbers (1942) reported that those utterances marked by faulty rhythm (55% of all utterances) accounted for only 26% of all the intelligible sentences read by their deaf subjects. The remaining utterances which was characterized by good use of rhythm, regardless of whether there numerous articulatory errors, accounted for74%ofall the intelligible sentences. Thus it would seem that if a sentence is produced with appropriate rhythm it.stands a better chance of being understood. The proper rhythm of speech is affected by such factors as over all rate of speech, pauses in speech grouping of syllables and duration of phonemes (Gold 1980).

B.III.1. Rate of speech

Rate of speech has been defined as the number of words spoken per minute during a complete speech performance (Kelly and Steer, 1949). The rate of speech has also been defined s the number of syllables uttered per minute (Pickett, 1968). Franke (1939) found that the normal speech rate varies from 203 syllables per minute to 265 syllables per minute.

Several investigators (Voelkar, 1938 ; John and Howarth, 1965, Boone, 1966 ; and Colton and Cooker, 1968) have noted that deaf tend to speak at a much slower rate than do hearing persons. "Reduced speaking tempo is considered quite properly to be one of the aberrant characteristics of the speech of the deaf (Colton and Cooker, 1968). Voelkar (1938) and Hood (1966) reported that deaf speakers tend to speak more slowly than even the slowest hearing speakers, and when deaf and hearing speakers were studied under similar conditions, the measured rates of syllable or word omission often differed by a factor of there or more. Osberger and Levitt (1979) suggested that the speech of the deaf individuals has often been described as slow and laboured, because of errors like, reduced speaking rate (Voelkar, 1938 ; John and Howarth, 1965), excessive prolongation of speech segments (Hood, 1966 ; Levitt et. al., 1976), insertion of long pause (Nickerson et. al., 1974), introduction of adventitious sounds between phonemes and syllables (Hudgins and Numbers, 1942 ; John and Howarth, 1965 ; Smith, 1975), failure to temporarily differentiate stressed and unstressed syllables (Nickerson et. al., 1974) and failure to modify segment duration as a function of phonetic environment (Monsen, 1974). Monsen (1974) suggested that perceived slowness of speech is a phenomenon more immediately related to the rate of utterances than to relative phoneme duration. Monsen (1974) opined that "under identical circumstances (that is reading lists of words) the speech of the deaf can not be characterized as slower than the normal subjects. The reverse in fact is true, if the total durational range for both vowels is considered". This contradicts the common feeling that the speech of the deaf is slow. Rate of speech is not apt to be considered defective unless it interferes with intelligibility. However, recent investigations have indicated a relationship between syllable duration and speaker's intelligibility.

B.III.2 Pauses

Hearing impaired speakers have been found to insert more pauses, and pauses of longer duration in running speech than do hearing speakers. These noted increases within and between phrase pauses have been reported to contribute to the overall rate problem noticed earlier and also to the reduced speech intelligibility (John and Howarth, 1965 ; Hood, 1966; Boone, 1966 ; Boothroyd et. al., 1974; Levitt et. al., 1974 and Nickerson et. al., 1974). Stark and Levitt (1974) reported that their deaf subjects tended to pause after every word and to give stress to almost every word. According to John and Howarth (1965) the silences between words seen in their deaf subjects often accounted for one half the total time taken in saying the test sentences. Nickerson et. al., (1974) reported that total pause time for hearing children constituted 25% of the time required to produce their test sentences while the pause time for the deaf was 40% of the total time. Boothroyd et.al., (1974) found within phrase pauses to be a more serious problem than between phrase in deaf speakers. Hudgins and Numbers (1942) categorized rhythm errors as follows. 1) Sentences broken up into unusual breath groups, 2) Word accents misplaced and normally unaccented syllables added, 3) adventitious syllables added and 4) syllables omitted from polysyllabic words.

The problem of pauses have been attributed lo poor breath control during speech production. The deaf have been reported to use too much of breath per syllabic and do not group syllables into words and phrases as normals would do (Hudgins, 1946; Dicarlo, 1964 ;Forner and Hixon, 1977). They found the muscle activity to be normal for deaf individuals during quiet breathing but noted that they do not lake enough air when breathing for speech.

B.III.3. Increased duration of phonemes

The duration of phonemes bears important information to the perception of speech message. The duration of phonemes has been reported to be distorted in the speech of the hearing impaired. The prolongation of speech segments may be seen in the production of phonemes, syllables and words. A general tendency towards lengthening of vowels and consonants has been reported by several investigators and this has been discussed elsewhere in this article. Another manifestation of the problem of duration is that the hearing impaired speakers fail to differentiate between the durations of stressed and unstressed syllables. Although they prolong the durations of both stressed and unstressed syllables, the increase tends to be proportionally greater for the unstressed syllables. Also hearing impaired speakers lengthen stressed syllables and syllables in word final and sentence final positions. Bobthroyd, Nickerson and Stevens (1974) reported the unstressed syllables in the deaf to be twice longer than those of normals. Angelocci (1962) found that the durations of the unstressed vowels produced by the hearing impaired speakers were 4 to 5 times longer than those of normal speakers. 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).

B.III.4. Diadochokinetic rate

Diadochokinesis has been defined as the ability to perform rapid, alternating and repetitive bodily movements such as opening and closing of the jaws and lips, raising and lowering the eyebrows or taping the fingers (Wood, 1971). Diadochokinetic rate is a number of such movements per minute.

In the speech of the hearing impaired relatively a little is known of the underlying speech motor coordination skill. One of the measures in this direction is oral diadochokinetic rate. Only recently a few investigators (Robb et. al., 1985 ; Shukla, 1988 ; Bagul, 1991) have attempted to measure the diadochokinetic rate in the hearing impaired speakers.

Robb et. al., (1985), using time by count procedure, measured the oral diadochokinetic rate in 30 prelingually hearing impaired children. The results indicated slower diadochokinetic rate for the hearing impaired subjects compared to normals and when oral diadochokinesis was analyzed as a function of hearing loss a consistent trend was observed. The speed in the production of the diadochokinetic rate was closely related to degree of hearing loss for each child. These findings imply that exposure to auditory stimulation could very well be a stimulation factor to the development of co-ordination within the speech motor mechanism. Shukla (1988) measured the diadochokinetic rate in the hearing impaired speakers using a spectrograph and observed that the hearing impaired speakers had lower diadochokinetic rate when compared to the normally hearing speakers. On the average, the hearing impaired individuals uttered /pa, ta, ka/ 90 times per minute whereas the normals uttered 155 times per minute, and the difference was statistically significant. Bagul (1991) found a significant negative correlation between the degree of hearing loss and the ability to perform rapid and alternate movements of the articulators.

Shukla (1988) attributed the lower diadochokinetic rate in the speech of the hearing impaired 1) to the grater time lapse between syllable and 2) to prolongation of vowels within the syllables. Slower diadochokinclic syllable production by the hearing impaired speakers has been attributed to aberrant respiratory patterns observed in them (Forner and Hixon, 1977 ; Whitehead, 1982 ; Itoh and Horii, 1985). fomer and Hixon (1977) reported that the hearing impaired speakers initiate phonation at an inappropriate lung volume range. Whitehead (1982), while confirming the above findings, demonstrated that the hearing impaired speakers with low speech intelligibility initiated speech at substantially lower lung volumes and continued well below the functional residual capacity. Osbergerand McGarr(1982) suggested that speech attempted at such reduced lung volume is exceedingly difficult because the speaker is working against the natural recoil forces of the respiratory mechanism. Most probably, because of this abnormal respiratory patterns hearing impaired speakers produced fewer number of diadochokinetic syllables per minute. Recently, Itoh and Horii (1985) reported that speech respiration of the hearing impaired subject is characterized by high air expenditure per syllable, high average expiratory air flow rates, frequent inspiration at linguistically inappropriate places and short duration of expiration. These observations indicate that the hearing impaired speaker tended to waste much air which explains slower diadochokinetic syllable production rate.

III. Speech Intelligibility :

The ultimate goal of the speaker in the drama of interpersonal communications is to make himself understood to the listener. The importance rest on the intelligibility of speech which is considered as an overall measure of how well the speaker can make himself understood to the listener.

Speech intelligibility as a measure of speech potential of the hearing impaired has been investigated by several investigators. All these studies unequivocally suggest that the overall levels of speech intelligibility are utterly insufficient for oral communication (Hudgins and Numbers, 1942 ; Brannon, 1964 ; Markidcs, 1970 ; Smith, 1975 and Ravishankar, 1985).

Hudgins and Numbers (1942) who were the first to report data, had 192 hard of hearing and deaf subjects in the age range of 8-19 years. These subjects were asked to read sentences and a group of experienced teachers listened to the speech samples and wrote down whatever was understood by them. The number of sentences intelligibly produced were scored by awarding 10 points to each correct sentence. The mean score for the group was found to be 29%. Brannon (1964) found the speech intelligibility of 12 to 15 year old hearing impaired children with hearing levels of 75dB or more, as judged by a group of inexperienced listeners to be 20 to 25%. In another study Markides (1970) reported mean intelligibility scores of58 hearing impaired children of age range 7 to 9 years to be 19% as judged by a group of inexperienced listeners and 31 % for experienced listeners. The intelligibility score was a measure representing the number of words understood correctly by a group of listeners, out of the total number of words produced by each subject, while describing five unrelated pictures. Smith (1975) found the mean intelligibility of 40 hearing impaired subjects of age groups 8-10 years and 13-15 years to be 18.7%. In this study the subjects with hearing loss greater than 80dB were asked to read sentences and the range of speech intelligibility was seen to be 76%. A relatively high mean intelligibility score of 76% was reported by Monsen (1978). Out of the 67 subjects studied 23 subjects classifiable as severely hearing impaired obtained scores up to 91 % and the rest (44 Subjects) classifiable as profoundly hearing impaired had a mean score of 67%. The differences in speech intelligibility scores obtained by various studies stem form differences in methodology and the heterogeneity of the samples studied. For example intelligibility ratings vary with the type of judge employed (naive vs experienced listeners), with the type of materials used (sentences vs words) and heterogeneity of the subjects themselves (the degree of hearing loss among the subjects).

The results of the all these studies suggest that the overall levels of speech intelligibility are utterly inadequate for oral communication. The low speech achievement of the hearing impaired has led to several attempts in the past to correlate speech intelligibility with variables related to reception and production of speech. Among the perceptual variables, residual hearing, lip reading, and tactile perception abilities have been studied. These studies have shown that the residual hearing abilities show the maximum correlation with the speech intelligibility. Audiovisual perception which has gained much attention in recent years, however, has not been much studied in relation to speech intelligibility of the hearing impaired. Oral sensory perception also has been found to be inferior in the hearing impaired.

On the production side speech intelligibility has been studied with relation to segmental and suprasegmental errors. The segmental errors in the speech of the hearing impaired have been reported to be strong deterrents to speech intelligibility (Hudgins and Numbers, 1942 ; Brannon, 1966 ; Markides, 1970 ; Smith, 1975 ; Gold, 1978 and Ravishankar, 1985). Studies on acoustic features of speech of the hearing impaired have also supported the findings these studies (Calvert, 1961 ; Monsen, 1976a, 1978). Researchers also have attempted to correlate speech intelligibility with suprasegmental errors (Hudgins and Numbers, 1942 ; John and Howarth, 1965 ; Smith, 1975 ; McGarret. ah, 1976; Monsen 1979). Suprasegmental errors have also been noted to be detrimental to speech intelligibility. Thus the results of several studies have indicated that the hearing impaired show errors on several perceptual and productive tasks which exhibit significant relationship with speech intelligibility..

Ravishankar (1985) reported that speech intelligibility score was highly correlated with the audiovisual recognition abilities, segmental errors, hearing loss, visual recognition ability and tactile perception ability. No significant relationship between speech intelligibility score and orosensory perceptual ability was observed.

To summarize, speech of the hearing impaired children differs from normals in all regards. Earlier studies, attempting to describe deviancies in the speech of the hearing impaired when compared to the speech of the normally hearing speakers, have employed perceptual method of evaluations. Recently, with the advancement in technology, great strides have been made in understanding the speech of the hearing impaired, but our knowledge in the area is far from complete. Further, research is needed to delineate the developmental stages of speech acquisition in the hearing impaired. Future research should also focus in finding out acoustic and physiological correlates of specific error types, be it segmental or suprasegmental error. Further research should also focus it's attention on determining the effect of specific error types on the speech intelligibility and attention should also be focused on developing remediation strategies based on the information gathered through acoustical and physiological studies.

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