ACOUSTIC ANALYSIS OF PROSODY OF PUNJABI — IN DEAF CHILDREN

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MAY 1998

DEDICATED

TO

THE SUFFERERS -

THE HEARING IMPAIRED

CERTIFICATE

This is to certify that the dissertation entitled "Acoustic Analysis of prosody of Punjabi - (in Deaf Children) has been prepared under my guidance and supervision.

Mysore
May 1999

Dr. N.P. NATARAJA
Guide

CERTIFICATE

This is to certify that the dissertation entitled " Acoustic Analysis of prosody of Punjabi" ***(in Deaf Children)*** *is the bonafide work in part fulfilment for the degree of Master of science (Speech and Hearing) of the*

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DECLARAT10N

This dissertation entitle "Acoustic Analysis of ***prosody of Punjabi".****(in Deaf children) is the result of my own study under the guidance of Dr. N.P. NATARAJA, Reader and HOD, Department of speech science. All India India Institute of a Speech and Heading, Mysore and has not been submitted earlier at any other university for any other diploma or degree.*

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INTRODUCTION

"Communication equals speech plus language plus listening. "Speech" is the process of producing meaningful sounds or words, "Language" is the content of speech, the meaning of words, "Listening" is the process of receiving and understanding those words" (Hamaguchi, 1995). Children start on the road of successful communication as soon as they are born. In order, for children to understand and use spoken language in a meaningful way, some prerequisites must be present, the important ones are (1) their ears must hear well enough from the childhood to distinguish one word from another, (2) some one must show or model, what words mean and how words are put together to form sentences, (3) the ears must hear prosodical variations, i.e. intonation patterns, accents, and sentence patterns.

I heard one parent saying "Most of the time I can figure out what my child wants from us. We have developed a "code" and we have learned to be good translators of his speech. I feel bad when other people don't understand him. I would not want him to feel as he is different from the other kids. We have given him so much stimulation from the time he was born and we came to know about his hearing loss. But still his speech is not clear".

Research to determine the factors responsible from poor intelligibility of speech in the hearing-imparied is not new. Several efforts have been made to determine the most important factors, the correction of which would improve intelligibility (Krunger et al., 1972; Lang, 1975; Bernstein, 1975; Massen and Povel, 1985. Speech correction in the hearing impaired has long been under study throughout the world, and attempts to teach speech to the hearing impaired are going on worldwide. Yet, the competence of the hearing impaired to make himself understood remains to be poor (Ling, 1976). Only about 20% of the speech of the hearing impaired may be understood by the person on the street (Gold, 1980). Such results have made it evident that speech may not be a viable communication medium for the hearing-impaired leading to frustrations and unrewarding experiences to them (Smith, 1975).

Both the articulatory and acoustic characteristics of speech of hearing-impaired have been well described by researchers (Monsen, 1976a, 1976b, 1974, 1978; Angelocci et al., 1964; Gilbert, 1975; McClumphe, 1966; Calvert, 162; Shukla, 1985; Rajnikanth, 1986; Sheela, 1988; Jagadish, 1989; Rasitha, 1997). Most of the attention, hov/ever has been devoted to aspects of segmental production - perhaps because this area is felt to be more critical for speech intelligibility. The role of suprasegmental aspects (see appendix I for definitions) the intelligibility of speech has not been studied much. The prosodic aspects of speech are more poorly understood than the segmental aspects (Graddol, 1990).

Prosody plays even more important role in tone languages. As cited by Connell et al. (1983) and Lyovin (1978), the Russian Linguist Rumjaneev (1972) contends that "... intensity and duration may both play a prominant role, particularly in tone languages where change in fundamental frequency is the main perceptual cue for the tones". Affective prosodic colouring of speech encompassing attitudes (eg. sarcasm, irony, disgust, sincerity), emotions (eg. happy, sad, surprise, anger) and idiodsyncratic and regional variations are said to be found in every human language, attitudes and emotions in tone languages are expressed using prosodic features (Crystal, 1976).

Prosody in deaf speech has not been studied to the same extent as they have been in the speech of normal-hearing speakers, even though it is apparent that deaf speakers have abnormal intonation and timing patterns. Differences between deaf and normal hearing speakers have been identified in general (Hudgins and Numbers, 1942; Mcgarr and Osberger, 1978; Parkhurst and Levitt, 1978; Stevens, Nickerson and Rollins, 1978; bocner et al., 1987; Metz, 1980). But the particular characteristics of intonation and timing in deaf speech have yet to be agreed upon. Researchers who have studied timing in deaf speech also differ in whether they interpret their results as differences in degree or quality. Some researchers emphasize the slowness of deaf speech, which would be a difference in degree. Deaf speakers generally take longer to say the same things as normal hearing speakers (Hood and Dixon, 1969; Voelker, 1938; Nickerson, 1975; Metz, 1980; Stathopoulous et al., 1986). Although pausing is associated with intelligibility of speech produced by deaf individuals (Osberger ad Levitt, 1979; Parkhurst and Levitt, 1978; Stromberg and Levitt, 1979), the precise nature of their relationship is not clear because little is known about the suprasegmental aspects of hearing impaired speech.

Since the speech related parameters are language specific, so there is need for studies in Indian language. There studies in India language. There was no study in this direction in Punjabi language. This would further help in planning better therapy programmes for hearing impaired children.

Importance and Need for the Present Study

1. Since, very few attempts (Nandayal, 1981) has been made to study prosodic aspects of speech hearing impaired in Indian languages, so there is great need for this study.

2. The information that is available on this aspect about speech hearing impaired is not sufficient to reach any

conclusions. This study is hoping to throw more light in terms of prosodic aspects of hearing impaired speech and the differences between speech of normal and hearing impaired.

3. Prosody plays a major role in tonal languages and "Punjabi" being a tonal language, it is eve more interesting to study prosodic aspects in this language.

Purpose of the Study

The purpose of the present study is to examine the following parameters in speech hearing impaired and normals.

1. Rate of speech
2. Pauses in hearing impaired speech in terms of number, location and duration of pauses
   - Interword pause durations
   - Intraword pause durations
   - Between sentences pause durations
3. To study stress in speech of hearing impaired and normals.
4. To study pitch and intonation contours in the speech of hearing impaired and normals.

Hypothesis of the study

1. There is no significant difference in the speech of hearing impaired and that of age and sex matched normal hearing speakers in terms of

   a. Rate of speech
   b. In terms of number, location and duration of pauses.

c. In terns of stressed syllables.

d. In terms of pitch and intonation contours.

e. In terns of fundanental frequency and frequency range.

2. There is no significant difference betv/een normal male and female subjects and hearing impaired male and female subjects in terms of above mentioned parameters.

Brief methodology

The speech samples (a story) from ten Punjabi speaking hearing impaired (five males, five females) and ten Punjabi speaking normals subjects matched for age and sex were collected and subjected for analysis using the software package "VAGHMI" of voice and speech systems (VSS).

Implications of the study

The results of the present study will be helpful in knowing

1. The contribution of prosodic aspects to speech intelligibility.
2. Prosodic aspects of Punjabi language in particular.
3. Differences between the speech of the hearing impaired and normals in terms of prosodic aspects and thus applying this knowledge in the correction of the speech of the hearing impaired.

Limitations

1. All range considered in this study limits to only 10-15 years.

2. Only read passages are studied.

REVIEW OF LITERATURE

"Language is undoubtedly the most important factor that differentiate man from other animals. Language is in, itself, a set of arbitrary symbols used to communicate thoughts and ideas" (Chomsky, 1966).

Language is expressed in various forms. Speech is one of the most important and characteristic form of language used in human being. Speech is a form of language that consists of sound produced by utilizing the flow of air exhaled from the lungs.

"The art of speaking is a very specialized way of using the vocal mechanism. The act of singing is seen more so. Speaking or singing demand a combination or interaction of the mechanism of respiration, phonation, resonance and speech articulation" (Boone, 1971).

Speech may be viewed as a unique method of communication evolved by man, the uniqueness of his mind. By its great flexibility, it permits man to produce a variety of signals commensurate with the richness of his imagination. At the same time, the ability to think in terms of casuality and purposiveness (time building) enables man to expand enormously his use of reciprocal communication for the co-ordination of social activities" (Eisenson, Auer and Irwin, 1963).

Speech is the acoustic end product of voluntary motion of the respiratory and masticatory apparatus.

"The one faculty which sets man apart from all living organisns - which makes him unique in his ability to communicate, using his vocal tones for special interaction" (Fisher, 1966).

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

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

Speech characteristics as described by various investigators typical to that of hearing impaired individuals include misarticulations, nasality, high pitch, flow rate, rhythm, pauses, and faulty stress and intonation patterns. This review deals with the characteristics of speech in terms of its suprasegmental features in normals as well as deviant population. This review also includes the relationship of intelligibility with suprasegmental aspects of speech.

"The sounds of speech are referred to as the segmental features. There are other features involved to indicate that, which segments are said. These include the loudness variations, pitch variations, duration changes, voice quality and others. Such features usually extend over utterances longer than one sound and are hence referred to as "suprasegmentals" or prosodic features (Cruttenden, 1986). The melody of speech is conveyed through the prosodic features. Both intonation and stress contribute to the intelligibility of contextual speech. Intonation (variations in vocal pitch) is used to mark the ending of a phrase, to differentiate a question and sometimes to change meaning. Stress is created by subtle changes in pitch, duration and intensity of a syllable or word. It can show feelings and can change the meaning of a word. These features are considered as the important aspects of speech, but highly evasive properties of spoken language (Price, Ostendorf, Shattuck-Hufnagel and Fong, 1991).

The prosodic structure of speech is the result of complex interaction with and within the different levels of language such as the semantic, pragmatic, syntactic phonatactic, rhymic and others (Rossi, 1993). But the interaction of these prosodic features within and across the languages are still poorly understood (Collier, 1991).

Variations in pitch occurs in the sentences of all languages. No language uses a pure monotone (Pike, 1945). In each language, however, the use of pitch variation tends to become semi-standardized, or formalized, so that all speakers of the language use basic pitch sequences in similar ways under similar circumstances. These abstracted characteristic sentence melodies may be called intonation contours (Pike, 1945).

The two most deep-seated characteristics of intonation are that (a) the distribution of its contours over phrases, and (b) the addition of shades of meaning to phrases rather than the giving of lexical meaning to words. Both of these characteristics can be seen in contrast with a different type of pitch system in tone languages (Pike, 1945).

According to Cruttenden (1986) languages can be divided into tone languages, intonation languages, 'stress accent' languages, and 'pitch accent' languages. In intonation languages, intonation involves the occurrence of recurring pitch patterns, each of which are used with a set of relatively consistent meanings, either on single words or on groups of words of varying length. Grammatical constituents of any level, upto the sentence may be treated as separate intonation groups having their own meaningful tune. Intonation groups or intonational phrases generally correspond to constituents of any level, upto the sentence may be treated as separate intonation groups having their own meaningful tune. Intonation groups or intonational phrases generally correspond to constituents of sentences, in a some what loose way.

"The distinction between 'stress accent' languages and the 'pitch accent[1] languages has never been very clearly defined" (Cruttenden, 1986). According to him, the term 'stress accent' is usually used to refer to languages, like English, using pitch primarily for intonational purposes. It implies that prominent syllables in such languages are washed primarily by 'stress', which in this sense seems to mean breath force or loudness.

Cruttenden (1986) states that in 'pitch accent' languages such as Japanese, words with an accent realize the accent by a high pitch on the accented syllable which is followed by a low pitch on the following syllable. The pitch of unaccented syllable is predictable by rule, i.e. an initial unaccented syllable is low, ant other unaccented syllable before the accent are high, and all unaccented syllables following the accent are low.

In tone languages, pitch is principle exponent of intonation. Pitch is also used for differences of tone being described in terms of prescribed pitches for syllables or sequences of pitches for morphemes or words; whereas intonation is a feature of phrases or sentences (Cruttenden, 1986). Tone concerns the pitch patterns of words. A change of meaning is produced if one tone is exchanged for another on one syllable, while keeping the segmental composition unchanged. This situation results in sets of words distinguished only by tone and applies to many languages of the far east (Bolinger, 1972).

Intonation differs from tone in the type of meanings it conveys. While tone is used for contrasts in lexical meaning or to produce modification of meaning of the utterance such as cases or tenses, the meanings conveyed by intonation are often less concrete. Intonation may indicate a discoursal meaning like inviting a listener to make a contribution to the conversation, or an attitudinal meaning. In some languages, the meanings associated with intonation may come nearer to the grammatical use of pitch in tone languages. This is the case where the use of particular tunes is closely tied to functional sentence types, such as statements, yes - no questions and commands (Cruttenden, 1986).

Punjabi being a tonal language, in which the pitch of each syllable is basic to the word. Pitch contours are located on single syllables, not on groups of syllables (Gill, 1969). In addition to their lexical pitch, however, tone languages may have various types of pitches superimposed upon them. Thus, the general pitch of the voice may carry implications of anger, disgust, joy and so on (Pike, 1945). Prosodic features extend over varying domains. They extend over short stretches of utterances like one syllable or one morpheme or one word, or may extend over relatively long stretches of utterances like a phrase, a clause or a sentence. The prosody of connected speech is analyzed and described in terms of variations of features.

Prosodic features comprise special phenomenon in language and have properties which set them apart from other phonological phenomenon. Sapir (1921) write that 'variations in accent whether of stress or pitch' or 'the subtlest of grammatical processes.

Speech prosody, the intonation, the stress, the rhythm of a language is a function of vocal pitch and loudness as well as of phonetic duration (O'Malley and Peterson, 1966). Although vocal quality is not considered a factor in prosody it probably is affected by stress and intonation. This is to say that prosody is not a function of vocal quality, but quality may well be a function of prosody; the difference lies in, which is the independent and which the dependent variable. This comment is based on the observation that vocal stredency is more likely to be associated with strong stress and intonation patterns (prosodic factors) than with relaxed patterns.

Another aspect of the speech signal which should be recognised is the prosodic variation of the voice. The prosodies are basic to such linguistic concepts as stress, intonation, rate and to nonlinguistic concepts such as individual voice characteristics and emotional characteristics of the voice. The human speech can provide simultaneous information about this plethora of nonlinguistic functions, to say nothing of its linguistic load, seems remarkable. Consider this unremarkable possibility; the telephone rings, you answer it, and within a few seconds a conversation, you manage to recognise the speaker by his voice, understand the words he is speaking, reflect on the generally agressive nature of his personality, note the elation, what he feels as he talks of his latest administrative group, can feel that he is apparently suffering from a cold, and respond with some aversion to unpleasant harshness of his voice. All these are possible because of prosodic variation of the voice.

The acoustic prosodic parameters function in language to signal certain meaningful distinctions between utterances. Syllable stress and sentence intonation in English are manifested primarily by variations in the prosodic parameters. Fry (1955, 1958) manipulated the intensity, duration and fundamental frequency patterns of a set of two syllable words such as 'object' which could be interpreted as either nouns or verbs depending on whether the first or second syllable was stressed. Fundamental frequency is also basic to intonation which for example, is sometimes employed by a speaker to change a declarative utterance into an interrogative one. Thus the linguistic functioning of fundamental frequency is complicated by its simultaneous involvement with both stress and intonation (Fry, 1958).

A good understanding of how variations in the acoustic prosodic parameters are to be interpreted as linguistic signals has yet to achieved. Overall, the 'prosodic aspects of speech' are more poorly understood than the 'segmental' aspects.

Prosody in the speach of deaf has not been extensively studied. The oral communication skills of the hearing impaired, have long been of concern to educators of the hearing-impaired speech pathologist and audiologists, because of the adequacy of such skills can influence social, educational and career opportunities available to these individuals (Osberger and McGarr, 1982).

"The ultimate goal in aural rehabilitation for the hearing impaired individual is to attain as far as possible the same communication skills as those of normal hearing individuals. The poor oral communication skills of the hearing impaired are evident to anybody who may have heard their speech. However, deaf children can be trained to speak proficiently, and these problems can be overcome, if we had greater insight into the essential problems" (Levitt, 1974).

Several methods have been employed to study speech production in hearing impaired. These include physiological (Metz et al., 1985), acoustic (Mosen, 1976a, 1976b, 1974, 1978; Angelocci et al., 1964; Gilbert, 1975; McClumpne, 1966; Calvert, 1962; Shukla, 1985; Rajanikanth, 1986; Sheela, 1988; Jagdish, 1989; Rasitha, 1994) and perceptual methods (Levitt et al., 1976; Stevens et al., 1983; Hudgins and Numbers, 1992; Markides, 1970; Geffner, 1980).

Use of acoustic analysis of speech for studying the speech production skills, offer several advantages as it is non-invasive, needs relatively simple instrumentation, may be used routinely to depict changes in the physical characteristics of frequency, intensity, and duration of speech segments (Leeper et al., 1987). Acoustic analysis of speech of hearing-impaired permits a finer grained consideration of some aspects of both correct and incorrect production than would be possible using methods applied in the subjective procedures (Osberger and McGarr, 1982). It provides objective description of speech of the hearing impaired. More information about the characteristics of hearing impaired would help in making use of the advances in technology with maximal effectiveness in facilitating the oral production skills of the hearing-impaired.

Importance of suprasegmental aspects in intelligibility of speech

Both the articulatory and acoustic characteristics of deaf speech have been described by researchers. Most of this attention, however, has been denoted to aspects of segmental production, perhaps because this area is felt to be more critical for speech intelligibility. However 'suprasegmental phenomenon, particularly those aspects which relate to prosody, i.e. voicing control, pitch control, pitch range and level syllable stress, vowel length, pauses, do play an important role for speech intelligibility (Graddol, 1991). Only about one in five words they say can be understood by a listener who is unfamiliar with the speech of this group (Brannon, 1966; John and Howarth, 1965; Markides, 1970; McGarr, 1978; Smith, 1975).

Various factors have been found to effect intelligibility. Among these factors, hearing level, segmental and suprasegmental aspects play an important role. Several investigators have observed that more than prosodic deviations, segmental deviations are primarily responsible for reducing the intelligibility of the speech of the deaf.

Only when the segmental articulation was satisfactory, improvement in intelligibility could be obtained from the correction of prosodic deviations. Improvement in prosody improves the naturalness and overall quality of the speech (Oster, 1985).

The role of suprasegmental features of speech in the intelligible verbal discourse has been well documented by several investigators (Eisenson, 1971; Lieberman, 1972; Geers, 1978). The suprasegmental errors that are studied in relation to speech intelligibility are timing errors, pitch and intonation errors and errors in nasality. Most of these errors have been found to be detrimental to speech intelligibility.

Studies that have attempted to determine the role of deviant suprasegmental production and unintelligible speech are of two types: 1. Correlational studies, i.e. where the intelli-gibility of speech is correlated with the number of errors in speech.

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

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

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

The other noted characteristics of the hearing impaired speech are an abnormal control over duration and fundamental frequency (Ando and Canter, 1969; Brannon, 1966; Hudgins, 1960). In particular duration of words or sentences often seem excessively long, and the pitch contour over individual words is either too high, too monotonal, or simply "inappropriate". Indeed, some have even suggested that the abnormal rhythmic or prosodic pattern is one of the most basic deterrants to good quality, intelligible speech (John and Howarth, 1965; Hudgins and Numbers, 1942; Voelker, 1938).

Higher intelligibility scores for severely hearing impaired (91%) and less for profoundly hearing impaired (76%) were reported by Monsen (1968). Though hearing loss is an important variable, this measure alone cannot reliably predict the intelligibility of a child's speech (Smith, 1975).

Timing

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 Hudgin and Numbers (1942). Although they correlated rhythm errors with intelligibility, many of,these errors appear to be due to poor timing control.

The results of other correlational studies have typically shown moderate negative correlation between excessive prolongation of speech segments and intelligibility (Monson and Lecter, 1975; Parkhurst and Levitt, 1978). In a study, Reilly (1979) found that relative duration (stressed:unstressed syllable nuclei duration ratio) demonstrated a systematic relationship with intelligibility.

Parkburtst and Levitt (1978) indicated that another type of timing error, the insertion of short pauses at syntactically appropriate boundaries had a positive affect on 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. Similar findings were reported by Oster (1987).

Intelligibility and respiratory control (Oster, 1990)

To be able to realize the prosodic system of a language, some physiological conditions must be perfectly controlled during speech. Deaf speakers have poor breath control. They use too much of air per syllable and have difficulties in controlling respiration for speech. Whitehead (1983) investigated the respiratory patterns during speech of 10 deaf male adults with a pure tone average loss of 105 dB. He found that some deaf speakers don not inhale while speaking, as the volume of air in the lungs decreases. Most of the subjects spoke on low lung volumes. Some even initiated reading and conversation below the residual air capacity without inspiration. They extended their expiration well into the reserve volume. When speaking below the functional residual capacity, the speaker must use higher muscular pressure to achieve speech. The lack of sufficient air is one reason for the bad control and low intelligibil-ity of their speech.

The relationship between errors involving Fo control and intelligibility

The inability to control Fo while speaking contributes to the low intelligibility of the speech of the hearing -impaired (Boothroyd and Deacker, 1975).

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

McGarr and Osberger (1978) found that for the majority of the children studied, there seemed to be no simple relationship between pitch deviancy and intelligibility. Some children whose pitch was judged appropriate for their age and sex had intelligible speech, while others did not. The exception to this pattern were the children who were unable to sustain phonation and whose speech contained numerous pitch breaks. Their speech was consistantly judged to be unintelligibility. Monsen (1979) found that pitch contours correlate significantly with voice quality ratings, and suggested that significant correlation with intelligibility will only be found when intonation patterns are taken into account.

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

The effect of prosody on intelligibility has been evaluated mainly by correlational techniques. In studies using subjective ratings of all prosodic features combined (F_o, temporal structure and intonation) it was found that errors in rhythm (Hudgins and Numbers, 1942) poor phonatory control (Smith, 1975) and staccato prosody (McGarr and Osbrger, 1978) or syllable speech (Levitte et al., 1976) till show moderate to high negative correlations with speech intelligibility (Povel, 1984).

Studies that attempted to determine the cause and effect relationship between speech intelligibility have dealt primarily with timing (Osberger and McGarr, 1982). John and Howarth (1965) reported significant improvement in the intelligibility of profoundly hearing-impaired children's speech after the children had received intensive training focussed only in the correction of timing errors. Houde (1973) observed a decrement in intelligibility when timing errors of hearing-impaired speakers were corrected, similar results were obtained by Boothroyd et al. (1974). A major problem with the training studies is that the training may result in changes in the child's speech other than those of interest. In addition to this, the effect of phoneme production and of prosodic feature production upon intelligibility have not been separated sufficiently in these studies (Osberger and McGarr, 1982). Recent investigations have attempted to eliminate this confounding variables by using modern techniques such as "Analysis by Synthesis".

In such studies speech is either synthesized with timing distortion (Lang, Hudgins, 1977; Bernstein, 1977) or synthesized versions of the speech of the hearing-impaired are modified so that the errors (timing or pitch and intonation errors) are corrected selectively (Osberger and Levitt, 1979; Povel, 1984; Oster, 1985; Massen, 1986; Jagdish, 1988; Sheela, 1988; Rasitha, 1994).

Gold (1980) gave a detailed review of a large number of studies dealing with the production characteristics of hearing-impaired individual. He concluded -

"Whereas there is much documentation of the kinds of segmental and suprasegmental errors in the speech of hearing-impaired, there is fat less evidence of the direct effects of each of these errors types on overall speech intelligibility". Thus although we may be able to identify those errors to occur most frequently in the speech of the deaf, we need further research to indicate how these error types interact to reduce speech intelligibility and to determine which error types should be the first to be considered when planning a training program for improved speech production in the hearing-impaired children". Through the use of modern speech synthesis techniques, it is possible to determine the causal relationship between the errors and the intelligibility without the presence of the confounding variables than are seen in the training studies (Osberger and Levitt, 1979).

In digital manipulation techniques it is easy to correct errors in the time domain (suprasegmental) but more difficult to correct segmental errors (Hudgins, 1977; Kruger et al., 1972; Osberger and Levitt,1979). If speech synthesis techniques are used, both types of errors can easily be corrected or inserted, especially if a synthesis by rule system is used (Bernstein, 1977).

Lang (1975) used an analysis-synthesis approach to correct timing errors in the speech samples produced by hearing-impaired speakers, and also to introduce timing distortions in the samples of normal speakers. Minimal improvements in intelligibility were observed for the speech of the hearing-impaired and minimal decrements in intelligibility were observed for the normal speakers. Bernstein (1977) found no reduction in the intelligibility of speech samples produced by a normal speaker when synthesized with timing errors. In contrast to this Hudgins

(1977) found that when normal speech was synthesized with the durational relationship between stressed and unstressed syllables reversed, there was a substantial reduction in intelligibility. 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 and Levitt (1979) quantified the relative effect of timing errors on intelligibility by means of computer stimulation. Speech samples produced by hearing-impaired children were modified to correct timing errors, only, leaving all other aspects of the speech unchanged. Three types of corrections were performed, relative timing, absolute syllable duration and pauses. Each error was corrected alone and together with one of the other timing errors. Six stage approximation procedure was used to correct the deviant timing patterns in the speech of six deaf children. They were:

1. Original unaltered sentences
2. Correction of pause only
3. Correction of relative timing
4. Correction of relative timing and pauses
5. Correction of relative pauses
6. Correction of absolute duration and pauses.

An average improvement in intelligibility was observed only when relative timing errors alone were corrected. The second highest intelligibility score was obtained for the original, unaltered sentences. The intelligibility scores obtained for the original sentences, on the average. However, the improvement was very small (4%). Since the timing modifications for this condition involved only the correction of the duration ratio for stressed to unstressed vowels, the overall durations of the vowels (eg. syllables) were still longer than the corresponding duration in normal speech. "These date indicate that the prolongation of syllables and vowels, which is one of the most obvious deviancies of the speech of the hearing-impaired, does not in itself have a detrimental effect on intelligibility (Osberger and McGarr, 1982).

Maassen and Povel (1984a) changed the syllable and phoneme duration such that they were either absolutely or relatively equal to durations of the corresponding segments in the normal utterances. Intelligibility improved from 25% to 30% when a phonemic relative correction was performed for 26 out of 30 sentences. Here, each phoneme got the same relative duration as the corresponding phoneme in a normal utterances. Improvement in speech intelligibility was 11% to 17% when syllabic relative correction was done, for eight sentences out of thirty sentences where the syllable was the unit of transformation. For five sentences largest increase resulted from a phonemic absolute correction (intelligibility improved from 21-28%).

Maassen and Povel (1985) conducted three experiments to study the effect of segmental and suprasegmental corrections in the intelligibility and judged quality of the speech of the deaf. By means of digital signal processing segmental and intonation corrections were carried out on 30 Dutch sentences spoken by 10 deaf children. The transformed sentences were tested for intelligibility and acceptibility by presenting them to inexperienced listeners. A complete segmental correction improved the intelligibility from 24% to 72% which for a major part was due to correction of vowels. The correction of temporal structure and intonation caused only a small improvement from 24% to 34%. Combination of segmental and suprasegmental corrections yielded almost perfectly understandable sentences, due to a more than additive effect of the two corrections. Quality judgements were in close agreement with intelligibility measures. "The results show that, in order for these speakers to become more intelligible improving their articulation is more important than improving their production of temporal structure and intonation" (Maassen and Povel, 1985) .

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

Sheela (1988) studied the effect of computer correction of some of the temporal aspects in the speech of the hearing-impaired on speech intelligibility. She studied eight children, four normal and four hearing-impaired. The age group was 8-10 years. The hearing-impaired children were having bilateral hearing loss of 70 dB or greater. The test materials consisted of 8 bisyllabic Kannada words. The recorded words were digitized and acoustic analysis was carried out to obtain of the vowel duration, word duration, F0, Fl, F2, F3, BW1, BW2 and BW3. Later the correction of vowel duration, pauses and F0 were made in the speech of the hearing -impaired for those words where in these parameters were deviant from the normal individuals mean value in order to match the mean values of the normals.

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

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

The correction of timing errors and average F0 did affect the intelligibility of speech of the hearing-impaired. The correction of different types of errors either in isolation or in combination had differential effect on the intelligibility. It was seen that the maximum improvement in intelligibility was observed when only the vowel duration was corrected. It was noticed that when pauses alone were corrected, and when the combination of vowel duration and pauses were corrected the scores were less.

Jagadish (1989) studied the effect of computer correction of some of the temporal aspects in the speech of the hearing-impaired on speech intelligibility. He studied six children normal hearing and three hearing-impaired aged between 9-12 years. The hearing-impaired children were having bilateral hearing loss of 70 dB or greater and without any additional handicaps. The test material consisted of eight bisyllabic words in Kannada. Speech samples were recorded and the acoustic analysis was done to find the vowel duration, word duration, F0, formant frequencies and bandwidth. The corrections of those parameters where there were significant differences between the values of the normal hearing group and the hearing-impaired group were done. The parameters corrected were, vowel duration and pause, and the combination of these two parameters.

The results of the study indicated that -

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

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

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

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

Thus it is seen that the speech of the hearing-impaired is characterised by several errors, which make it highly unintelligible. While several investigators have attempted to determine the contributions of various errors to the poor speech intelligibility, it is through modern speech analysis and synthesis techniques that the researchers have found it possible to control the variables in speech. The present study is aimed at analysing the speech of the hearing-impaired, to see how it varies from that of the normals in terms of prosodical aspects and thus how much it contributes for the intelligibility of speech of the hearing-impaired speech using modern digital signal processing techniques.

Temporal factors

1. Rate

Physical measures of speaking rate have shown that profoundly hearing impaired speakers on the average take

1.5 to 20 times longer to produce the same utterances as do normal hearing speakers (Boone, 1966; Hood, 1966; Howardh, 1965; Voelker, 1935) . Hearing impaired speakers have been found to speak more slowly than even the slowest speakers with normal hearing when hearing impaired speakers and normal hearing people have been studied under similar conditions. Nickerson et al. (1974) studied deaf and control groups on reading rate and found large differences between the groups although the mean rate for the deaf was as high as 108 words/min.

The problem of reduced rate of speaking in the deaf speaker seems to be related two separate problems:
1. Increased duration of phonemes, and 2. improper and often prolonged pause within utterances (Gold, 1980).

1. Increased duration of phonemes

The duration of phonemes bear important information in the perception of the speech message. 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). There is a general tendency towards lengthening of vowels and consonants in the deaf (Angelocci, 1962; Boone, 1966; Levitt et al., 1974; Levitt and Parkhurst, 1978; Sheela, 1988; Rasitha, 1994).

Calvert (1961) was among the first to obtain objective measurements of phonemic duration in the speech of hearing-impaired by spectrographic analysis of bisyllabic words. This study showed that hearing-impaired speakers extend the duration of vowels, fricatives, and the closure period of plosives upto five times the average duration for normal speakers. Monson (1946) studied 12 deaf and 6 normal hearing adolescents as they read 56 CVC, words containing the vowels /i/ or /I/. He found that the deaf subjects tend to create mutually exclusive durational classes for the two vowels, such that, the duration of one vowel could not approximate that of the other, even when they occurred in the presence of different consonants. For the normal subjects, the duration of /i/ was always longer than /I/ for a particular consonantal environment, but the absolute durations of the two vowels could overlap if the accompanying consonants differed. Thus, although the vowels produced by the deaf subjects were distinct in terms of duration, they were still less intelligible since the listener could not rely on normal decoding strategies to interpret the speech that was heard.

In a study by Obserger and Levitt (1979) observed that syllable prolongation in the speech of hearing-impaired was due primarily to prolongation of vowels.

Data by Obserger (1978) on mean syllable duration in a sentence produced by six normally hearing and six profoundly hearing impaired children showed a distinctive pattern of syllable durations for the two groups of speakers. Study indicated that there is greater variability in syllable duration among the hearing impaired than among the normal speakers.

Calvert (1961) varied the vowel duration with reference to the voice-voiceless distinction of the following consonants. The hearing-impaired fail to produce the appropriate modifications in the vowel duration as a function of voicing characteristic of the following consonant. Hence the frequent voice-voiceless confusions observed in their speech may actually be due to vowel duration errors.

Shukla (1987) compared vowel duration and consonant duration in thirty normal and hearing-impaired individuals matched for age and sex. The results indicated the following:

1. On average the duration of vowel /a/ was longer when followed by a voiced consonant than when followed by a voiceless consonant in both the groups of subjects. Hov/ever, in both the groups the difference was not very significant.

2. The duration of vowel /a/ in the medial position was longer in the speech of the hearing impaired than in the speech of the normal hearing speakers.

3. Hearing impaired speakers showed a greater variation in vowel durations than normal hearing speakers.

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

5. Hearing impaired speakers showed a greater variation in controlling the length of all the consonants than the normal hearing subjects.

Sheela (1988) studied vowel duration in four normal and four hard of hearing individuals, and the result indicated that on the average the hearing-impaired group had significantly longer durations for vowels than that of normal hearing group. Studies (Levitt, 1979; Stevans et al., 1978; Osberger and Levitt, 1979) showed that the hearing impaired produce mostly stressed syllables and that there is an overall tendency for increasing the duration of all phonemes in the speech of the hearing-impaired. The lack of differentiation between the length of stressed and unstressed syllables may contribute to the perception of improper accent in the speech of the hearing-impaired.

McGarr and Harris (1980) found that even though intended stressed vowels were always longer than unstressed vowels in the speech of profoundly hearing impaired speakers, the intended stress pattern was not always perceived correctly by a listener. Thus, the hearing-impaired speaker use some other suprasegmental features to convey contrastive stress. Variation in fundamental frequency would be likely alternative, but McGarr and Harris (1980) also found that while the hearing-impaired speakers produced the systematic changes in the fundamental frequency associated with syllable stress, perceptual confusions involving stress pattern were still observed.

Whitehead (1991) has stated that prolongation of stop consonants in hearing impaired speech, i.e. lengthy closure duration, may also be a significant contribution to the prolongation of syllables and words by some hearing-impaired speakers. Such information is useful in gaining a better understanding of the speech timing of hearing impaired individuals, but also for the development of appropriate assessment tools and remediation strategies. Prolonged closure durations for stop consonants, could have an impact on aerodynamic features of speech production in hearing-impaired people like increased build up of intraoral air pressure behind the stoppage, with a subsequent greater peak flow rate upon release. Also production of a specific phoneme would be prolonged and there will be air wastage and also production of subsequent phonemes on that same breath group may also be relatively affected because of the respiratory and aerodynamic excesses.

Problems associated with vowel length are often reported in the literature, and although they are strictly to do with the segmental phonology rather than prosody, at times the two interact. Levitt et al. (1980) reported that the deaf use durational cues in place of intonation. Thirumalai and Gayathri (1988) suggest that in many Indian languages including Kannada, durational cues get merged with the intonation cues.

The importance of length as a measure of intelligibility will depend in part on whether length is phonemically distinctive in the language being used. For example, in British English, there is no distinction between long vowels and short vowels. Quality rather than length is important. Vowel length in some languages is largely a prosodic rather than segmental feature, it is determined mostly by phonetic context and syllable stress (Graddal, 1991).

Pauses

The speech of the hearing-impaired often contains a large number of pauses, often between words or even syllables and at points judged inappropriate. This combined with vowel lengthening, is the major contributor to the slower pace of speech of deaf children (Graddol, 1991). Pauses have been found to be inserted at syntactically inappropriate boundaries, such as between two syllables in a bisyllabic word or within phrases by the hearing impaired speakers (Osberger and McGarr, 1980; Sheela, 1988; Jagdish, 1989). Profoundly hearing impaired speakers insert more pauses, and pauses of longer duration than do speakers with normal hearing (Boone, 1966; Boodhroyd et al., 1974; Stevens et al. , 1978). Strok and Levitt (1974) reported that the deaf subjects tended to pause after every word and stress almost every word. Nickerson et al. (1974) reported that the total pause time in the speech of normal hearing children constituted 25% of the time required to produce the test sentences, whereas it was 40% in the speech of the deaf. Boodhroyd et al. (1974) considered that within phrase pauses were more serious problem than between phrases pauses in deaf speakers.

The inappropriate use of pauses along with the timing errors leads to the perception of improper grouping of syllables and contributes to the poor rhythm perceived in the speech of the hearing impaired (Hudgins, 1996; Nickerson et al., 1974). Hudgins (1934, 1937, 1946) suggested that the frequent pauses observed in the speech of the hearing impaired may be the result of poor respiratory control, it was found that the deaf children used short, irregular breath groups, often with only one or two words per breath, and breath pauses that interrupts the flow of speech at inappropriate places. Also there was excessive expenditure of breath on single syllables, false grouping of syllables and misplacement of syllables. Thus hearing impaired children distort many temporal aspects of speech. Inspite of these deviancies, there is evidence suggesting that hearing impaired talkers manipulate same aspects of duration as those involving relative duration, in a manner similar to that of a speaker with normal hearing.

Stress

Stress may be defined as an articulatory gesture, related to the degree of force of an utterance. According to Lehiste (1970), stress was prominence produced by means of respiratory effort. Phonetic stress conveys the meaning of emphasis or exclamation (Pike, 1945). The emphatic stress is used to reinforce either a normal innate stress or reinforce regular stress to convey the meaning of more emphasis in special sentence placement. Several acoustic cues exist for stress. One of the important acoustic correlates of stressed syllables in words is intensity, amplitude and fundamental frequency (Liberman, 1968; Hadding-Koch, 1961; Ladefoged and McKinney, 1963). However Fry (1955,58) felt that duration was a better cue compared to intensity. Also, the duration of change in fundamental frequency rather than magnitude of change in Fo, is an important cue for stress.

Commenting on the ambivalent nature of sentence stress, Ladd (1978) reported that in analysis of American English, sentence stress was considered to be another "level of stress" and stress and variation in pitch were considered to be independent elements of the suprasegmental system. In British tradition, sentence stress was called the 'nucleus'.

It was considered as an intonational phenomenon and had nothing to do with stress. He further stated that "... the debate between the British and American tradition concerning the phonological status of sentence stress is a moot question. Sentence stress is simply the place where the greatest prominance of the rhythmic structure is associated with the nucleus of the intonational configuration. This means, that the question of sentence stress placement becomes an instant of the large question of how rhythmic structure is determined and what grammatical function it serves".

Cutler and Ladd (1983) also stated the terms 'sentence accent', 'sentence stress', 'nuclear accent', 'nucleus', focal 'accent' and 'tonic' all referred to a phenomenon at the conceptual level between prominence and intonation. The quote Brov/n (1970), according to whom there was no basis for designating one syllable in a sentence as more prominent than the rest. Garding (1972) was of the opinion that sentence accents could have separate phonetic basis for the distinction. Cutler and Ladd (1983) however, believed in the existence of one most prominent syllable in a given domain when the domain was not a sentence, than nuclear stress or nuclear accent, was considered to be a more appropriate term than sentence stress or sentence accent. The function of sentence accent or the accent, according to them was to highlight, focus, contrast, comment or indicate new information.

Location of stress based on acoustic cues

Liberman (1960) presented a 'flow chart' representing a method for locating stressed syllables in pairs of syllable from acoustic cues alone. "At first, the syllable that has higher fundamental frequency was to be noted. This is indicated on the diagram by the positive arrow. If the amplitude of this syllable is also higher than it is the stressed syllable. If however, the peak amplitude is lower as indicated by the negative arrow, the integral of the amplitude with respect to time over the entire syllable is noted. If this is positive and the pitch difference and amplitude ratio between the stressed and unstressed syllable falls into the permissible limits, then the syllable is considered stressed. Many other paths could be followed which lead at either a stressed or unstressed judgement".

Identification of stress made on the basis of this scheme on the data were in agreement with the perceptual stress judgements 99.2% of the time. It should be noted that the algorithm was framed in relative and not absolute terms, and was suitable only for comparing two syllables. The criterion at the top of the flow chart corresponded to the traditional notion of "pitch prominence".

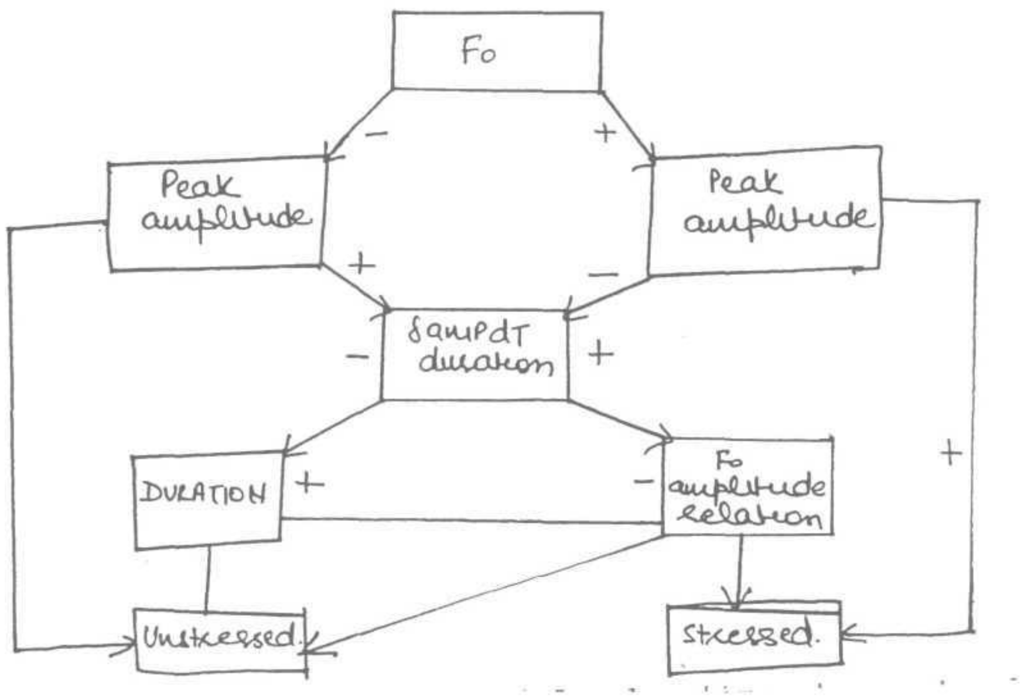


Diagram showing the method for locating stressed syllables in pairs of syllable (after Lieberman, 1960)

Stress is an important feature of prosody. It is also seen that it is a feature which influences and determines some of the characteristics features of the Fo curve. The position of stress in an utterance, the influence of segmental factors on stress placement and its influence on intonation is highlighted in the review of literature.

In the speech of the hearing-impaired unstressed syllables may be given similar prominence (in intensity, pitch obstrusion and duration) as in stressed syllables, and may be given similar treatment to stressed syllables when phonologically conditioned lengthening (such as in word final and sentence final positions) is required. Nickerson (1975) has remarked that it is almost as if the deaf speaker produces only stressed syllables.

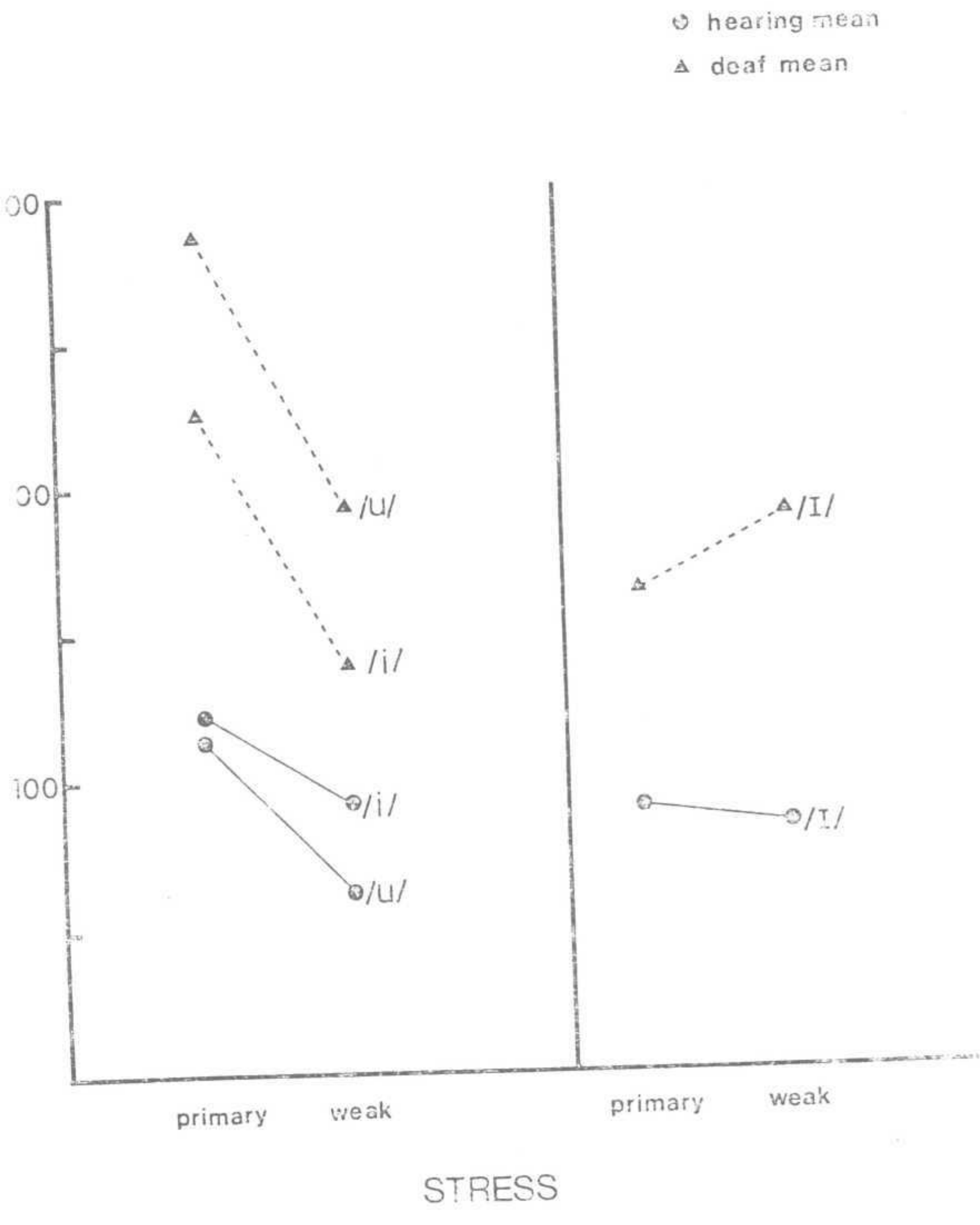
In English, changes in contrastive stress have been found to produce systematic changes in vowel duration. When vowels are stressed, they are longer in duration than when the same vowels are unstressed (Parmenter and Trevino, 1936). This durational variation has also been found to be an important cue for the perception of stress (Fry, 1955, 1958).

The stress is an important feature of Punjabi. In general the position of the stress is determined by the number and distribution of long and short syllables in a word. The stress in Punjabi is phonemic. In monosyllabic words stress is syntactical. In disyllabic words, the stress normally falls on the first syllable. In trisyllabic words the stress falls on the second syllable of the words if it is long. In case of the second syllable in short, the first syllable is stressed. In compound words each component of it retains its own stress pattern (Dulai, 1989).

Several investigators have shown that while hearing-impaired speakers make the duration of unstressed syllables shorter than that of the stressed syllables. The proportional shortening is smaller, on the average, in the speech of hearing-impaired than in the speech of normal hearing subjects (Osberger and Levitt, 1979; Steven et al., 1978).

The stress is an important feature of Punjabi. In general the position of the stress is determined by the number and distribution of long and short syllables in a word. The stress in Punjabi is phonemic. In monosyllabic words stress is syntactical. In disyllabic words, the stress normally falls on the first syllable. In trisyllabic words the stress falls on the second syllable of the words if it is long. In case of the second syllable is short, the first syllable is stressed. In compound words each component of it retains its own stress pattern (Dulai, 1989). In contrast to this, Reilly (1979) found larger than normal durational differences between vowels in primary and weak stress syllables produced by a group of profoundly hearing-impaired children shown in Fig. 2. In Fig. , duration has been calculated for the vowels (i, a, u) produced in both primary in weak stress syllables by hearing and hearing-impaired children. For /i/ and /u/ longer average durations were measured for greater stress for both groups, with the hearing impaired durations being longer overall, and the differences between the primary and weak syllables being more extreme than in the samples produced by the children. There was almost no difference in duration between primary and weak /I/ in normal children's sample, whereas the hearing-impaired speakers showed longer durations of /I/ in weak syllables than in primary stress syllables.

Exact way a hearing impaired speaker uses temporal manipulations to convey differences in syllabic stress pattern is not clear. In a study, McGarr and Harris (1980) found that eventhough intended stressed vowels are always longer than unstressed vowels in the speech of one profoundly hearing-impaired speaker, the intended stress pattern was not always perceived correctly by listener. Thus the hearing-impaired speaker was using some other suprasegmental features to convey contrastive stress. Variations in Fo frequency would be likely alternative, but McGarr and Harris also found that until the hearing-impaired



Mean vowel duration (msec) in primary- and weak-stress syllables produced by a group of normal-hearing and a group of profoundly hearing-impaired children (after Reilly, 1979).

speaker produced the systematic changes in Fo associated with syllable stress, perceptual confusions involving stress pattern were still observed.

Another suprasegmental temporal effect occurring in normal speech is prepausal lengthening, when a syllable occurs before a pause that marks a major syntactic boundary, it is longer in duration than when it occurs in other positions in a phrase (Katt, 1975). It has been observed that hearing-impaired speakers do not always lengthen the duration of phrase final syllables relative to the duration of the other syllables in the phrase. Stevens et al. (1978) observed that when there was evidence of prepausal lengthening in the speech of profoundly hearing-impaired talkers, the increase in the duration of the final syllables was much smaller, on the average, for the hearing-impaired than for the normal hearing speakers. In contrast to this Reilly (1979) found that the profoundly hearing-impaired speakers in her study used duration to differentiate prepausal and non-prepausal syllables. As was this case for primary and weak stress syllables, discussed above, Reilly (1979) observed a larger than normal difference between the duration of syllables in the prepausal and non-prepausal position in the samples produced by the hearing-impaired children. Speech produced by persons with severe to profound hearing loss is staccato like, suggesting a failure to differentiate stressed and unstressed syllables.

PITCH INTONATION

The fundamental frequency of a voiced segment may serve simultaneously to identify the segment as voiced and to constitute part of the manifestation of a tonal or intonational pattern (Lehiste, 1970). Intonation is the perceived pattern of change in fundamental frequency within a phrase or a sentence. When a layman speaks of intonation he usually means one of two things: The total quality of the sound by which he can distinguish one dialect or language from another whether he understands what is being said or not, and the tone of voice to which he reacts more or less emotionally. The tone of voice comes closer to being purely a matter of fundamental pitch (Bolinger, 1972). Every sentence, every word, every syllable, is given some pitch when it is spoken. Even a sound in isolation is produced by vibrations whose frequencies constitute its pitch. There are no pitchless sentences (Pike, 1945).

It is a well known fact that intonation patterns are acquired even before the actual acquisition of speech sounds. Jacobson (1967) identified two phases of speech development. The 'babbling' stage in which the infant simply exercises his vocal apparatus and makes sounds for the sake of making sounds. Deaf children, for example, babble quite normally for the first 6-7 months of their life. The second stage is from one to two years, when the child begins to use speech sounds in a meaningful way and he employs the distinctions that are apparent in the adult speech that he hears. Now the first element of meaningful speech behaviour that can be observed in children actually occurs much earlier than one to two years of age. In the very first few months of life, during the babbling stage, and indeed during the very first minutes of life children employ meaningful intonational signals. The cries are at first meaningful only in that they have a physiological reference. It is believed that these signals, which appear to be innately determined, provide the basis for the linguistic function of intonation in adult speech.

The infant cry has a characteristic pattern. The pattern is apparently innately determined. Mongoloid infants, for example, often lack these characteristics, cries and deviations from the normal pattern often signal other neurological abnormalities (Rubinstein, 1964). The infant cry has nine rising-falling fundamental frequency contours. The duration of the cry is usually from 1-2 seconds, and the fundamental frequency (FF) initially rises. The FF then remains relatively steady or gradually falls until the end of the cry, when it typically falls at a faster rate (Ostenald, 1963). As the infant matures, the vocalizations differentiate and various types of cries occur.

The shift to intonation as am meaningful speech signal that has a reference to specific social situations is comparatively rapid. Schafer (1922) reported that a nine month old infant who responded to the intonation in the phrase "Wo 1st die tick tock" by looking at the clock, also looked at the clock when similar phrases like, "Wo 1st die lala ?" were spoken with the same intonation. The same child played hand clapping games when the phrase "muche bitte bitte" was spoken in the exaggerated intonation of the nursery. The child would not respond when the phrase was spoken with a normal intonation.

It has been noted that children soon mimic adult intonation. A ten month old boy and a 13 month old girl were recorded under several different conditions. It was recorded while the boy babbled alone in his crib. He was also recorded, while he babbled in an identical play situation with his father and mother. The average of the FF of the child's babbling under these conditions was measured. The same experiment was then repeated with the 13 month old girl who was just beginning to speak. The average FF of the boy's babbling while he speak to his father was 340 cps, while his average FF was 390 cps when he was with his mother. Both of these fundamental frequencies are lower than that of his solitary babbling or crying. The girl also apparently attempted to mimic the FF of her parents (Lewis, 1936).

In a study by Russian investigators (Tokava and Yampolskaya, 1969) using 170 infants upto 2 years of age, at about the first month of life babies could indicate hunger, pain and other such disagreeable status with a characteristic variation of pitch in their cry. In second month, they can differentially produce sounds of discomfort and placid cooing from sounds of happiness. The sound of laughter emerges by the third month. Exclamatory delight is expressed by 6th month, a requesting intonation from the 7th month and then, questioning intonation after about 2 years of age.

Lewis (1936) noted three stages in the development of language: (1) At an early stage, the child shows discrimination in a broad way between different patterns of expressions in intonation. (2) When the total pattern - the phonetic form together with the intonational form is made effective by training, at first the intonational rather than the phonetic form dominate the child's response. (3) Then the phonetic pattern becomes the dominant feature in evoking the specific response. But while the function of the intonational pattern may be considerably subordinated, it certainly does not vanish.

There are very few studies in the area of 'hemispheric specialization' for intonation. Blumstein and

Cooper (1974), conducted two dichotic experiments to investigate the lateralization of intonation contours. In the first experiment, intonation contour that had been filtered from real speech examples of four English sentence types yielded a significant left ear advantage. In the second experiment, nonfiltered versions of four intonation contours superimposed on a nonsense syllable medium as well as their filtered equivalents were presented to subjects, again in a matching taste. For both sets of stimuli, a left ear advantage was obtained. In another experiment by Safer and Levendhal (1977) suggested that the right hemisphere is directly involved in perception of intonation contours and that normal language perception involved the active participation of both cerebral hemispheres.

Speech is organised in terms of the expiratory air flow from the lungs. At the end of each expiration, the flow of air out of the lungs ceases and the sub-glottal air pressure abruptly falls. The fundamental frequency of phonation is directly proportional to the subglottal air pressure and thus the fundamental frequency also falls. It is universal of human speech that, except for certain predictable cases, the FF of phonation and acoustic amplitude fall at the end of sentence, the physiological basis of this phenomenon may be a condition of least articulatory control. If the tension of the laryngeal muscles is not deliberately increased, at the end of expiration when the subglottal air pressure falls, the FF of phonation will also fall. This pattern of articulatory activity thus produces a prosodic pattern that is characteristic of the ones that are used to delimit the boundaries of unemphatic, declarative sentences in normal speech. The FF of the vibrating vocal cord appears to be a function of the subglottal air pressure and rises from a medium pitch to a higher pitch at the stress peak (which occurs at the peak subglottal air pressure) and then falls as the subglottal air pressure falls at the end of the utterance (Liberman, 1968) within intonation, the linguistic features of intonation, the linguistic features of intonation are determined by factors like the FF, intensity and duration. Most of the investigators refer to the FF as the essential ingredient of intonation, but some don't.

"The intonational differences heard as high or low, rising or falling are primarily related to the frequency of the sound waves" (Lado, 1960). The pitch variations in intonation of a language constitute a system of distinctive units and patterns. It is found that English intonation has five distinctive pitch units as low, mid, high and extra high (Lado, 1971; Bolinger, 1971). According to Gill and

Sandhu (1968, 1969) there are three tones in Punjabi: high, mid and low. It is very important to listen to the pronounciation of a native speaker for getting an auditory impression of these tones and to imitate them for acquiring an accurate pronounciation. While producing these tones, there is neither friction nor stoppage of air in the mouth. There are produced always concurrently with a syllable. High tone is higher than the other two tones and the syllable with this tone is also shorter than those with other two tones. High tone occurs in initial, medial and final positions. Mid tone is considered to be an intermediate in pitch between the high and low tones. The syllable is of an intermediate height in this case. Low tone has been described as the lowest of the three tones. The pitch tends to fall. The syllable under this tone is longer in comparison with the other two. Low tone occurs mostly in medial and final positions.

While emphasizing the role of fundamental frequency or pitch in intonation, Pike (1945) states that "every sentence/every word and even every syllable is given some pitch when it is spoken".

Although Pike (1945) and Lado (1961) believe that variation in FF is the basis for various intonation contours, it was shown not to be true always by Denes (1959) from his experiments. According to him, it is still possible that variations of other acoustic characteristics like intensity, duration of spectrum, may also serve as cues for the recognition of intonation. He obtains the support for his statement from whispered speech. He says that "in whispered speech there is no vocal cord vibrations, and hence no FF, but still the speaker is able to convey to the listener much of the information that is normally considered to be contained in the form of intonation".

Liberman and Michaels (1962) carried out an experiment to examine the contributions of FF and of amplitude to the transmission of the emotional content of normal human speech. The conclusions drawn were that

1. There is no single acoustic correlate of the emotional modes. Phonetic content, gross changes in FF, the time structure of the FF, and the speech envelope amplitude, contributed to the transmission of the emotional modes.

2. Different speakers favoured different acoustic parameters for the transmission of the same emotional mode.

3. The fine structure of the FF, that is, the perturbations in FF appears to be an acoustic correlate of the emotional modes when these perturbations, were smoothed out confusions between the emotional modes increased.

Some researchers like Bolinger (1972) consider intonation as only a peripheral part of oral communication. According to Bolinger, "Intonation is not as central to communication as some of the other traits of language. If it were so, we could not understand some one who speaks in a monotone". This is like saying that voicing is not crucial to communication because we can understand whispered speech (Ling, 1971). On the other hand, Liberman (1967) believes that intonation plays a central role in the process of recognition of syntactical arrangement of words.

Bolinger (1975) states that there are three features of intonation which have similar uses in all languages. They are:

1. Range: The range conveys emotions when we are excited our voice extends its pitch upwards when we are depressed, we speak almost in a monotone.

2. Direction: It is usually connected with pause.

3- Relative height: It is associated with the importance given to particular word or words in a sentence.

Intonation also plays a useful role in the determination of voice quality (Brown, Strong and Reniker, 1973) and in recall of verbal materials (Leonard, 1973).

Reference is made, even in the early literature, to the difficulties that hearing impaired speakers experience in controlling their intonational aspect of speech. Haycock (1933), Rawlings, (1935), Russell (1929), Scripture (1913), and Story (1971) all describe the speech of congenitally deaf persons as "monotonous" and devoid of melody. Later investigators showed that hearing-impaired speakers did produce pitch variations, but the average range was more reduced than those of speakers with normal hearing (Green, 1956; Hood, 1966; Voelker, 1935).

In normal hearing speakers, the average F decreases with increasing age until adulthood for both males and females (Fairbanks, 1940; Usha, 1979; Gopal, 1980). The difficulties that the deaf speakers has with pitch are of two general types. They are (a) Inappropriate average pitch and (b) improper intonation.

Intonation problems may in turn be divided into two major types: 1. Monotonous voice, 2. Excessive or erratic pitch variations (Nickerson, 1975).

Hearing-impaired speakers often tend to vary the pitch much less than the normal hearing speakers and the resulting speech has been described as flat or monotone (Calvert, 1962; Hood, 1966; Martony, 1968). A particular problem is that of inappropriate or insufficient pitch range at the end of a sentence (Sorenson, 1974).

A terminal pitch rise such as that occurring at the end of some questions may be even more difficult for a deaf child to produce than a terminal fall (Phillips, Remillard, Bass and Pronovost, 1968). Deaf speakers who tend to produce each syllable with equal duration may also generate a similar pitch contour on each syllable. Such speakers may fail to indicate variations in stress either by changing the syllable durations or by modifying the pitch contours on the syllables. Thus for example a common error would be is that it may fail both to shorten an unstressed syllable and to lower the pitch on such a syllable (Nickerson, 1975).

Some hearing-impaired speakers may demonstrate an intonation problem in the form of excessive and inappropriate changes in fundamental frequency. These speakers may raise or lower F_O 100 Hz or more within same utterance. Often after a sharp rise in fundamental frequency, the hearing impaired speakers loss all phonatory control and there is a complete cessation of phonation (Monsen, 1979; Smith, 1975; Stevens et al., 1978).

Fig. 1 shows the intonation contour of a simple, declarative sentence spoken by a normal, 14 year old female. There is a rise in F_o at the beginning of the sentence with a peak on the first stressed syllable (the second syllable in the sentence). As the sentence is produced, there is a gradual reduction in F , known as declination. The sharp drop that occurs in F at the end of sentence is referred to as the terminal fall. The Fig. 2 shows the same sentence spoken by a hearing-impaired male speakers 14 year of age, judged to have insufficient variation in intonation. The extent of the F throughout the utterance is more restricted than that observed for the child with normal speech in

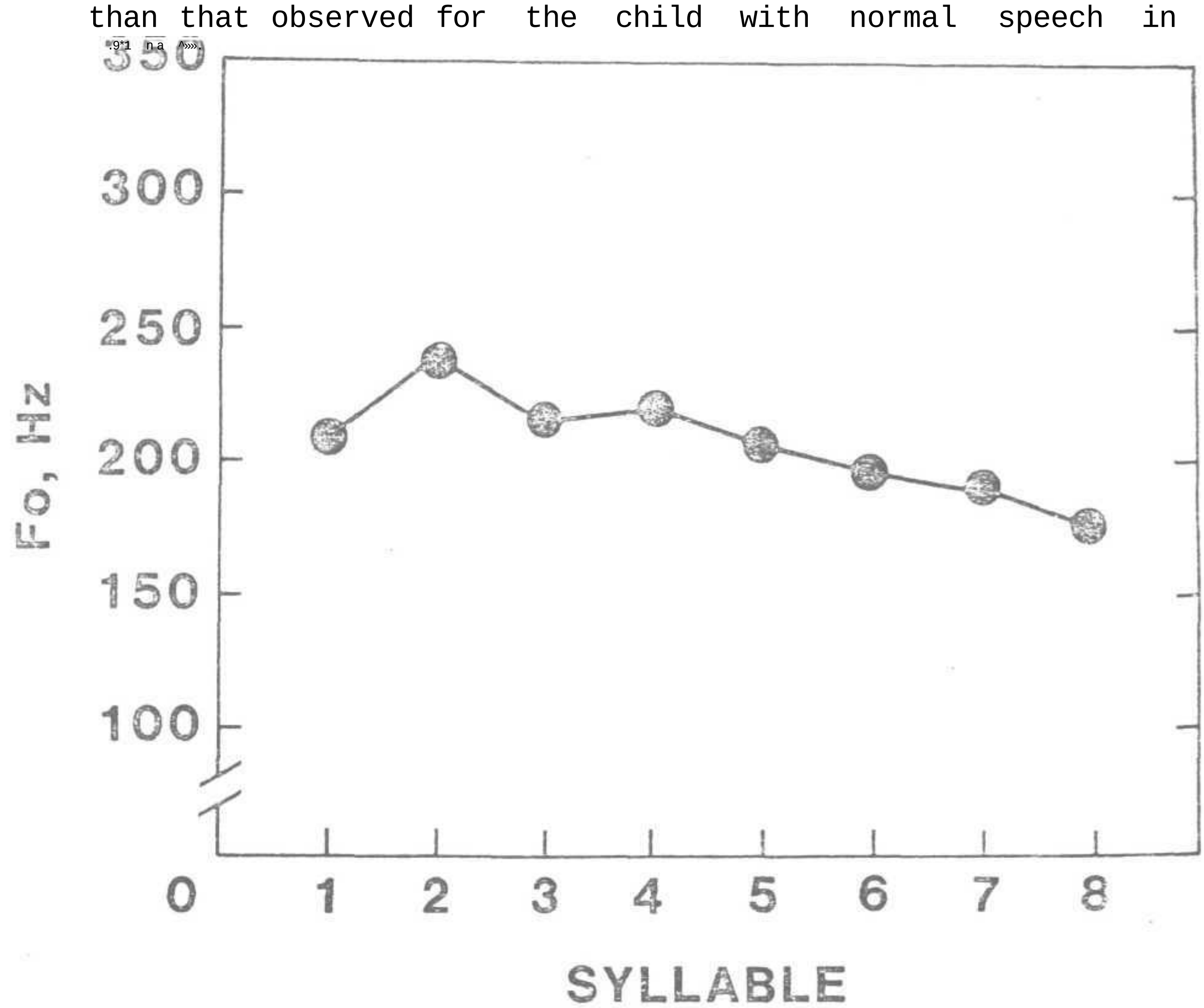


Fig. 1: The intonation contour of the simple declarative sentence, "I like happy movies better" spoken by a normal child. Each data point is the fundamental frequency value in Hz, measured at the centre of the vowel in each syllable of the sentence.

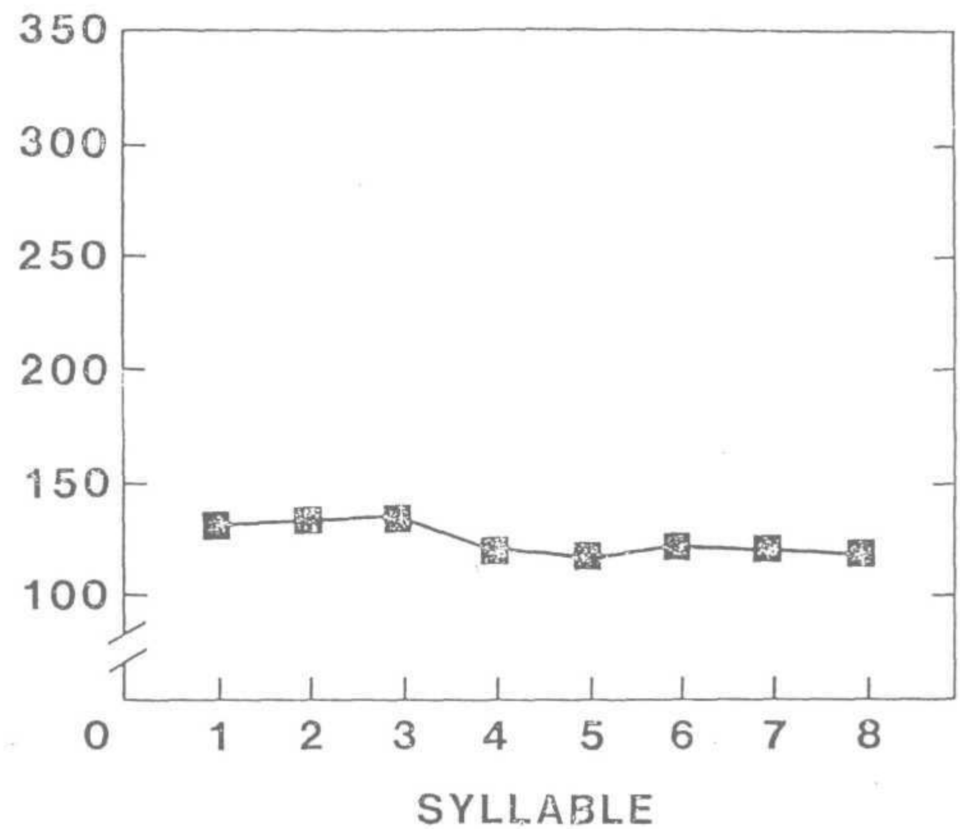


Fig. 2: The intonation contour of the sentence, "I like happy movies better" spoken by a profoundly hearing-impaired speaker judged to produce insufficient variation in intonation. Each data point is the fundamental frequency value in Hz, measured at the centre of the vowel in each syllable of the sentence.

Fig. 3 shows contours for two females, 14 year old, who produced the sentence with excessive and inappropriate changes in F . Speaker 1 produced the first part of the sentence with a sharp rise in F_o, followed by a sharp fall in F over the last half of the utterance. Speaker 2 produced inappropriate fluctuations in F throughout the utterance.

There have been few attempts to arrive at quantitative classification of intonation contours produce by hearing-impaired children. Monson (1979) has described

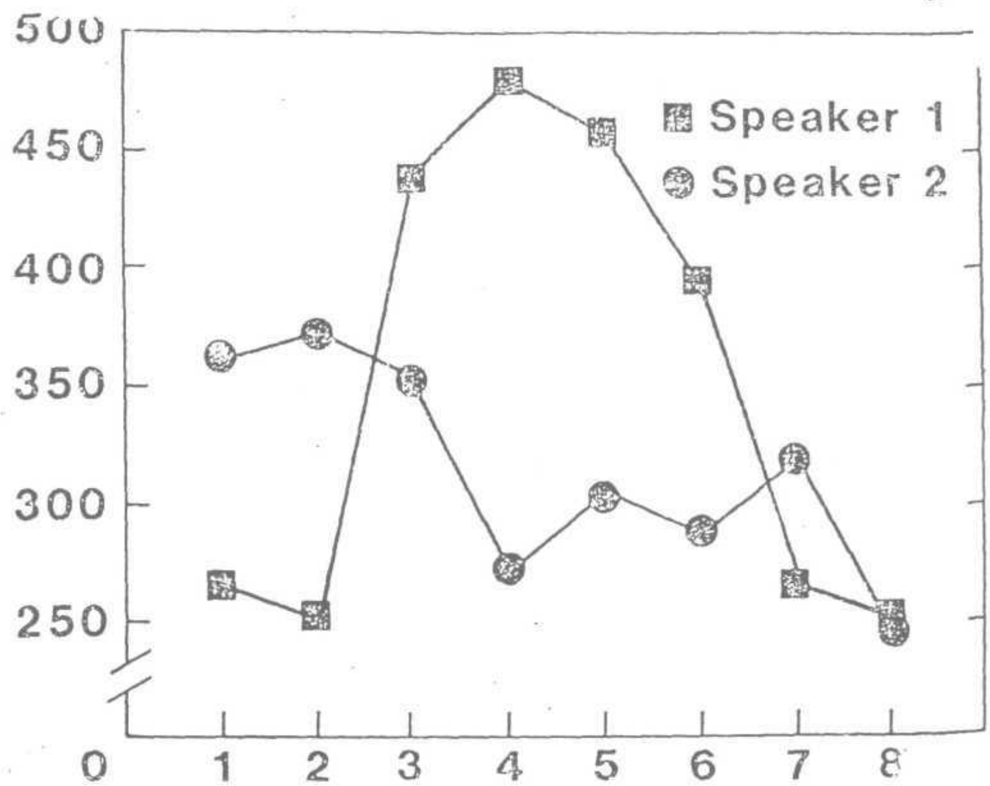


Fig. 3: The intonation contour of the sentence, "I like happy movies better" spoken by two profoundly hearing-impaired females judged to produce excessive and inappropriate changes in fundamental frequency. Each data point is the fundamental value in Hz, measured at the centre of the vowel in each syllable of the sentence.

the following four types of contours that he found to occur in the production of CV syllables by 3 to 6 year old hearing-impaired children: (1) a falling contour characterised by a smooth decline in F at an average rate greater than 10 Hz per 100 msec; (2) a short falling contour, occurring on words of short duration - the F_o fall may be more than 10 Hz per 100 msec but the total change may be small; (3) a falling flat contour, characterized by a rapid change in frequency at the beginning of a word, followed by a relatively unchanging, flat portion; (4) a changing contour, characterised by a change in frequency, the duration of which appears uncontrolled, and extends over relatively large segments.

Monsen (1979) found that the type of contour appeared to be an important characteristic in separating the better from the poorer hearing-impaired speakers. His classifica-tion scheme represents a substantial step forv/ard in describing the intonation patterns of the hearing-impaired. It remains to be determined, if such a classification scheme can be used to describe objectively the intonation patterns of entire sentences as well as isolated syllables.

One factor that strongly influences F changes is the degree of stress placed on syllables within a breath group. Typically, stressed syllables are spoken with a higher fundamental frequency than are unstressed syllables (Fry, 1955). Thus, the contour consists of peaks (rises) and valley (falls) in F_o that correspond to the stressed and unstressed syllable pattern of the sentence. This pattern has been observed to be distorted in the speech of the hearing-impaired. An example of this distortion is apparent in the F contours of the two speakers in Fig. 3.

Rubin, Spitz and McGarr (1990) showed that hearing impaired children in their study were able to produce declarative sentences correctly with a falling contour, however, they didn't produce non-declarative sentences with a rising contour. All sentences were produced with a terminal fall.

The study by Most and Frank (1991) indicated that severely and profoundly hearing impaired children are able to perceive and produce intonation contours. These results corroborate studies by Enger et al. (1983) and Most (1985).

The production of the intonation in a sentence context requires a more complex production ability than the intonation carried on short syllables, because of the length of the stimuli and/or the need for additional language knowledge on top of the ability to perceive variations in the F • Consequently, in general, no correlation was observed between the imitation and discrimination of intonation and production of intonation in a sentence (McGarr, 1976; Stark and Levitt, 1979; Frank, 1991). But a significant correlation was found between the imitation of rising contours (Frank, 1991).

Some children with severe and profound hearing-impaired were found to produce correct intonation contours (Green, 1956; Hood and Dixon, 1969; Williams, 1978), while others demonstrated production difficulties (Stark and Levitt, 1974; Smith, 1975).

Frank, Bergman and Tobin (1987) described the difficulties encountered by children with hearing-impaired in producing orally said sentences with the correct intonation contour. According to their findings, during attempts to form a sentence, some of the children read each of the words separately as if the words comprised a list of unrelated vocabulary. The children failed to employ a look around strategy that includes planning the production of the whole sentence while considering the intonation as well. Other children with similar hearing losses succeeded in producing sentences with the appropriate intonation contour.

It has been suggested that some of the unusual pitch variations that occur in the speech of the deaf persons may result from attempts by the speaker to increase the amount of proprioceptive feedback that he receives from the activity of producing speech. Martony (1968) and Williams and Lee (1971) have observed that deaf speakers sometimes tend to begin a breath group with an abnormal high pitch and then to lower the pitch to a normal level.

Angelocci et al. (1964) first examined some of the vowel changes in F_o in the speech of the hearing-impaired. They found that the average F_Q and intensity for all vowels were considerably higher for the hearing-impaired than for normal hearing subjects. In contrast, the range of frequency and amplitude values for the vowel formants were greater for the normal hearing than for the hearing-impaired speakers. To explain this they suggested that the hearing-impaired subjects attempted to differentiate vowels by excessive laryngeal variation rather than by articulatory maneuvers as in normal hearing speakers.

Bush (1981) found that vowel variations produced by the hearing-impaired speakers were in some way a consequence of the same articulatory maneuver used by normal speakers in vowel production. Bush (1981) has postulated that because of the nonlinear nature of the stress-strain relationship for vocal fold tissue, increase in vocal fold tension may be greater in magnitude when the tension on the vocal fold is already relatively high (as in the case of hearing-impaired) resulting in some what larger increases in F during the articulation of high vowels.

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

In summary it can be stated that at suprasegmental level of production, poor timing control produces the following deviations.

a. Prolongation of speech segments.

b. Distortion of temporal relationship between speech segments.

c. Insertion of frequent and lengthy pauses often at syntactically inappropriate boundaries.

d. Distortion of phonetic context effects.

e. Insertion of adventitious phonemes.

Poor control of F_0 can result in problems such as:

a. Average pitch level too high.

b. Insertion with insufficient variability.

c. Intonation with excessive variability.

Abnormal voice characteristics such as harshness, breathiness, hyper and hypo-nasality may be present.

Study of prosody is useful in planning, speech training for hearing-impaired. However studies in Indian languages particularly Punjabi are not available. Punjabi being a tonal language, it was considered that it would be interesting and useful to study the prosody. Therefore the present study was planned.

METHODOLOGY

Brief introduction

The objective of the study was to compare the speech of Punjabi speaking normal and hearing impaired children in terms of suprasegmental features, i.e. rate, pause durations, word durations, stress and intonation.

For this purpose, study was carried out in following steps:

1. Selection of normal and hearing impaired subjects
2. Collection of speech samples
3. Analysis of speech samples

Parameters Studied

The following parameters have been **studied.**

1. Psychoacoustic parameters

- Intelligibility ratings of hearing impaired speech.
- Perceptual analysis of stressed syllables.

2. Acoustic parameters

A. Stress: Comparisons of stressed vs. unstressed syllables in terms of duration, amplitude and fundamental frequency.

B. Pitch and Intonation

a. Fundamental frequency of speech (mean F_0)

b. Fundamental frequency (F_0) range

c. Variations in fundamental frequency in sentences to not intonation contours

d. Intensity peaks

C. Pause durations and word durations

a. Interword pause durations

b. Intraword pause durations

c. Between sentence pause durations

d. Word durations

D. Rate: Number of syllables spoken per second and number of words spoken per second.

These parameters were studied for both normal and hearing impaired children and comparisons were made.

Subjects

The subjects were ten normal hearing children (5 males and 5 females) and ten congenitally hearing impaired children (5 males and 5 females). The hearing impaired children were selected from "Vatika Deaf School", Chandigarh. They 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 other problems or deviations other than directly related to the hearing impairment.

3. All the subjects were having Punjabi as their native language and were able to read simple sentences in Punjabi.

Normal hearing children were selected to match each hearing impaired subject in terms of age and sex. The hearing screening test showed that they had normal hearing and a qualified speech pathologist also evaluated the speech of these children and considered normal

Table I: Detailed information of each hearing impaired subject

	Age (yrs)	Thresholds R(dB)	Thresholds L(dB)	Education (yrs)	Duration of speech therapy
Male subjects					
1	11.5	100	105	3rd grade	3.0
2	13.0	90	98	4th grade	4.0
3	14.5	95	95	5th grade	4.5
4	12.5	110	90	4th grade	1.5
5	15.1	105	95	6th grade	4.0
Female subjects					
1	15.2	110	100	6th grade	3.5
2	11.5	90	95	3rd grade	2.5
3	13.2	100	100	4th grade	3.0
4	14.3	95	95	5th grade	4.0
5	12.2	100	90	4th grade	4.0

Mean age (Males) = 13.3 Mean age (Females) = 13.28

Normal hearing subjects were matched in terms of mean age and sex.

Test material

The test material consisted of a story. ("Thirsty Crow")(Appendix I). The story chosen was simple and was in common use so that both normal and hearing impaired children could easily read the story with proper emotions.

Since the purpose of the present study was to study intonation in addition to other parameters. So the investigator presented a story to hearing-impaired and normal hearing speakers (familiar to both the groups) which each subject read aloud. This allowed them to use intonation and timing creatively and this provided the speech sample for each subjects which were submitted for further analysis.

In most studies for analysing the prosodic features, syllable is considered as the fundamental unit (Mermelstein, 1975; House, Bruce, Erickson and Lacerda, 1989). Punjabi being a tonal language, the pitch contours are located on single syllables, not on groups of syllables (Gill, 1958). Therefore in the present study also, syllable was considered as a unit for analysis for studying intonation contours and stress.

The story consisted of 41 words and 54 syllables (Appendix II). Most of the words were monosyllables and simple for both the groups. Oral reading was preferred over spontaneous speech because it tends to have the advantage of being more intelligible (Subtelny, 1977) and fluent (Butterworth, 1980), and it affords greater control over utterance content, thereby enabling direct comparisons to be made among speech samples and expediating the analysis of pause location.

Speech Recording

A. In order to record the speech sample of the subjects, Panasonic portable cassette tape recorder (Model RO-al70) with high quality microphone was used.

B. For the purpose of recording the subject was seated comfortably with the investigator in a quite room. No other person was present in the room during the recording. The written story was given to each subject. Each subject was seated in a such way that the distance between the microphone and the mouth of the subject was at a distance of around 6-8 cms.

In order to enhance pronunciation accuracy and fluency, subjects first read the story aloud twice as a practice trial, and third time they read the story aloud and their utterances were recorded on audiocassette (Meltrack C-90) .

Speech Intelligibility Rating

The intelligibility of each sample was rated independently by three trained listeners on a fine point rating scale. The procedures to establish the intelligibility ratings consisted of two tasks.

First, the judges listened to the story and rated the speech sample of each speaker using a rating scale from 1 to 5 (not at all to perfectly). Then the sentences of each deaf speaker were presented randomly and the listeners were instructed to tell whatever the subject had said word by word. The rating scale used is given below.

Subjects	Not at all intel.	Slightly intel	Just intel	Intel	Perfectly intel
1					
2					
3					
4					
5					

To check the reliability (interjudge and intrajudge) criterion for each subject the same sentences were played in different order and were compared with the earlier written sentences by the different judges.

Perceptual analysis of stress

The two judges (investigator and one trained speech and hearing pathologist) marked the stress in the speech of normal speaking and hearing-impaired children. The two judges had independently identified stresses in separate situations. They did not discuss the data among themselves.

The syllables marked as stressed by both the judges were taken up for further analysis of stress and comparison of the stressed syllables were done to find out parameters used to mark stress in Punjabi language and then their comparison with the hearing impaired speech (syllables stress in hearing-impaired samples).

Analysis

The analysis was carried out using the following steps:

Fig. 1 shows the instrument used for objective analysis, i.e. to obtain speech wave form, fundamental frequency curve and relative intensity curve on a temporal scale for each sentence.

The recorded speech samples were digitized using the speech interface unit and 16 bit A/D converter of VSS at a sampling rate of 16 kz using the programme (record) of VSS software. Before digitizing, each sample was passed through

FIG 1

the anti-alaising filter at 7.5 kHz at a rate of 48 dB per octave. Digitized data was stored on the hard disk of the computer (HCL AT486). The software package, 'Vaghmi' of voice and speech systems (VSS) was used to extract the fundamental frequency and intensity readings of the sample. The digitized signal was displayed on the computer screen using DISPLAY programme. The cursors were moved to check for the sentence initiation and ending. The edited, digitized data was used for extraction of fundamental frequency (F_0), and intensity (I_0) using INTON programme of VSS softwares.

A window size of 30 millisecond in case of the speech samples of males and 20 milli seconds in case of speech samples of females were used. A resolution of 10 milliseconds was used for speech samples of males and 5 milliseconds was used for speech samples of females. The extracted F_0 and I_0, for each of the interrogative sentence was stored on the harddisk of the computer and displayed on the screen of computer. Printout for F_0, I_0 curves and waveform (Fig. 2) were obtained using a printer (Epson FX 1000). Using the F_0 programme, the table consisting of F_0 and I_0 values at every 10 milliseconds duration were obtained for each sentence of all the speakers (Table II). These also provided the values for the following parameters for each of the sentences.

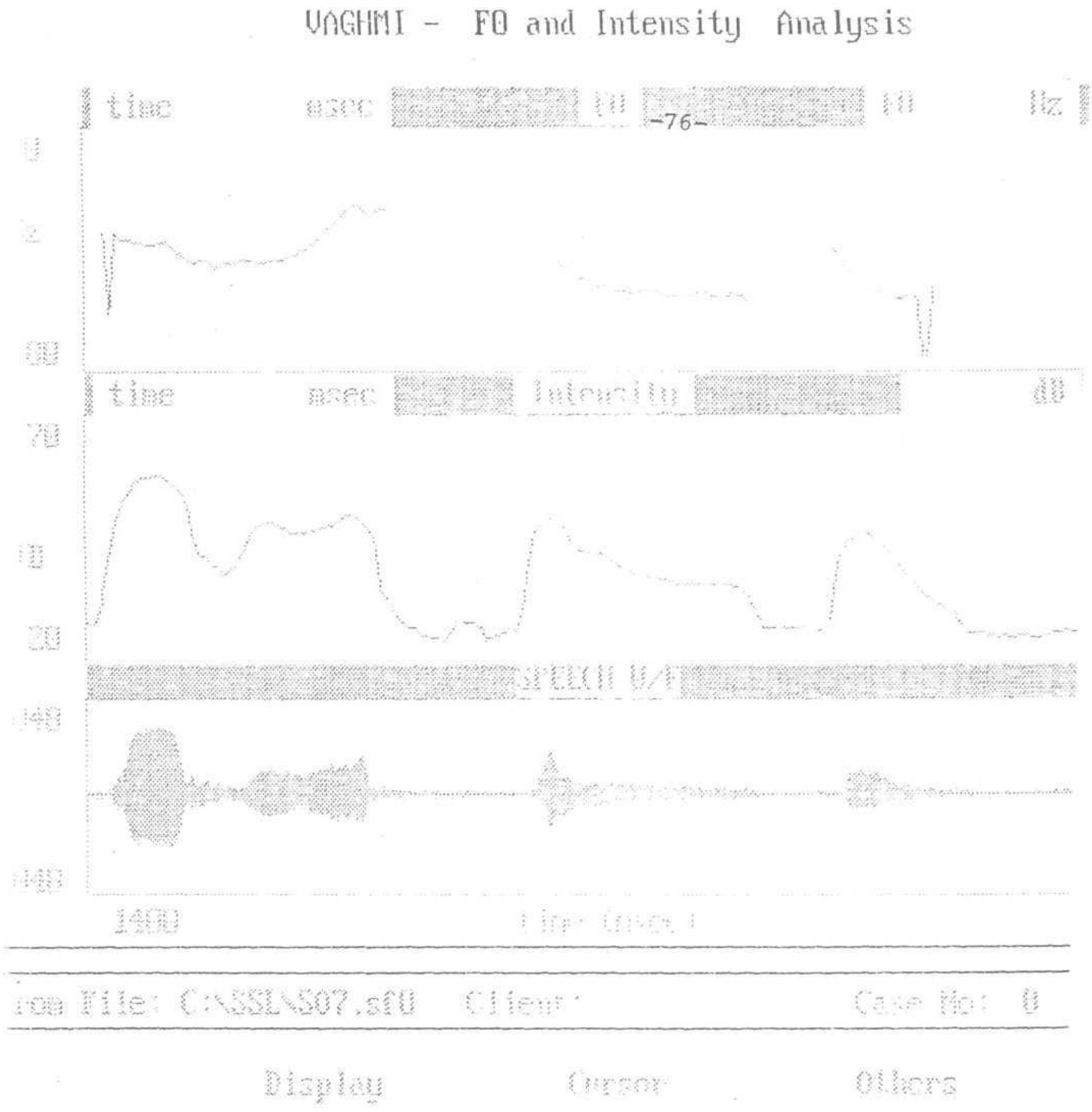


Fig-2: Fundamental Frequency (F₀) and Intensity curves and waveform.

Duration	Fo	Intensity	VUS
3200	0	25.36175	S
3210	0	25.45039	S
3220	0	25.52394	S
3230	0	25.13194	S
3240	0	29.92469	S
3250	170.1785	33.46886	V
3260	170.4463	35.83404	V
3270	171.7660	37.85061	V
3280	173.6188	39.44142	V
3290	174.3911	41.49455	V
3300	174.3374	42.71078	V
3310	173.5674	43.62270	V
3320	172.8095	44.12795	V
3330	171.2342	44.75532	V
3340	170.2348	44.85983	V
3350	170.1651	44.58805	V
3360	170.2594	44.42806	V
3370	169.9115	44.07807	V
3380	168.7436	43.21409	V
3390	167.5034	42.12867	V
3400	166.1336	41.63798	V
3410	165.7273	40.29522	V
3420	165.3039	39.53691	V
3430	164.2698	39.05553	V
3440	162.4284	38.67384	V
3450	160.2953	38.14259	V
3460	158.0132	38.47967	V
3470	158.9906	38.39331	V
3480	157.8871	38.04366	V
3490	155.1035	37.20183	V
3500	149.7727	36.21774	V
3510	147.8869	34.59046	V
3520	158.4158	32.93859	X
3530	0	31.66552	S

Table II: Frequency and Intensity Variations

- Maximum of F_0 (in Hz)
- Minimum of F_0 (in Hz)
- Maximum of I_0 (in dB)
- Minimum of I_0 (in dB)
- Range of F_0
- Range of I_0

Using the INTON programme, data point (averaged F_0 variations) for each syllable was extracted for plotting intonation contours and to mark stress using VAGHMI - F_0 and Intensity Statistical values were noted (showed in table III) for intonation and stress analysis.

Temporal measurements

Temporal measurements were made from oscillographic displays with the aid of a waveform - editing (computer program), which calculates the duration of an internal defined by the placement of two cursors and thus highlighting the portion to be studied. The speech waveform was visually inspected for silent intervals and the duration of silence was then calculated by placing the cursors at the points of pause onset and termination. Pause onset was defined as the point where the waveform stopped crossing the zero axis on the display screen, and the pause termination was defined as the point where the waveform next crossed the zero axis. The portion was highlighted every time and listened through headphones for more validity.

Mean		Intensity in dB	
Mean	264.14	36.65	Pauses (%) : 42.92
Absolute max.	489.97	54.47	Unvoiced (%): 0.66
Effective max.	380.93		
Absolute min.	80.00	24.05	Others (%) : 3.10
Effective min.	160.00		
Absolute range	409.97	30.42	Voiced (%) : 53.32
Effective range	220.93		
Psigma	62.90		

Table III: Vaghmi - Frequency and Intensity Statistical Data

When pauses were identified, their location and durations were noted (Interword, Intraword, between sentences). Locations were confirmed by an acoustic playback of the portion of the signal surroundings the pause. The durations of syllables were also noted by the same procedure for stress measurements. All the durations were again checked from the VAGHMI Inton values for duration (Table II).

Stress

For locating stress, the perceptually marked stressed syllables by the two judges were compared with the mean values of each syllable for the three parameters, viz. mean fundamental frequency, mean intensity and mean duration. Only those syllables were chosen which were marked as stressed by both the judges. Values were obtained by marking the duration of each syllable from the aid of a waveform-editing computer programme, which calculates the duration of an interval defined by the placement of the two cursors and thus highlighting the portion to be studied. The highlighted port ions were listened through headphones every time for confirmation. In this way durations for 54 syllables in a story were noted for each subject. These edited and digitized portions were used for extraction of fundamental frequency (F_0), and intersity (I_0) using INTON programme of VSS software. The peaks for intensity and frequency were studied for each stressed syllable. And then data points (averaged F_0 and I_0) were calculated from Vaghmi F_0 and Intensity statistical data for comparison of stressed syllable. These values were further confirmed from the Vaghmi Inton values for F_0, I_0 and duration variations (showed in Table II).

Rate

The speaking rate was calculated of syllables divided by the time taken for reading .

Thus the study of each sentence provided

1. The average of mean F_0 values across the sentences for comparison of fundamental frequency of speech.

2. The maximum and minimum F_0 values in speech provided range of F_Q.

3. The mean F of each syllable provided data for plotting the intonation contours.

4. The mean I_0, F_0 and duration values for each syllable and intensity peaks provided data for stress comparison.

5. The table consisting of F_0 and I_0 values at every 10 milli seconds duration and edited portions from the waveform provided durations, locations and numbers of pauses.

Statistical analysis

Descriptive statistics consisting of mean, standard deviation and minimum and maximum values were obtained for all the parameters.

To check whether there were any significant differences between the values of the normal group and hearing impaired group and between the male and female group. Mann-Whitney V test was applied using SPSS programme.

RESULTS AND DISCUSSION

The present study was undertaken to compare the speech of normal speaking Punjabi children and Punjabi speaking hearing impaired children at discourse level, in terms of prosodic aspects. The study also aimed to find out parameters which contributed more towards intelligibility of speech.

PARAMETERS STUDIED WERE

1) Psychoacoustics Parameters

a) Intelligibility ratings of hearing impaired speech

b) perceptual marking of stressed syllables

2) Acoustics Parameters

A. Fundamental Frequency Features

a)fundamental frequency of speech

b)fundamental frequency (fO) range

c)variations of fundamental frequency in sentences to note intonation contours

d)Mean fO of each syllable for stress correlation

B. INTENSITY FEATURES

a) mean intensity for each syllable for stress measures

C. TEMPORAL FEATURES

a) rate of speech (words/min, syllable/min)

b) Interword pause duration

c) Intraword pause duration

d) between sentence pause duration

e) word duration

f) mean duration of each syllable for stress measurements

1. PSYCHOACOUSTICS PARAMETERS

Intelligibility Rating Of Hearing Impaired Speech :-

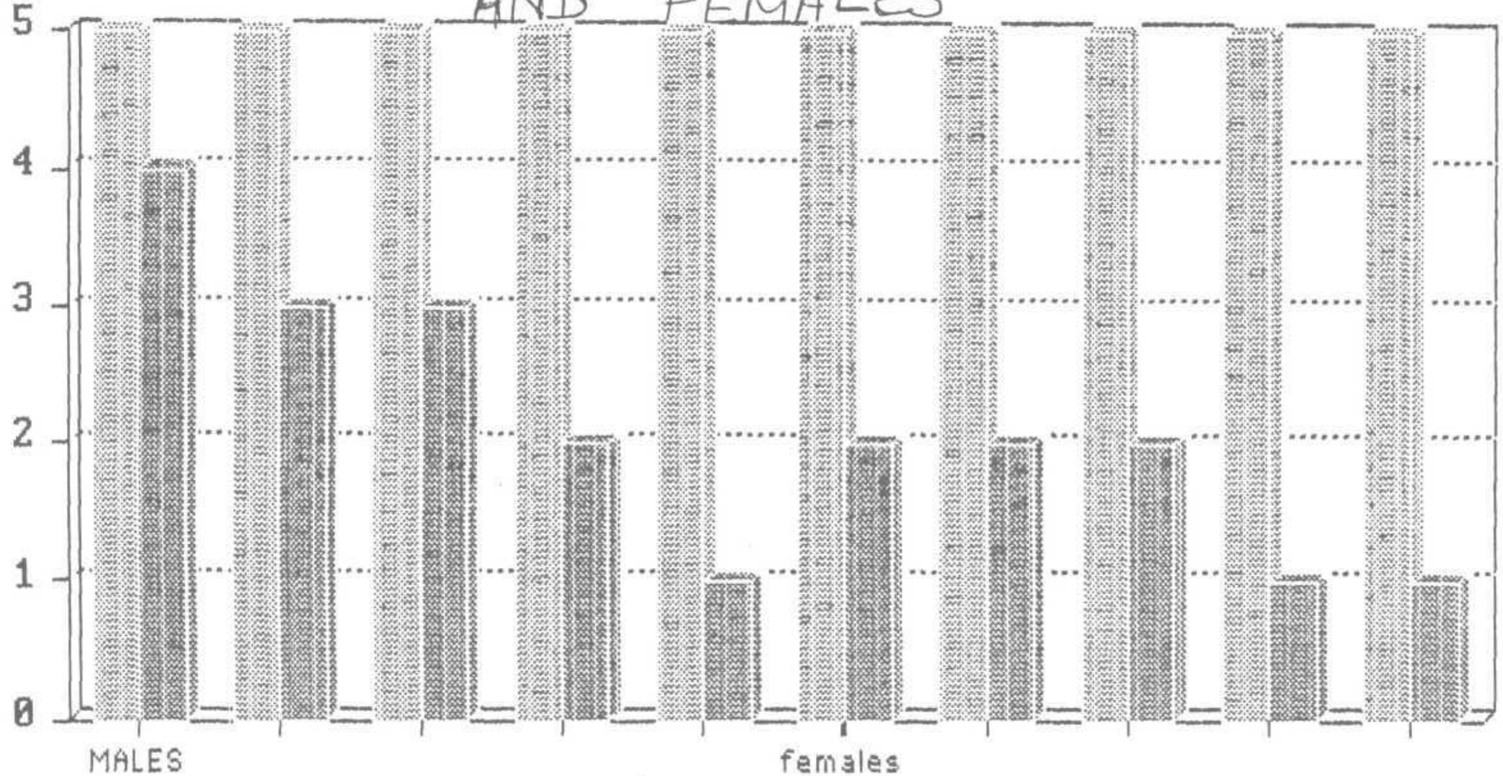
The results of intelligibility test,using the following table showed that males had overall good intelligibility ratings than females. Among males all the judges rated one subject as intelligible, two as just intelligible, one as slightly intelligible, one as not at all intelligible. Among females, three as slightly intelligible,and two not at all intelligible.

In the following discussion these ratings will be compared with each parameter to find out to comment upon

	Not at all intell-igible	Very slightly intelli-gible	Just intelli-gible	Intelligible	Perfectly intelligible
	1	2	3	4	5
Hearing impaired:					
Male (No.)	1	1	2	**1**	
Female(No.)	2	3			
Normal:					
Male *(No)*					5
Female *{No)*					5

Table 1: Intelligibility rating scale for hearing impaired and normal subjects

INTELLIGIBILITY RATING IN MALES AND FEMALES



GRAPH-I NORMALS HEARING IMPAIRED

how much role supra segmental play in intelligibility of speech.

2. ACOUSTIC PARAMETERS

A. Temporal Features

1) Rate of Speech :- As rate of speech has been defined as the number of spoken minute during a complete speech performance (Kelly and steer, 1949) and Pickett,1968 defined the rate of speech as the number of syllables uttered per minute. So both words/minute and syllables/min were calculated for hearing impaired subjects and normal hearing subjects for comparisons.

Table 2 shows the rate of speech for male group (normal hearing and hearing impaired) and table 3 shows the rate of speech values for female group (normal hearing and hearing impaired)

As it is clear from Table 2 and 3r that there is a significant difference between the rate of speech of hearing impaired children and normal children in both the groups (male and female).The mean rate of speech of male normal children is 139.2 words/min and 183 syllables/min and for female normal children is 137.8 words/min and 181.4 syllables/min.For hearing impaired male children the mean rate is 47.46 words/min and 62.54 syllables/min and for

Story total words = 41

Reading syllables = 54

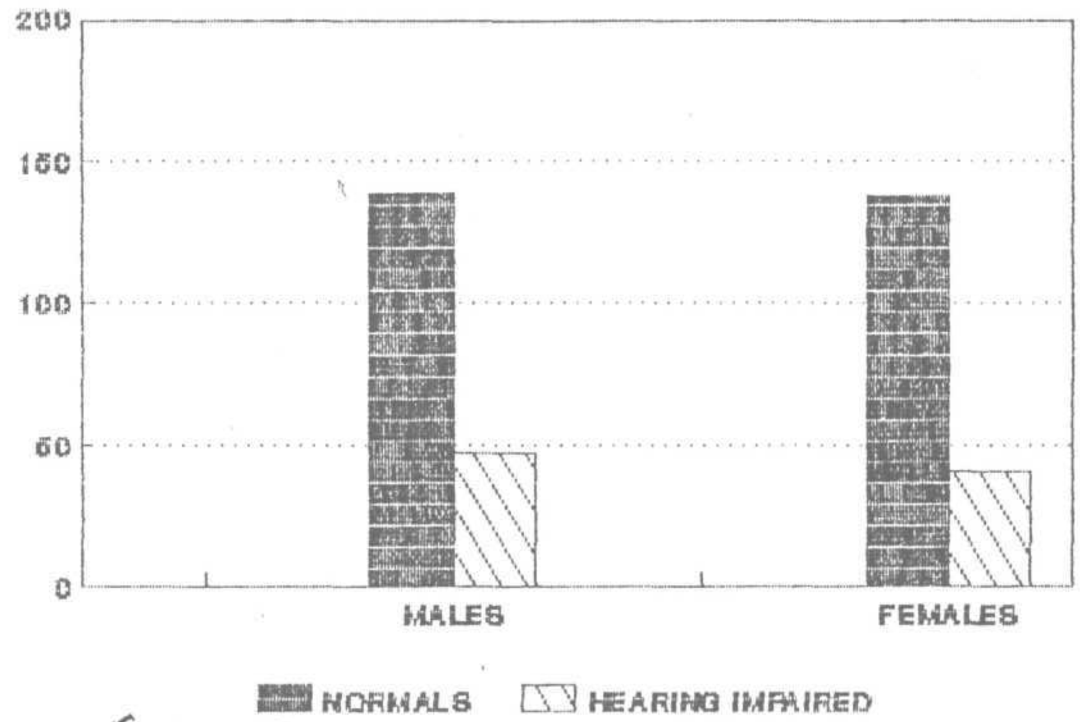
Subjects	Words/min		Syllable/min	
	N.H.	H.I.	N.H.	H.I.
1	145	49.2	190.5	64.8
2	137	50.2	180.0	66.1
3	154	54.6	202.5	72.0
4	123	49.2	162.0	64.8
5	137	34.1	180.0	45.0
Mean	139.2	47.46	183.0	62.54
S.D.	11.45	7.79	14.96	10.24
Significance at 0.05			Significance at 0.05	

Table 2: Rate of speech (words/min, syllable/min) for normal hearing male children and hearing impaired male children. Mean and SD are depicted in the table

Subjects	Words/min		Syllable/min	
	N.H.	H.I.	N.H.	
1	123	44.7	162.0	58.9
2	164	54.6	*216.0*	72.0
3	123	40.99	162.0	54.0
4	159	25.89	209.0	34.1
5	120	35.14	158.0	46.2
Mean	137.8	40.26	181.40	53.04
S.D.	21.74	10.70	28.59	14.14
Significance at 0.05				

Table 3: Mean and SD of rate of speech for normal and hearing impaired female subjects

RATE OF SPEECH (WORDS/ MIN)



GRAPH-II

female children it is 40.26 words/min and 53.04 syllables/ min. Significance was found at. 009 for both the groups. But no significant difference was found between the normal males and females and hearing impaired males and females. Overall speech rate of hearing impaired was slow. This fact is supported by many other authors also in the past (Voelker,1938. John and Howarth, 1965, Boone, 1966 and Colton and Cooker, 1968)Colton and cooker, 1968 have reported that "Reduced speaking tempo is considered quite properly to be one of the abarrent characteristics of speech of the deaf. "

This reduced rate can be accounted because of several factors i.e prolongation of speech segments, insertion of long pauses between phonemes and syllables as well as between words and sentences, failures to modify segment duration as a function of phonetic environment. These all factors are supported by other authors also (Hood,1966, Nickerson et all, 1974, Hudgins and Numbers,1942, Shukla,1987,)Monsen (1974) suggested that perceived slowness of speech is a phenomenon more likely related to the rate of utterances, than to relative phoneme duration.But in the present study it was found that longer phoneme durations itself contributes towards slowness in speech rate of hearing impaired individuals.

As the rate of speech is language specific, this normative data also has see practical implications.

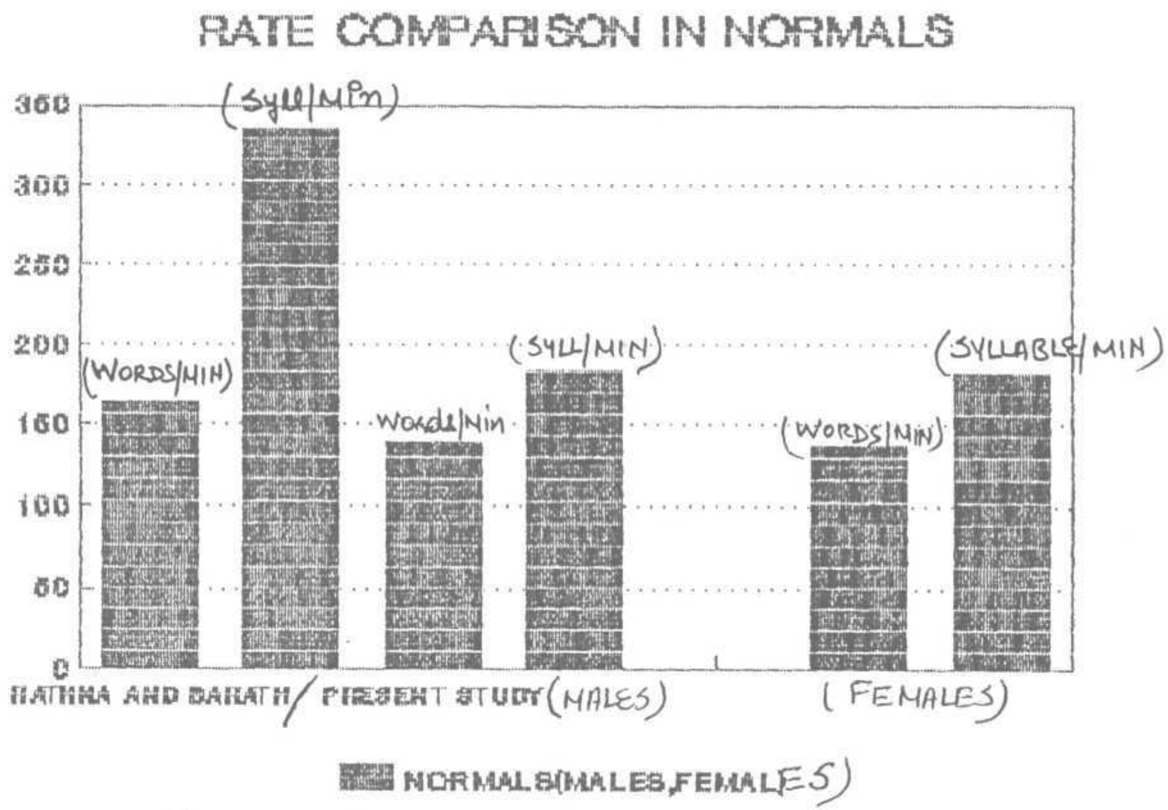
Rathna and Bharadwaj(1977) measured rate of speech in five Indian languages namely, Kannada,Punjabi,Tamil, Marathi and Hindi. It was found that rate varies in different languages and in "Punjabi" language the rate of speech in reading was found to be 163 words/min and 334.66 syllables/min.The spontaneous rate was found to be 149words/min, and 317.66 syll/min. However in present study rate of speech for male group is 139.2 words/min and 183 syll/min and for female group,it is found to be 137.8 words/min and 181.4syll/min and range being 123-154 words/min for males and 120-164 words/min for females.Table 4 shows the comparison.

However, there is a lot of difference in the rate, found in the two studies but may be this difference can be accounted on the basis of age factor and it can be implied that till 15 years also children do not acquire adult standards (because present study considered age range from 11-15 years).

So, in the present study hypothesis stating that there is no difference between normal and hearing impaired children in terms of rate is rejected.

	Mean rate		Word/min		Syllable/min	
Rathna and Bharadwaj (1977)	163 word/min 334.66 Sy/min		156-174		326-351	
	M(5)	F(5)	M	F	M	F
Present study	139.2 w/min	137.8 w/min	123-154	120-164	162-202.5	158-216
	183.0	181.4				
	sy/min	sy/min				

Table 4: Rate comparison of two studies


RATE COMPARISON IN NORMALS
350
300
250
200
150
100
50
0
(WORDS/MIN)
(Syll/Min)
Words/Min
(SYLL/MIN)
(WORDS/MIN)
(SYLLABLE/MIN)
RATHNA AND BARATH / PRESENT STUDY (MALES)
(FEMALES)
NORMALS(MALES,FEMALES)

GRAPH – III

Rate and Intelligibility

In the present study, no correlation of rate and intelligibility was found. For example in the Table I the subject 1 who was rated as most intelligible of all the subjects has the same rate as that of subject 4 who was rated not at all intelligible by all the judges. Overall also no correlation was found between the rate and intelligibility of speech. It can be inferred that rate as a factor does not contribute much towards intelligibility of speech in hearing impaired children.There should be other factors that affect their intelligibility of speech. So it can be said that rate of speech is not apt to considered defective unless it interferes with intelligibility.

2) PAUSES:-

The pause analysis revealed that hearing impaired speakers had more number of pauses than normal speakers.The hearing impaired group had long and short pauses. The short pauses ocurred within words long pauses ocurred between words and sentences.This trend is summarised in Tables IV, V,VI.The mean of Interword pause durations,Intraword pause durations, and between sentence pause durations and their respective standard deviations are for each speaker.The group mean and S.D is also given for more close comparison.

A. Interword Pauses

Table 5 shows that there is a significant difference for the pause durations, between hearing impaired and normal hearing subjects.It was observed that hearing impaired speakers paused after each word whereas normal speakers didn't pause after each word and duration of pauses for hearing impaired group was very much greater as compared to normal group. The mean pause duration for male and female normal group was 210.96 and 172.69 msec respectively, and for male and female hearing impaired group was 476.23 and 669.82 respectively. There was no significant difference found between normal male and female group, but for H.I male and female group significance was found at 0.07 (Table 5).

B. **Intraword** Pauses

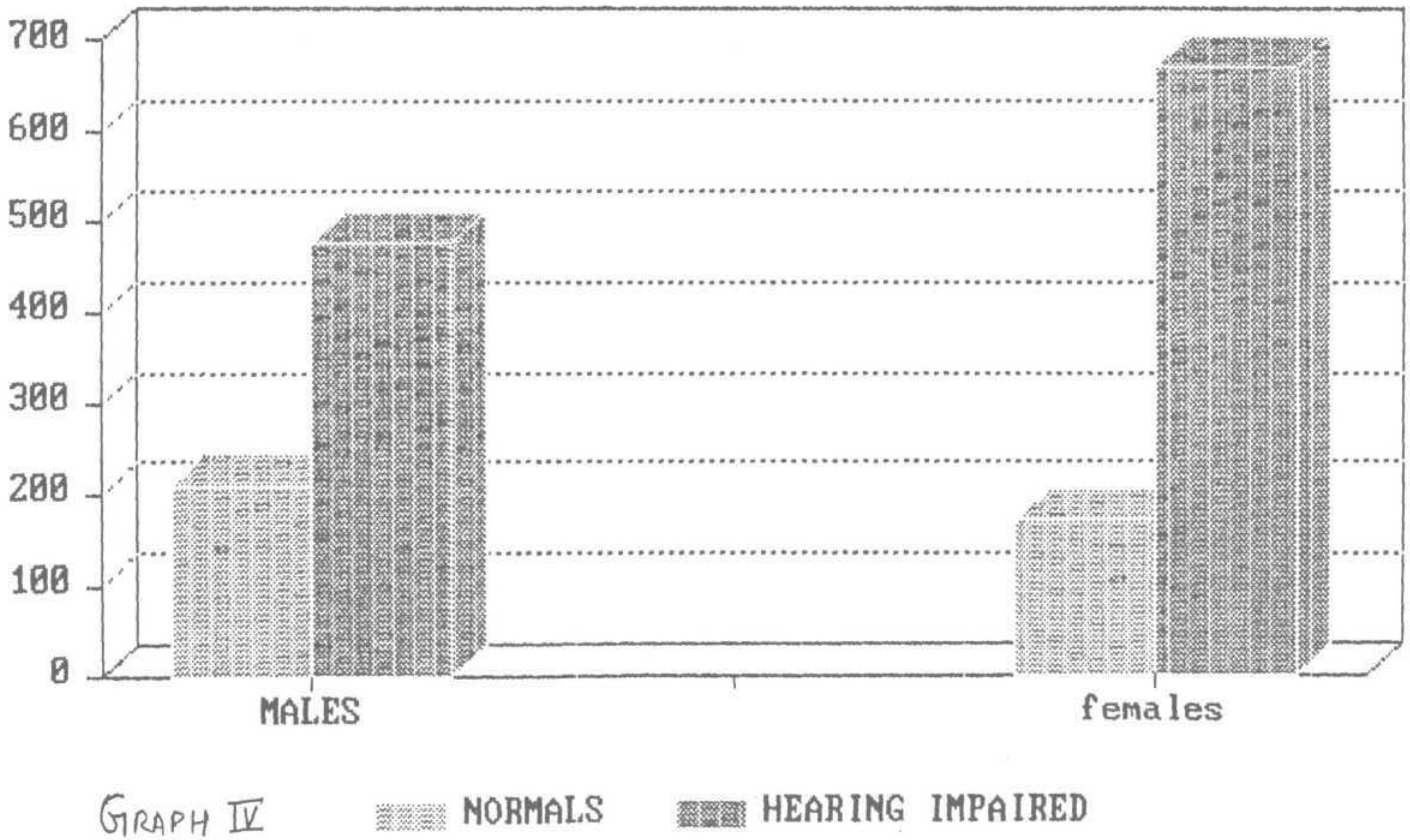
The analysis of intraword pauses revealed that normal hearing speakers did not pause within the words while hearing impaired speakers paused within the words. The number and duration of intraword pauses was significantly less as compared to interword pauses. Table 6 summarizes the fact.

Tables 6 and 7, showed that normals did not have any intraword pauses and mean intraword pause duration for male group was 225.64 msec and for female group, it was 328.80 msec.

Subject	Male group				Female group			
	Normal		H.I.		Normal		H.I	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	121.25	42.27	541.34	163.35	132.00	0	395.58	113.68
2	89.14	24.83	402.26	150.25	90.76	31.25	619.06	204.69
3	99.08	12.57	506.86	112.22	306.83	89.95	802.60	291.43
4	291.25	143.89	573.33	110.79	187.86	110.77	738.28	462.07
5	454.11	112.01	357.36	93.45	146.00	8.48	793.61	195.36
Group mean ± SD	210.96+158.88		476.23+147.95		172.69+82.62		669.82+169.87	
Significance at 0.028					Significance at 0.009			

Table 5: Mean, interword pause duration (in msec) and SD of normal and hearing impaired male and females (calculated by averaging all interword pause durations in full story for each subject)

MEAN INTERWORD PAUSE DURATION

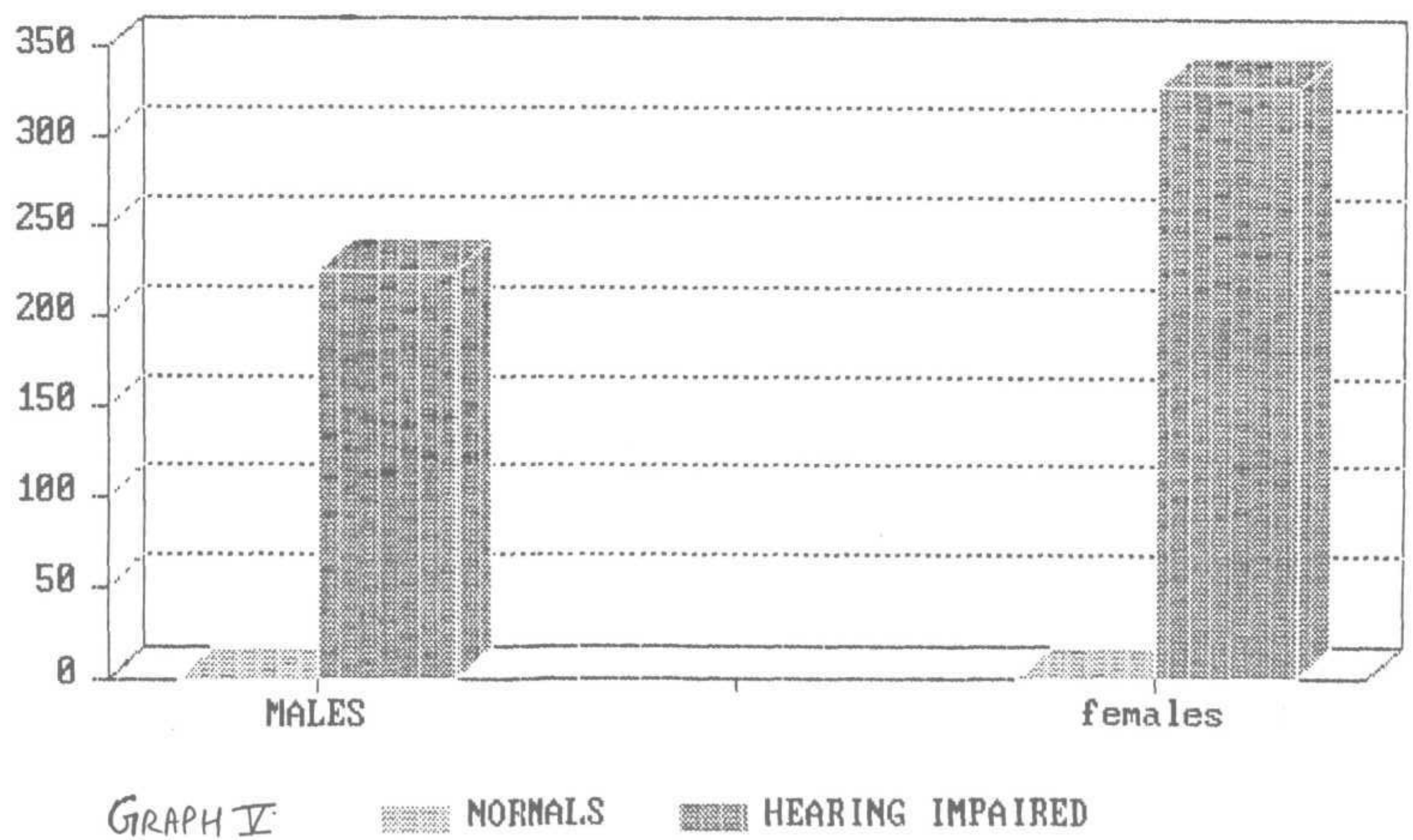


GRAPH IV

Subject	Male group				Female group			
	Normal		H.I.		Normal		H.I.	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	0	0	124.66	0	0	0	393.40	257.86
2	0	0	241.45	0	0	0	266.50	20.50
3	0	0	40.00	0	0	0	194.14	87.00
4	0	0	474.11	0	0	0	317.66	202.96
5	0	0	248.00	0	0	0	472.33	328.91
Group mean + SD	0	0	225.64	0	0	0	328.80	108.29

Table 6: Mean and SD for intraword pause durations normal and hearing impaired male and female groups (calculated by averaging all interword pause durations in full story for each subject)

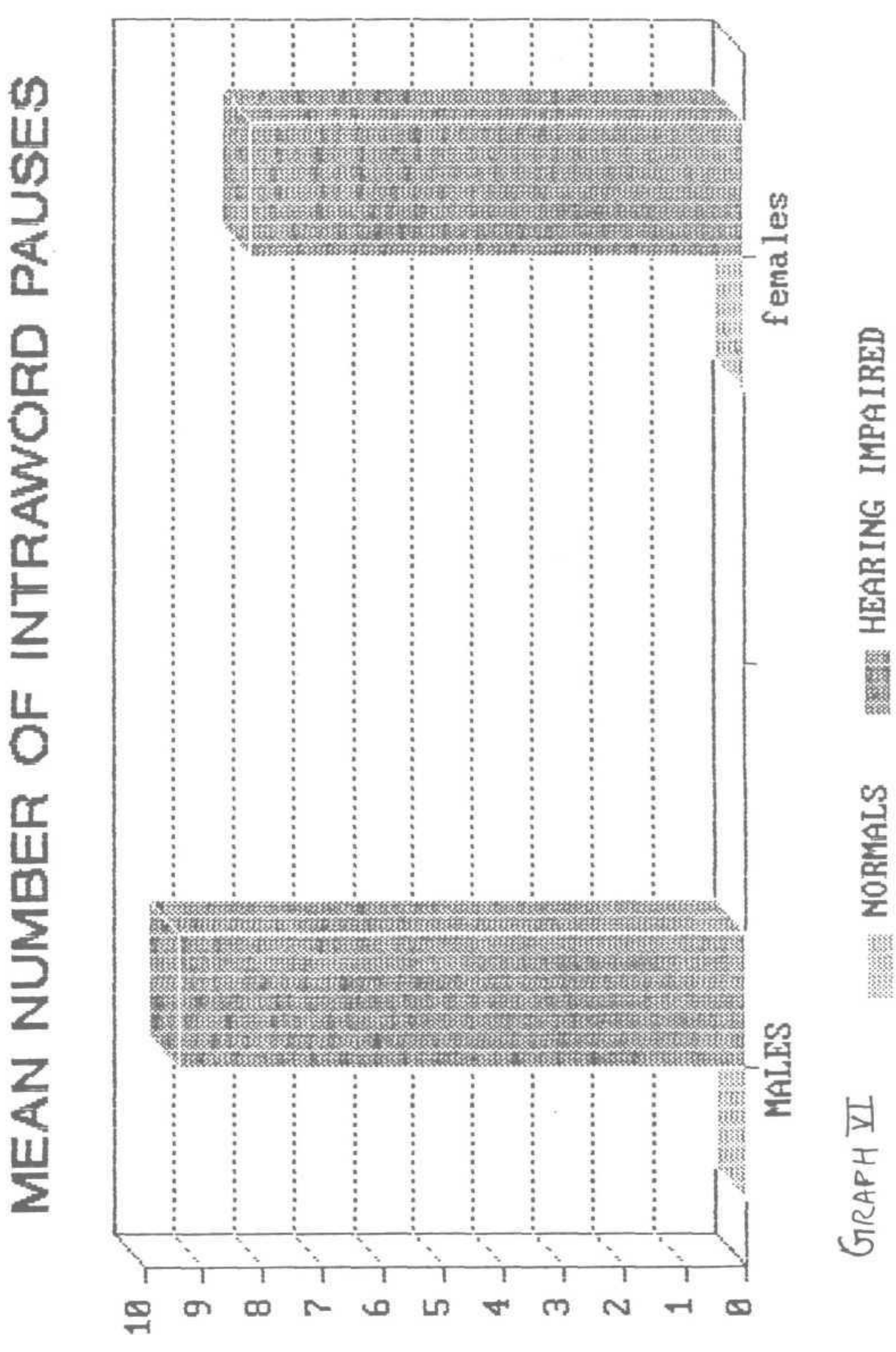
MEAN DURATION INTRAWORD PAUSES



GRAPH V

Subjects	Subjects words/min		Syllable/min	
	N.H.	H.I.	N.H.	H.I.
1	0	15	0	9
2	0	18	0	3
3	0	1	0	12
4	0	12	0	4
5	0	1	0	13
Group mean	0	9.4	0	8.2

Table 7. Number of intraword pauses for normal and hearing impaired group


MEAN NUMBER OF INTRAWORD PAUSES
10
9
8
7
6
5
4
3
2
1
0
MALES
females
NORMALS
HEARING IMPAIRED

GRAPH VI

Mean number of pauses for male group (hearing impaired) found was 9.4 and for female hearing impaired group was 8.2. There was not significant difference between male and female hearing impaired group in terms of number of pauses.

C. Between Sentence Pauses

Analysis of between sentence pauses showed that both normal and hearing impaired children have between sentence pauses. But durations of pauses more significantly greater for hearing impaired group.

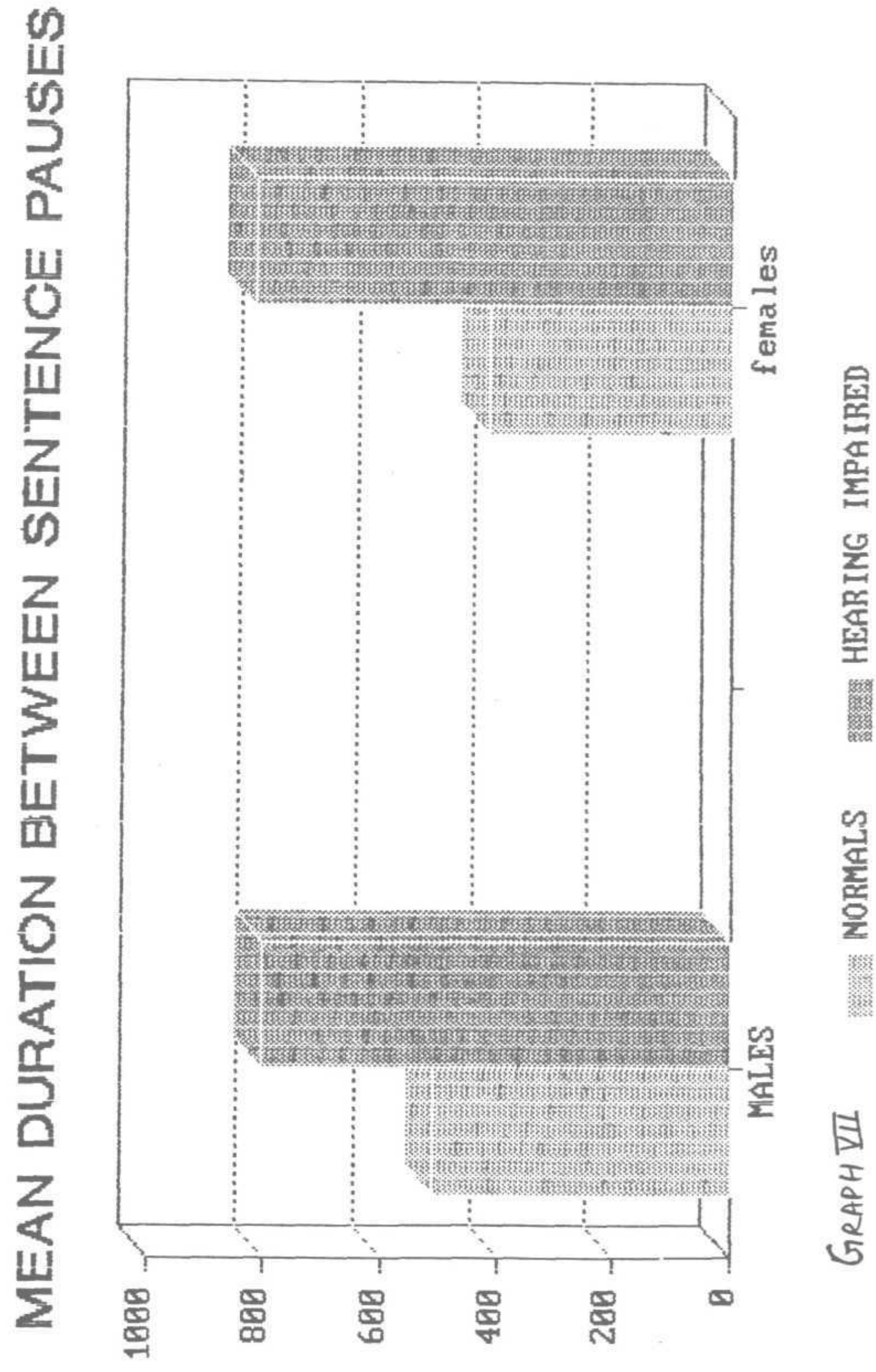
Table 8 summarises the findings in both the groups. The mean duration of pause of normal male group is 513.36 and standard deviation is 168.16. For hearing impaired male group mean duration of pause is 803.22 and standard deviation is 222.97. For female group, the mean duration found was 425.28 and 826.25 for normal and hearing impaired group respectively. For male group significance was found at 0.05 level and female group it was at 0.009. So much variation is seen within the subjects of both male and female hearing impaired group. No significant difference was found between normal male and female groups between hearing impaired male and female groups.

So in the present study, the hypothesis stating that there is no difference between normal and hearing impaired

Subject	Male group						Female group					
	Normal			H.I.			Normal			H.I.		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
1	518.57	84.63	225	1054.28	736.11	2204	319.71	117.80	328	585.57	209.65	521
2	538.42	233.47	756	508.57	244.50	590	513.85	174.43	589	705.28	331.50	883
3	379.28	238.05	661	839.28	355.25	1100	324.57	102.91	301	726.71	257.22	708
4	539.57	158.10	399	961.42	565.14	1690	520.57	204.33	553	1177.42	538.51	1492
5	591	126.55	359	652.57	226.30	586	430.28	85.64	200	936.28	249.76	786
Group Total	513.36	168.16	917	803.22	222.97	1915	425.28	102.30	722	826.25	233.39	1963

Significance at 0.05 Significance at 0.00

Table 8: Mean, SD and range between sentence pause duration for normal and hearing impaired male and female group


MEAN DURATION BETWEEN SENTENCE PAUSES
1000
800
600
400
200
0
MALES
females
NORMALS
HEARING IMPAIRED

GRAPH VII

individuals in terms of (a) interword pauses, (b) intraword pauses and (c) between sentence pauses is rejected.

To summarize, in this study the number, duration and location of pauses was compared for normal and hearing impaired groups. The hearing impaired group had significantly more number of pauses (both intraword and interword). Hearing impaired pause after each word whereas normals don't pause after each word. No intraword pauses were seen for normal group, whereas intraword pauses were present for hearing impaired group. In terms of duration hearing impaired group had both short and long pauses. Short pauses within the words and long pauses between words and between sentences. But the duration of their pauses is significantly greater as compared to normal group.

These findings are in correlation with other author's findings (Stathopoulos et al., 186; Bochner et al., 1987; Gold, 1980; Graddol, 1991; Oberger and McGarr, 1980; Sheela, 1988; Jagdish, 1989) and others. Authors support the view that pauses are the major contributor to the slower pace of deaf children speech and the present study is in agreement with this finding.

Pauses and Intelligibility

In the present study it was observed that though hearing impaired speakers pause after each word but he children, who were judged to be more intelligible by the judges had longer duration of interword pauses and between sentences pauses and short durations of intraword pauses as compared to other hearing impaired children who were judged to be less intelligible and not at all intelligible. With respect to number of intraword pauses, the present study failed to find any correlation, and it can be inferred that number of pauses as such is not contributing as a factor towards intelligibility of speech. These findings need further research before its generalization.

The present findings get support from the study done by Stathopoulos et al. (1986) who hypothesized that deaf speakers intonation and timing patterns relate to their linguistic competencies, but in way that are different from normal-hearing speakers specifically, deaf speakers, in relation to pausing, use long pauses to distinguish sentence boundaries while normal-hearing speakers rely more on falling terminal contours. Furthermore, since normal hearing speakers pauses within and between sentences have overlapping durations, they may serve similar functions. Deaf speakers, on the other hand, use markedly shorter pauses within sentences than between them, leading them to hypothesize that the difference in pause length may be used to mark the distinction between word and sentence boundaries. Finally, they concluded that the abnormal use of pauses by deaf speakers may actually improve the intelligibility of their speech. And the present study actually quantify this aspect and put further light into the possible factors contributing towards intelligibility of speech.

The possible explanation given by Osberger and Levitt (1979) and supported by present study is that the pauses between words in deaf speech after the listeners needed time to process the distorted speech listener.

The present findings does not support the findings of Bernstein (1977) who found no reduction in the intelligibility of speech samples produced by a normal speaker when synthesized with timing errors. However studies of Sheela (1988) and Jagadish (1989) found correlation of temporal aspects and intelligibility, when they studied computer correlation of some of the temporal aspects in the speech of the hearing-impaired on speech intelligibility.

The findings of present study have some therapeutic implications. The speech therapists can work on the improvement of the intelligibility of the HI by reducing the within word pauses, whereas difference in duration of pause can be taught to mark the distinction between word and sentence boundaries and thus enhancing their speech intelligibility.

3. Word Duration

The hearing impaired subjects had longer word durations as compared to the normal hearing speakers. The hearing impaired subjects had a mean word length of 744.75 ms (SD = 188.07) for male group and 730.07 ms (SD = 61.28) for female HI group. In normals the male group had a mean word length of 294.57 ms (SD = 22.30) and female group had a mean word length of 343.49 (SD = 99.31). Longer word durations were characteristic of all the hearing impaired subjects (means in millisecond for male hearing impaired are 646.61, 634.68, 549.29, 944.54, 948.67 and for female group are 733.30, 613.56, 769.36, 755.92, 768.25).

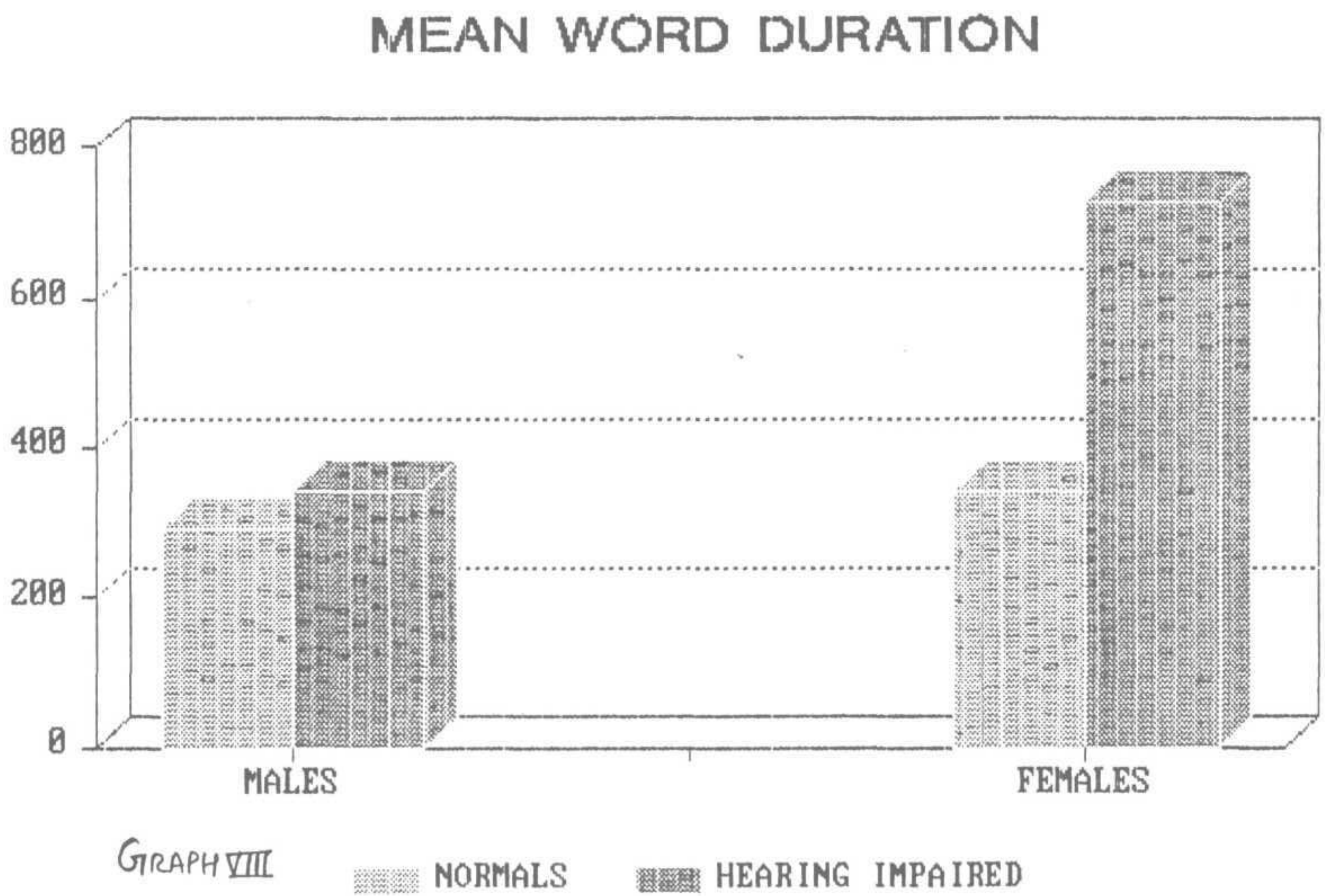
As the table 9shows the individual means of hearing impaired subjects didn't overlap with the individual means of normal hearing speakers and there was a significant difference between the two groups at the level of 0.009. But hearing impaired males and female didn't show any significant difference as well as normal males and female group did not show any significant difference.

The present study findings correlate with the findings of Leeper (1987), Osberger and McGarr (1982).

So in the present study the hypothesis that there is no difference between normal and hearing impaired children is reflected.

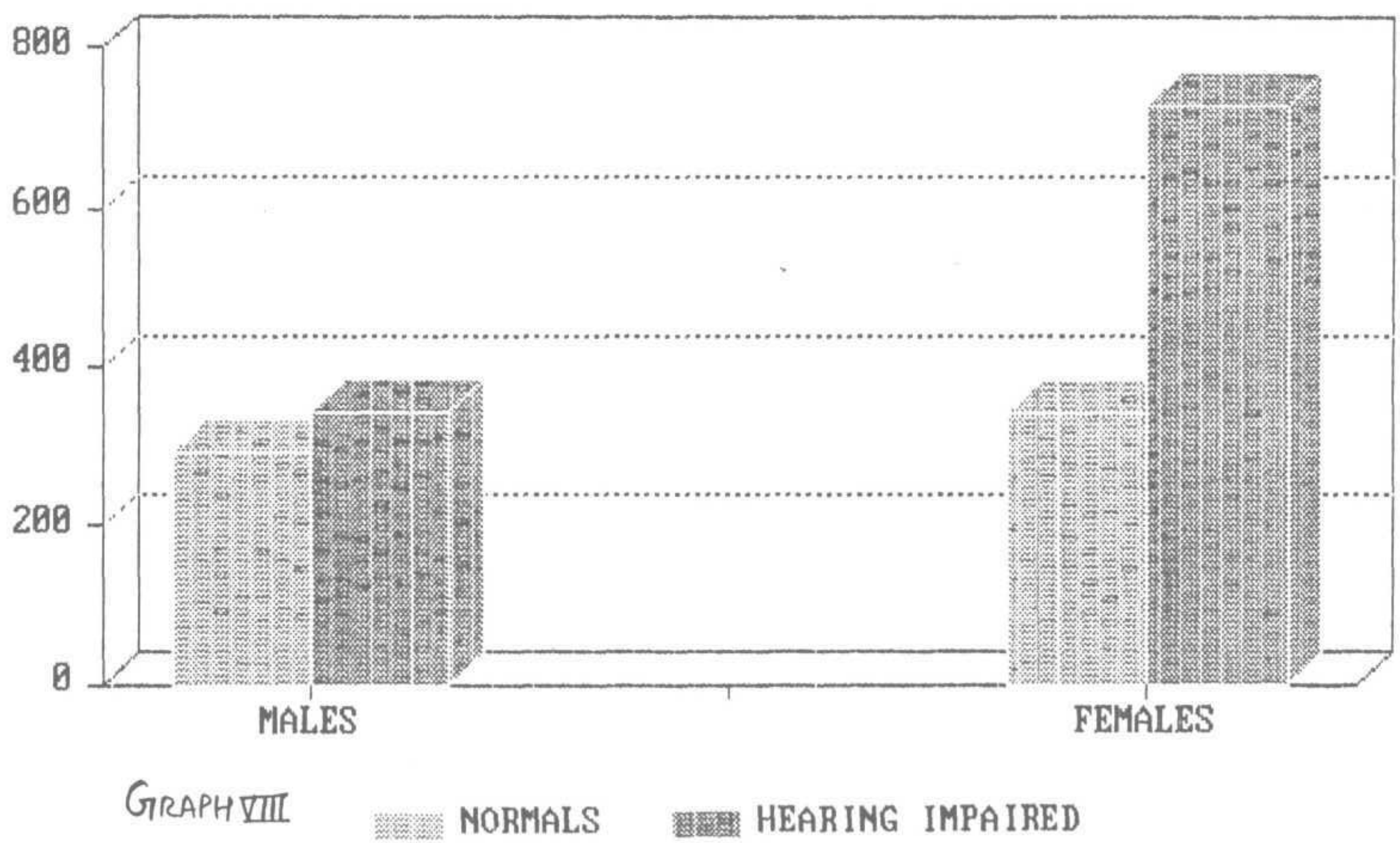
Subject	Male group				Female group			
	Normal		H.I		Normal		H.I.	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	264.34	30.62	646.61	63.50	302.85	26.94	733.30	170.42
2	314.73	44.31	634.68	100.90	244.76	20.29	623.56	157.43
3	313.92	50.67	549.29	114	434.04	39.62	769.36	129.88
4	278.70	37.87	944.54	216.67	464.52	64.18	755.92	122.61
5	301.20	34.48	948.67	105.22	271.31	25.19	768.25	146.75
Group mean + SD	294.57+22.30		744.75+188.04		343.49+99.31		730.07+61.28	

Table 9: Mean word duration and SD for normal and hearing impaired male and female impaired male and female subjects


MEAN WORD DURATION
800
600
400
200
0
MALES
FEMALES
NORMALS
HEARING IMPAIRED

GRAPH VIII

MEAN WORD DURATION



GRAPH VIII

B. Fundamental Frequency Features

1. Fundamental frequency in discourse (story) and Fundamental frequency range

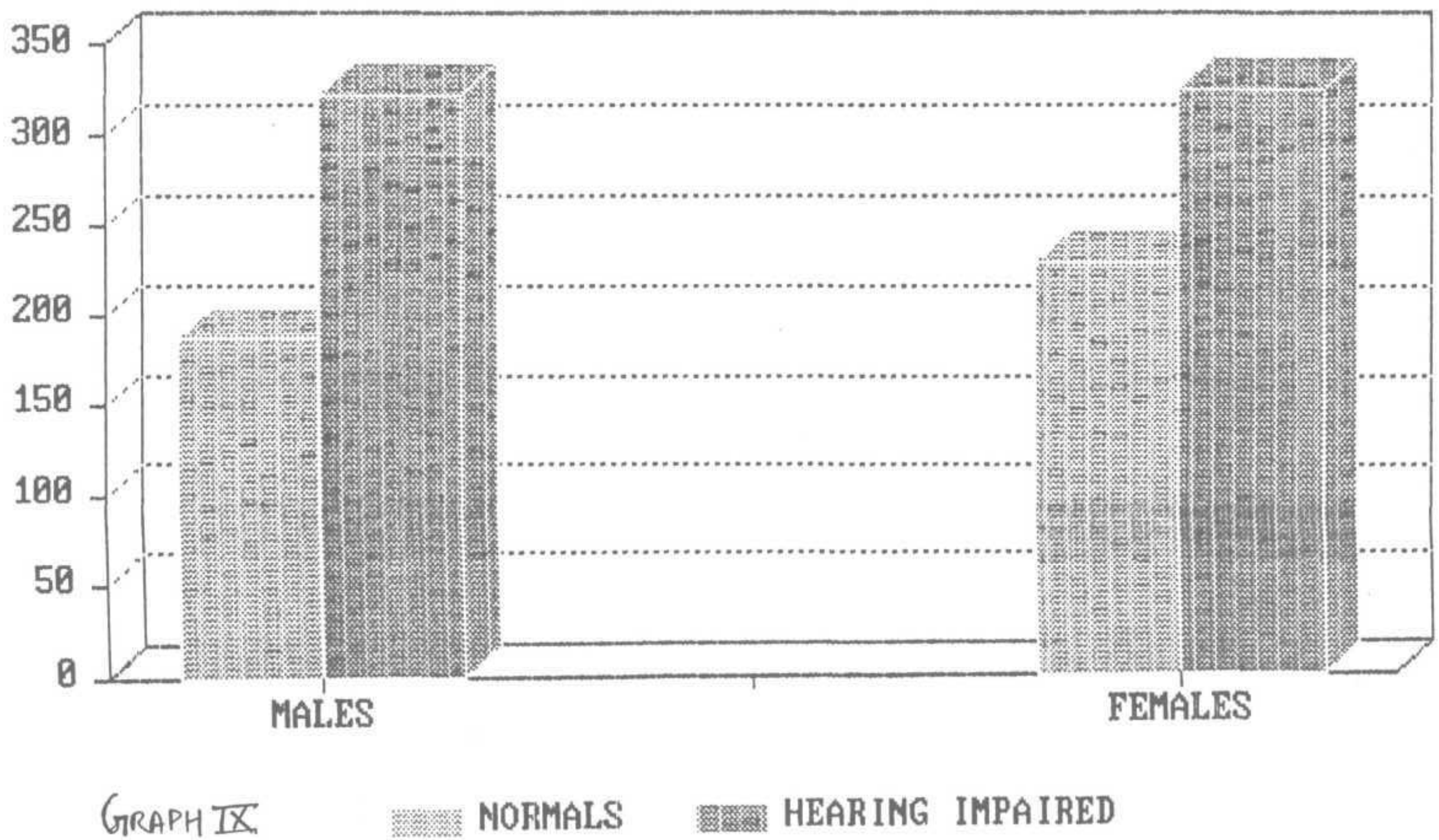
The findings of the fundamental frequency in full story for the hearing impaired group and normal group is given in tables 10 & 11 and graphs IX .X

Absolute values of F_0 averaged across the entire read story for each subject, and group are reported in tables 10 and 11. Hearing impaired subjects had an overall higher F_0 than normal hearing subjects. For male hearing impaired group the mean F_0 was 322.39 and for normal male group was 188.31. For female group mean F_0 for hearing impaired subjects was 326.088 and for normal subjects was 230.58.

	Story F_0	Highest F_0	Lowest F_0	range
Hearing impaired male subjects				
1	352.23	443.39	242.42	200.97
2	274.70	282.36	123.08	159.00
3	284.81	371.69	108.35	263.26
4	404.61	522.74	151.60	371.14
5	295.60	315.76	187.98	127.78
Group mean ± SD	322.39 ±55.64	387.18 ±97.29	162.68 ±53.94	224.43 ±96.44
Normal hearing male subjects				
1	178.01	320.00	84.34	235.66
2	163.94	282.29	129.12	153.17
3	232.21	354.99	96.61	258.38
4	177.41	333.33	101.10	232.23
5	190.00	314.12	100.62	213.50
Group mean ± SD	188.31 ±26.21	320.94 ±26.71	102.35 ±16.42	218.58 ±39.89

Table 10: Mean F_0 (Hz) averaged across total story, and highest and lowest F_0 points and ranges of F_0 variation for each hearing impaired and normal hearing male subjects

MEAN FO



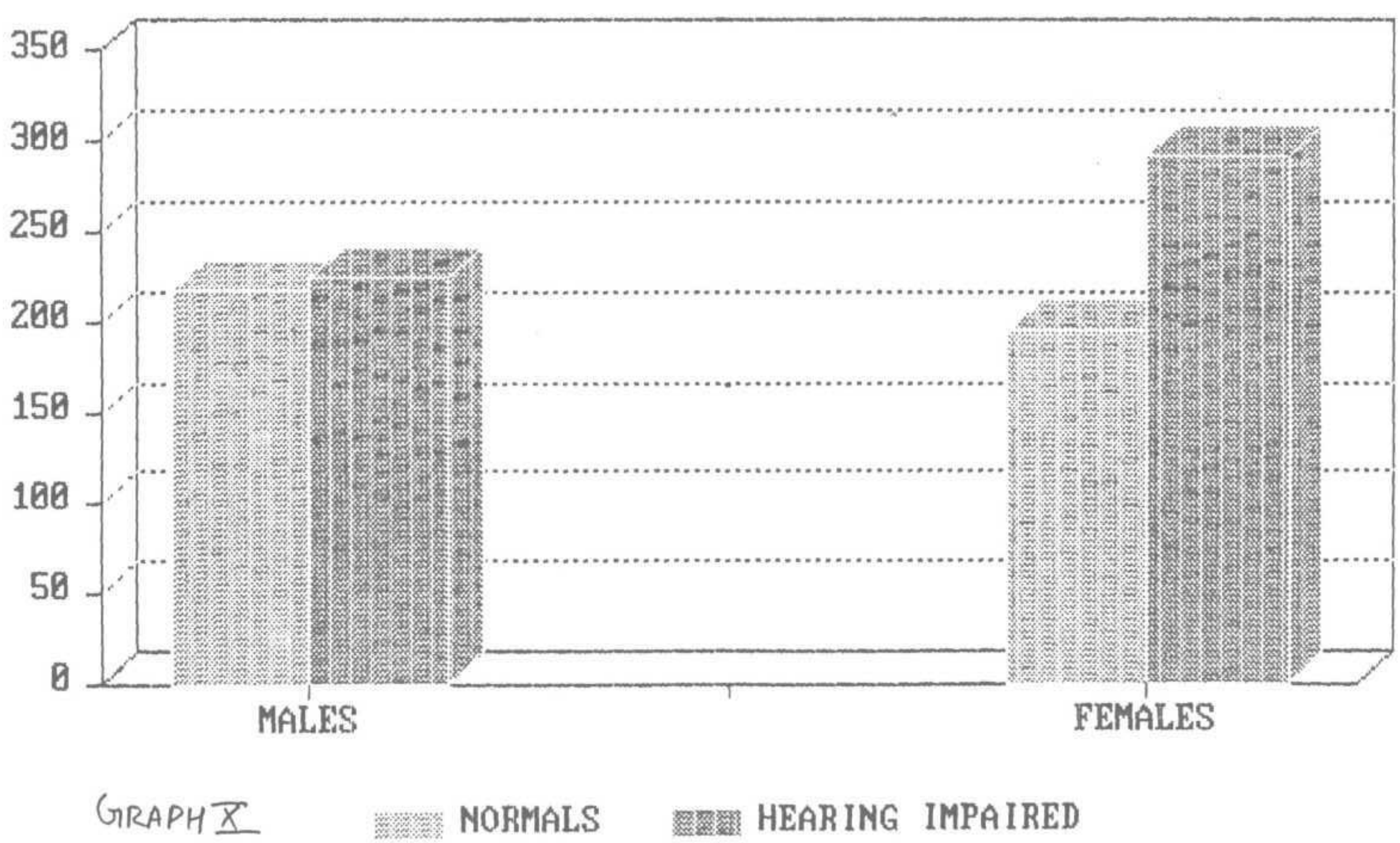
GRAPH IX

	Story F_0	Highest F_0	Lowest F_0	F_0 range
Hearing impaired female subjects				
1	409.16	582.52	104.58	477.94
2	277.69	345.83	91.63	251.19
3	269.95	382.96	158.42	224.54
4	335.90	473.85	89.89	383.96
5	337.74	401.60	279.97	121.63
Group mean + SD	326.088 $\pm$56.18	437.30 $\pm$93.56	145.49 $\pm$80.49	291.85 $\pm$139.88
Normal hearing female subjects				
1	256.49	327.25	214.15	150.10
2	262.11	340.89	226.17	160.72
3	208.54	320.70	92.49	228.21
4	214.68	336.91	91.95	244.96
5	211.11	314.71	115.50	199.21
Group mean $\pm$ SD	230.58 $\pm$26.37	328.09 $\pm$10.90	148.05 $\pm$66.64	196.62 $\pm$41.21

Significant at 0.05

Table 11: Mean F_0 (Hz) averaged across total story, and highest and lowest F_0 points and ranges of F_0 variation for each hearing impaired and normal hearing female subjects

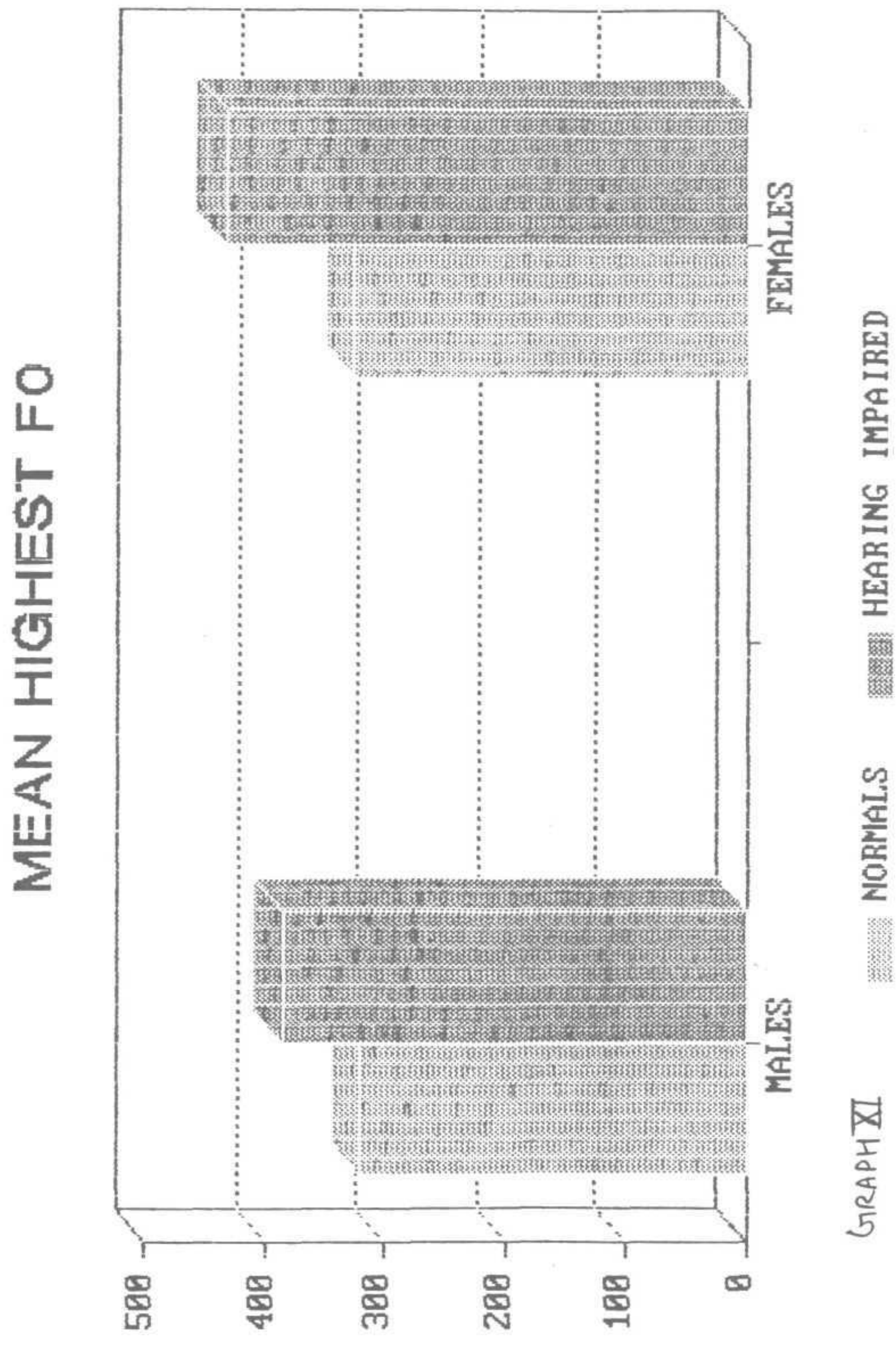
MEAN FO RANGE



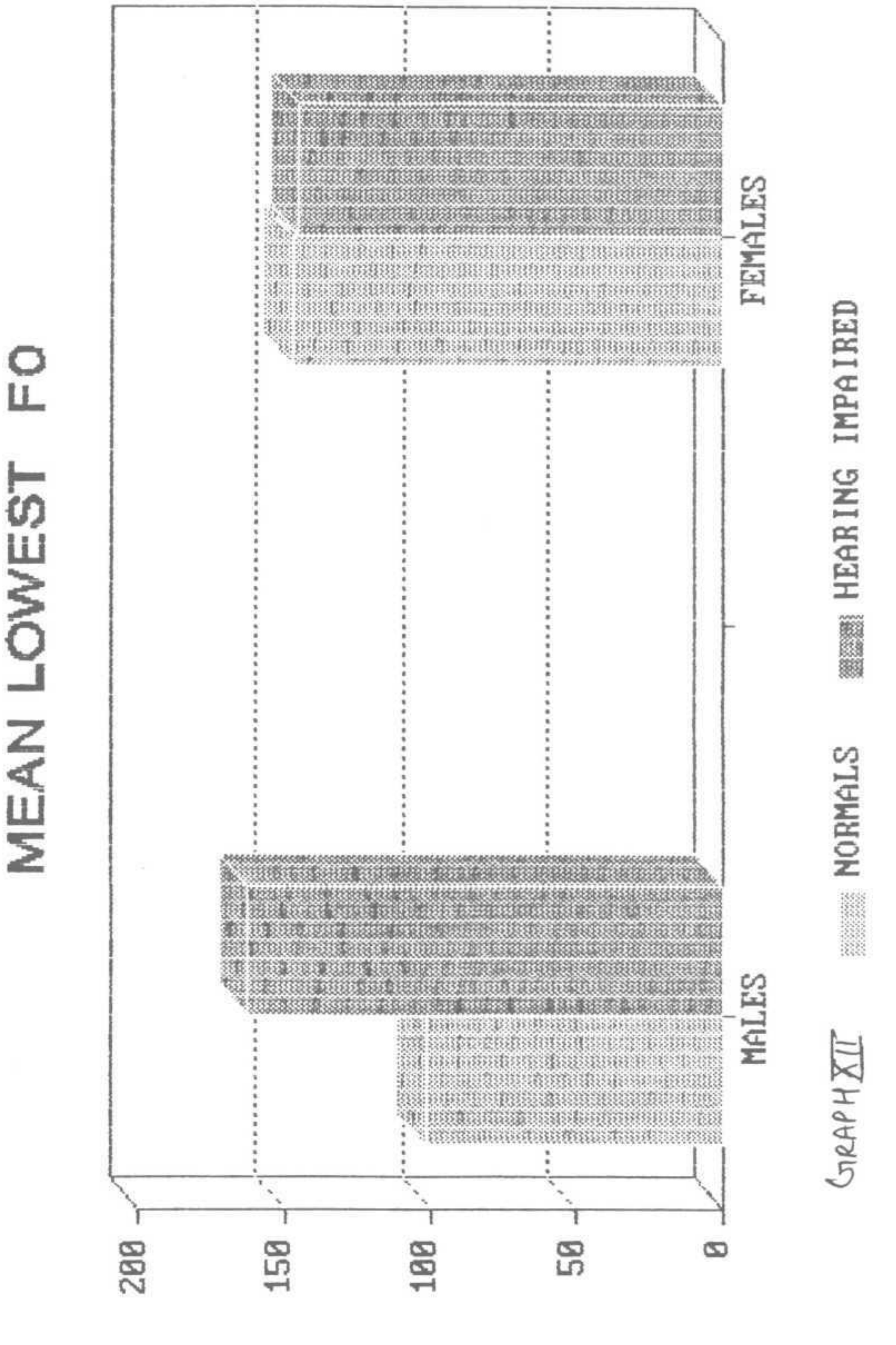
GRAPH X

The highest and lowest frequency points are also reported for each subject. It was observed that hearing impaired females as a group had wider frequency range when compared to normal group. But in males the average Fg range of two groups did not had a significant difference. But there was a considerable overlap and drastic difference when compared with the individual subjects. Hearing impaired subjects showed too much variability among themselves, whereas normal group did not show much variability. These factors however can be accounted on the basis of different intelligibility scores for hearing impaired group, which will be discussed later. The findings of this study however did not correspond with the reports of other investigators in terms of frequency range. Hood and Dixon (1969), Calvert (1962), Staphopoulos, Duchan, Sonnenmeier and Bruce (1986) found that on the average, deaf speakers had a more limited F_0 range. They reported that this was true for all speakers and did not seem to be related to their level of reading competence. The present study does not support this finding. However three kinds of frequency range were observed in the present study when individuals studied were namely:

1. Limited range as compared to normal group.
2. Range approximating the normal group (also observed by Whitehead and Maki (1977) and Monsen (1979).
3. Wider range as compared to normal group (also observed by Angelocci et al., 1964).


MEAN HIGHEST FO
500
400
300
200
100
0
MALES
FEMALES
NORMALS
HEARING IMPAIRED

GRAPH XI


MEAN LOWEST FO
200
150
100
50
0
MALES
FEMALES
NORMALS
HEARING IMPAIRED

GRAPH XII

Th is fact has been accounted for, by the findings of Nickerson (1975) who observed two kinds of F_0 variations.

1. Excessive variation in F_0 and
2. Little variation in F_0 resulting in flat and monotonous speech.

Nickerson (1975) has also commented that such variations are not simply normal variations that have been somewhat exaggerated but rather pitch breaks and erratic changes that don't serve the purpose of intonation. The findings of the present study agree with the Nickerson"s explanation. To explain this it can be suggested that some hearing impaired speakers attempted to differentiate syllable boundaries by excessive laryngeal variations rather than using other parameters which are normally used by other normal speakers and this abnormal pitch variations have been considered to be major cause of faulty intonation in speech of the hearing impaired and resulting in wider frequency range.

The fact that hearing impaired speakers had an overall higher F_0 as compared to normal speakers is in agreement with findings other investigator's (Angelocci, Kopp and Holbrook, 1964; Boone,1966; Mortony, 1968; Whitehead and Maki, 1977; Monsen, 1979). The following table summarizes different findings.

This fact has been accounted for, by the findings of Nickerson (1975) who observed two kinds of F_0 variations.

1. Excessive variation in F_0 and
2. Little variation in F_0 resulting in flat and monotonous speech.

Nickerson (1975) has also commented that such variations are not simply normal variations that have been somewhat exaggerated but rather pitch breaks and erratic changes that don't serve the purpose of intonation. The findings of the present study agree with the Nickerson's explanation. To explain this it can be suggested that some hearing impaired speakers attempted to differentiate syllable boundaries by excessive laryngeal variations rather than using other parameters which are normally used by other normal speakers and this abnormal pitch variations have been considered to be major cause of faulty intonation in speech of the hearing impaired and resulting in wider frequency range.

The fact that hearing impaired speakers had an overall higher F_0 as compared to normal speakers is in agreement with findings other investigator's (Angelocci, Kopp and Holbrook, 1964; Boone,1966; Mortony, 1968; Whitehead and Maki, 1977; Monsen, 1979). The following table summarizes different findings.

Investigator	Findings
Angelocci et al. (1964)	Mean F_0 of hearing impaired adolescents between 11 to 14 years was 43 Hz higher than that of the normally hearing subjects.
Boone (1966)	Problem was greater for teenagers than for pre-adolescents.
Monsen (1979)	Mean F_0 for speech for normals 124 Hz and for hearing impaired = 297 Hz.
Boothroyd (1970)	The auditory feedback system is the main channel for appropriate establishment and production of F_0. F_0 subjectively called as pitch, has been a particularly difficult property of speech for deaf children to learn to control.
Martony (1968)	F_0 is high because deaf children may lack a conceptual appreciation of what pitch is.

So, in present study, the hypothesis stating that there is no difference (1) between hearing impaired and normals (males and females) in terms of fundamental frequency and fundamental frequency range is rejected. (2) between hearing impaired males and females is accepted in terms of F_0 but rejected in terms of F_0 range and (3) between normal males and females is rejected in terms of F_0 and accepted in terms of F_0 range.

Intonation contours

As mentioned in the methodology, the objective analysis of intonation, for each of the sentence was carried out using the programme INTON. Mean F_0 of each syllable was calculated and intonation contours were plotted and analyzed for the patterns present in hearing impaired and normals. The intonation contours were analyzed in two ways:

a. Frequency differences between first and last syllables for individual sentences (shown in tables) and Fig. 1 vs l(a) and 2 vs 2(a). Positive values represent falling intonation and negative values indicate rising intonation. Also shown are mean and standard deviation differences for each speaker across all sentences.

b. Analysis of complete intonation contours, i.e. analysing each syllable variation in a sentence and analyzing the patterns. Results showed variable patterns for each hearing impaired speaker which are presented in figures 4, 5, 6 and 7.

c. Tables 12 and 13 show differences in scores (in Hz) between sentence ending F_0 and sentence beginning F_0 (mean of syllable) for hearing impaired and normal-hearing subjects.

The data of tables 12 & 13 and Fig. 1, l(a) and 2, 2(a) reveal substantial variability across the sentences and speakers of hearing impaired group. For normal hearing group it was seen that tendency is for falling intonation but hearing impaired group showed greater variability in terms of falling and rising intonation. In terms of range of variability also, sometimes hearing impaired showed wider ranges of variation in F_0, they start the sentences at a low F_0 or vice versa. Secondly they sometimes show very less variability or it is almost flat pattern. Although these values overlap with the normal group when individual values are compared. But normals had a more stable pattern suggesting that variations hearing impaired was not simply normal variations but rather pitch breaks and erratic changes that did not serve the purpose of intonation. These findings correlate with the findings of Nickerson (1975) and Stathopeulos, Duchan and Sonnemeier, Bruce (1986).

	Sentence								Falling sentences	Rising sentences
	1	2	3	4	5	6	7	8	Mean ± SD	Mean ± SD
Hearing impaired males										
1	-3.51	-13.1	0.57	16.23	14.4	-41.03	21.95	+16	13.83±7.94	-19.20±19.49
2	-21.5	-21.5	-19.0	-30	7	18	25	133	45.75±58.63	-22.5±4.97
3	-107	-53	71	43	-69	19	1	20	30.80+26.96	76.33±27.73
4	-36	-35	28	-8	-37	-46	6	-22	14.00±12.16	-35.2±8.5
5	-34	-43	4	-13	-76	17	19	31	17.75±11.05	-41.5±31.51
Normals										
6	16.80	44.71	37.67	63.42	50.63	57.75	11.43	55.07	42.18±19.07	0
7	114.7	16.56	91.62	45.26	28.18	38.67	67.457	115.94	64.25±38.84	0
8	56.53	78.75	61.74	41.82	26.78	19.12	38.55	55.07	46.75±19.51	0
9	38.53	3.65	44.58	23.96	4.15	16.76	25.08	4.41	24.62±16.48	0
10	24.86	40.79	52.73	71.66	48.19	14.83	18.38	56.69	40.37+20.11	0

Table 12: Difference scores (in Hz) between sentence-ending F_0 and sentence-beginning F_0 for hearing impaired and normal hearing male subjects

Positive numbers indicate that sentence ending frequency was lower than sentence beginning frequency (falling) while negative numbers indicate sentence ending frequency was higher than sentence beginning frequency (rising).

	Sentence								Falling sentences Mean ± SD	Rising sentences Mean ± SD
	1	2	3	4	5	6	7	8		
Hearing impaired males										
1	-93	-51	14	51	-128	-76	3	11	19.75±21.34	-87±32.32
2	0	-20	-7	6	-15	4	11	-13	7±3.6	-13.75±5.37
3	-118	5	-1	20	9	14	141	-2	37.8±51.96	-40.33±67.26
4	14	-52	5	-13	-13	13	-7	-17	10.66±4.9	-20.40±18.02
5	10	-24	1	-100	-4	-2	16	-17		
Normals										
6	15.53	33	24	56	12	13	22	36	26.37±14.84	0
7	52	3	36	15	4	15	25	49	24.87±19.08	0
8	56	230	15	43	13	15	50	35	32.12±16.78	0
9	73	41	62	66	53	40	62	38	54.37±13.38	0
10	53	40	24	55	30	44	20	50		

'Table 13: Difference scores (in Hz.) between sentence-ending F_0 and sentence-beginning F_0 for hearing impaired and normal hearing male subjects

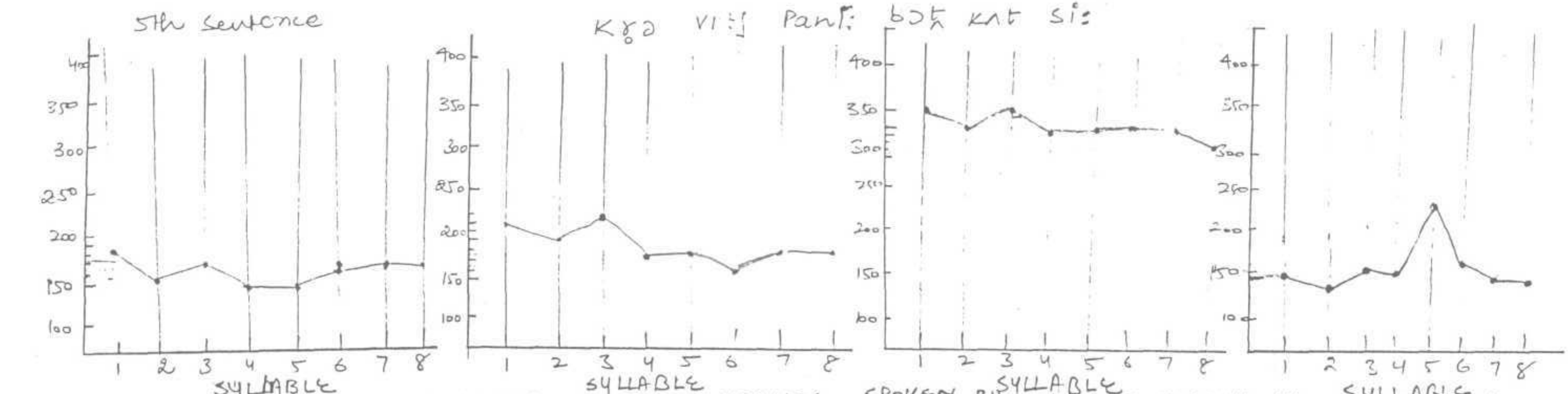


Fig: 1 — INTONATION CONTOURS OF A SENTENCE SPOKEN BY NORMAL HEARING CHILDREN. EACH DATA POINT IS THE MEAN FUNDAMENTAL FREQUENCY VALUE MEASURED FOR EACH SYLLABLE.

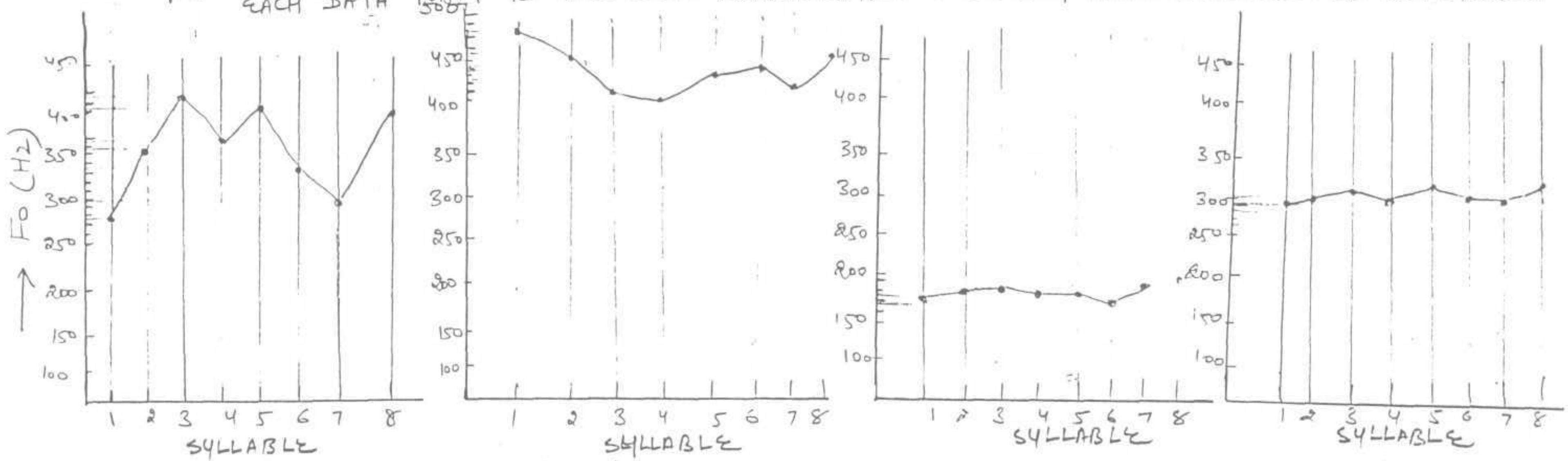


Fig (2) INTONATION CONTOURS OF A SENTENCE SPOKEN BY HEARING IMPAIRED MALE SUBJECTS EACH DATA POINT IS THE MEAN FUNDAMENTAL FREQUENCY VALUE MEASURED FOR EACH SYLLABLE.

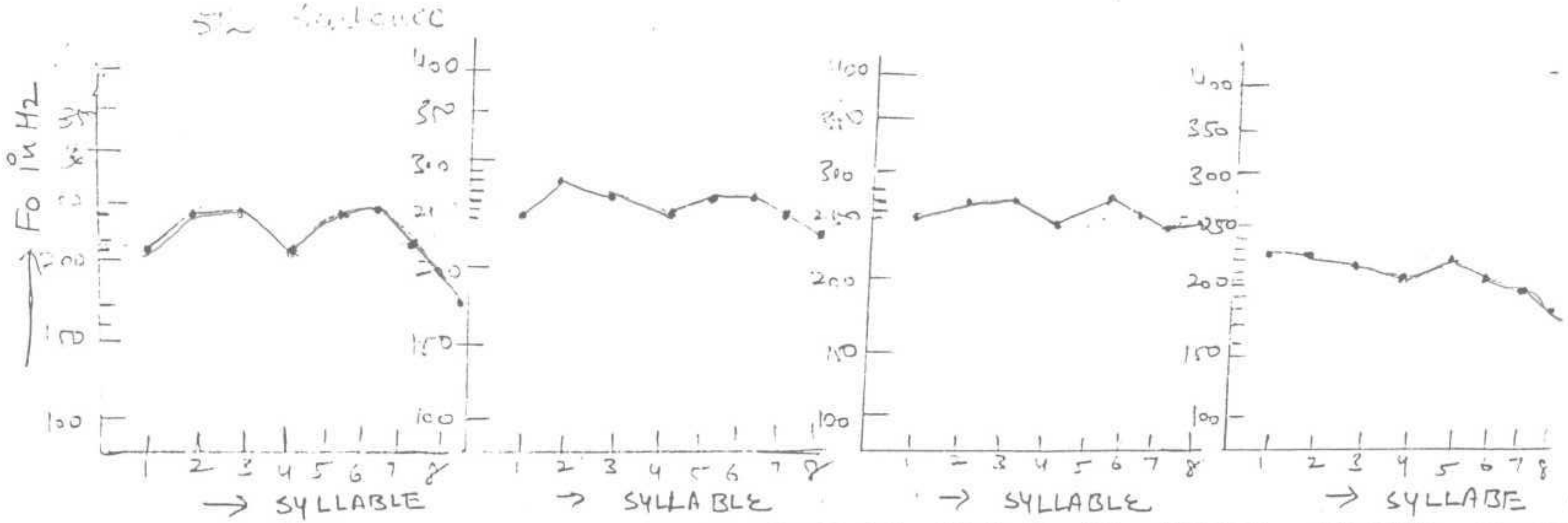


Fig:-9 INTONATION CONTOURS OF A SENTENCE SPOKEN BY NORMAL-SPEAKING FEMALE SUBJECTS. EACH DATA POINT IS THE MEAN FUNDAMENTAL FREQUENCY MEASURED FOR EACH SYLLABLE.

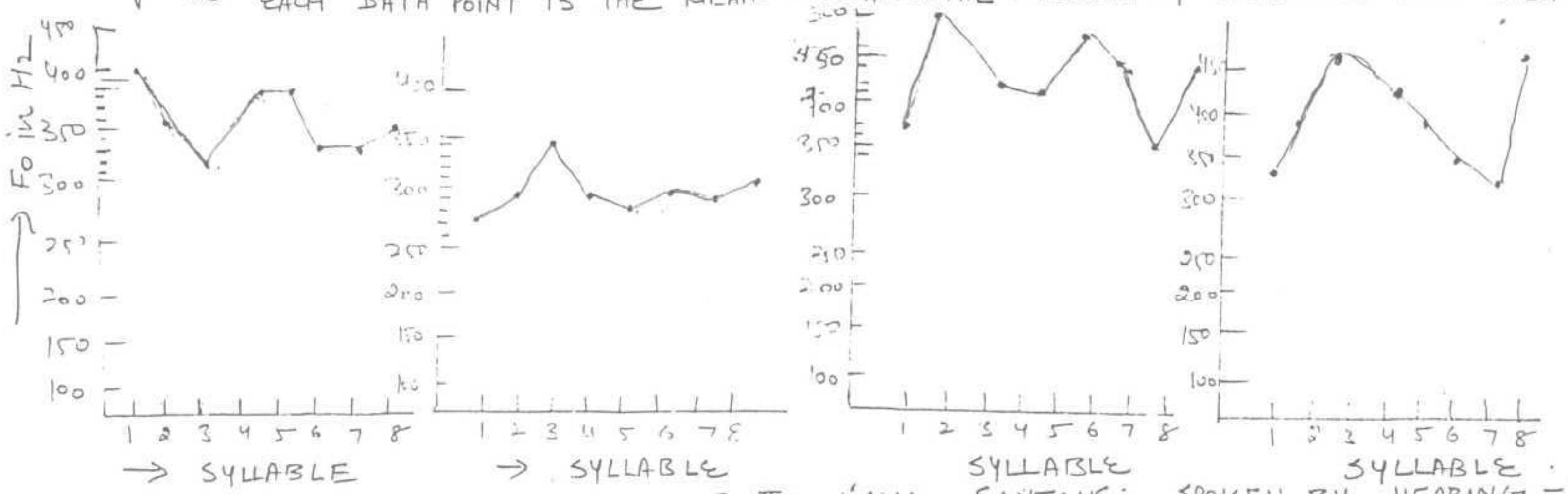


Fig 9(a):- INTONATION CONTOURS OF THE SAME SENTENCE SPOKEN BY HEARING-IMPAIRED FEMALE SUBJECTS. EACH DATA POINT IS THE MEAN FUNDAMENTAL FREQUENCY MEASURED FOR EACH SYLLABLE

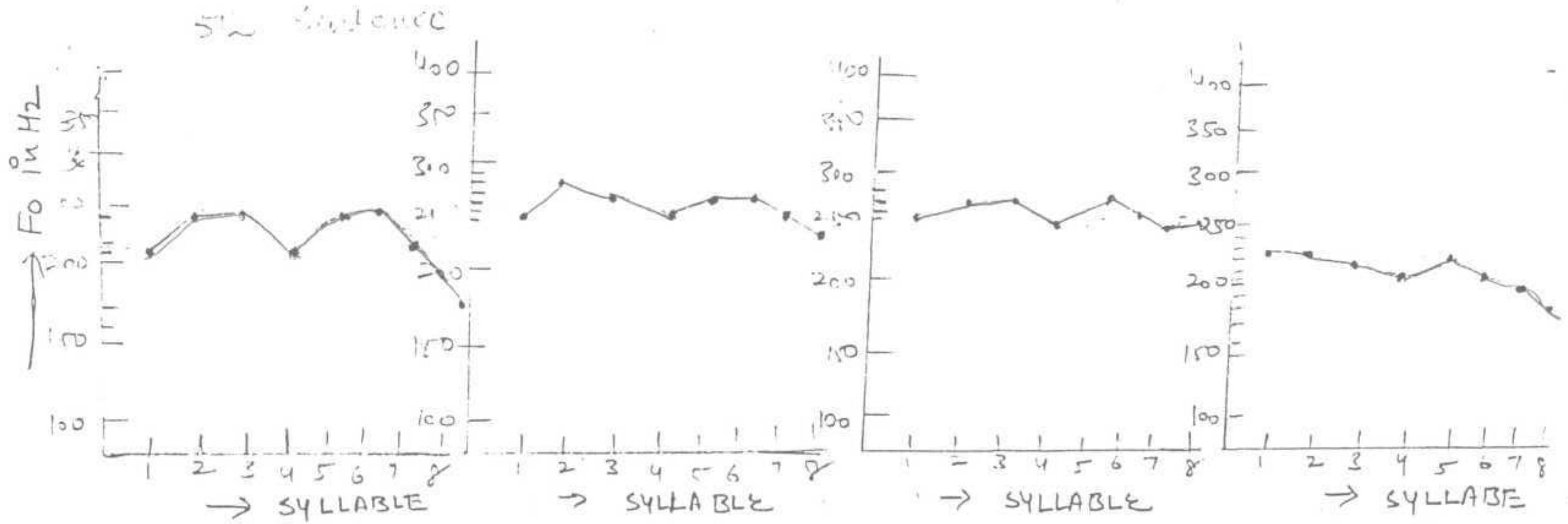


Fig: -2 INTONATION CONTOURS OF A SENTENCE SPOKEN BY NORMAL-SPEAKING FEMALE SUBJECTS. EACH DATA POINT IS THE MEAN FUNDAMENTAL FREQUENCY MEASURED FOR EACH SYLLABLE (Falling at the end)

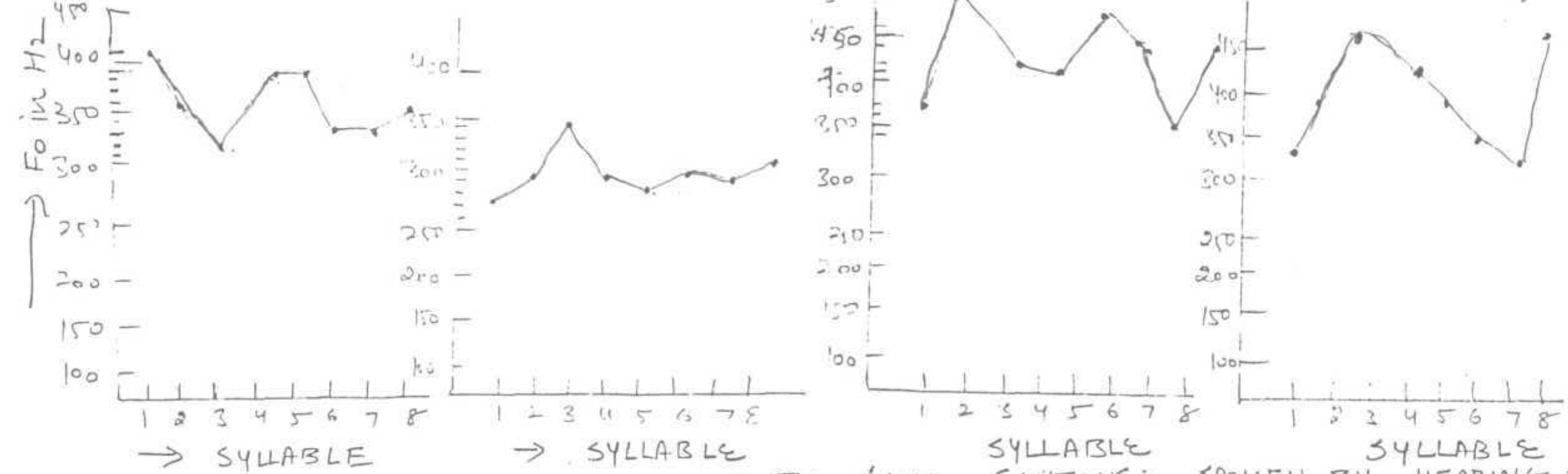


Fig 2(a):- INTONATION CONTOURS OF THE SAME SENTENCE SPOKEN BY HEARING-IMPAIRED FEMALE SUBJECTS. EACH DATA POINT IS THE MEAN FUNDAMENTAL FREQUENCY MEASURED FOR EACH SYLLABLE

b. Analysis of complete intonation contours

The analysis of variation in each syllable F_0 in different sentences for hearing impaired and normals revealed the following patterns.

In hearing impaired

a. Each hearing impaired is different in terms of intonation contours across all sentences and no generalized pattern was seeing for hearing impaired children.

b. Sometimes intonation contours matched with the normal group but that was considered as a chance factor because it was found only in one or two sentences. Otherwise they showed too much variability from normal group when compared across full story.

c. The hearing impaired speakers, however, tended to begin their sentences at a slightly elevated or relatively normal frequency, exhibit one or more positive or negative or no peaks in the middle and end their sentences with either a sharp rising frequency or with a sharp fall in frequency or with a frequency which is slightly lower or higher than their starting frequency.

Overall, five types of contours could be identified in speech of the hearing impaired (considering the F_0 at the end and beginning of the sentence) (Figures A, B, C, D and E).

1. A falling contour characterised by a sharp decline in F_0.
2. A falling contour characterised by a smooth fall in F_0.
3. A flat contour.
4. A rising contour characterised by a sharp rise in F_0.
5. A rising contour characterised by a smooth rise in F_0.

Both kinds of patterns were observed in the speech of hearing impaired speech as described by various workers, i.e. (Monsen, 1979; Smith, 1975; Stevens et al., 1978 and others).

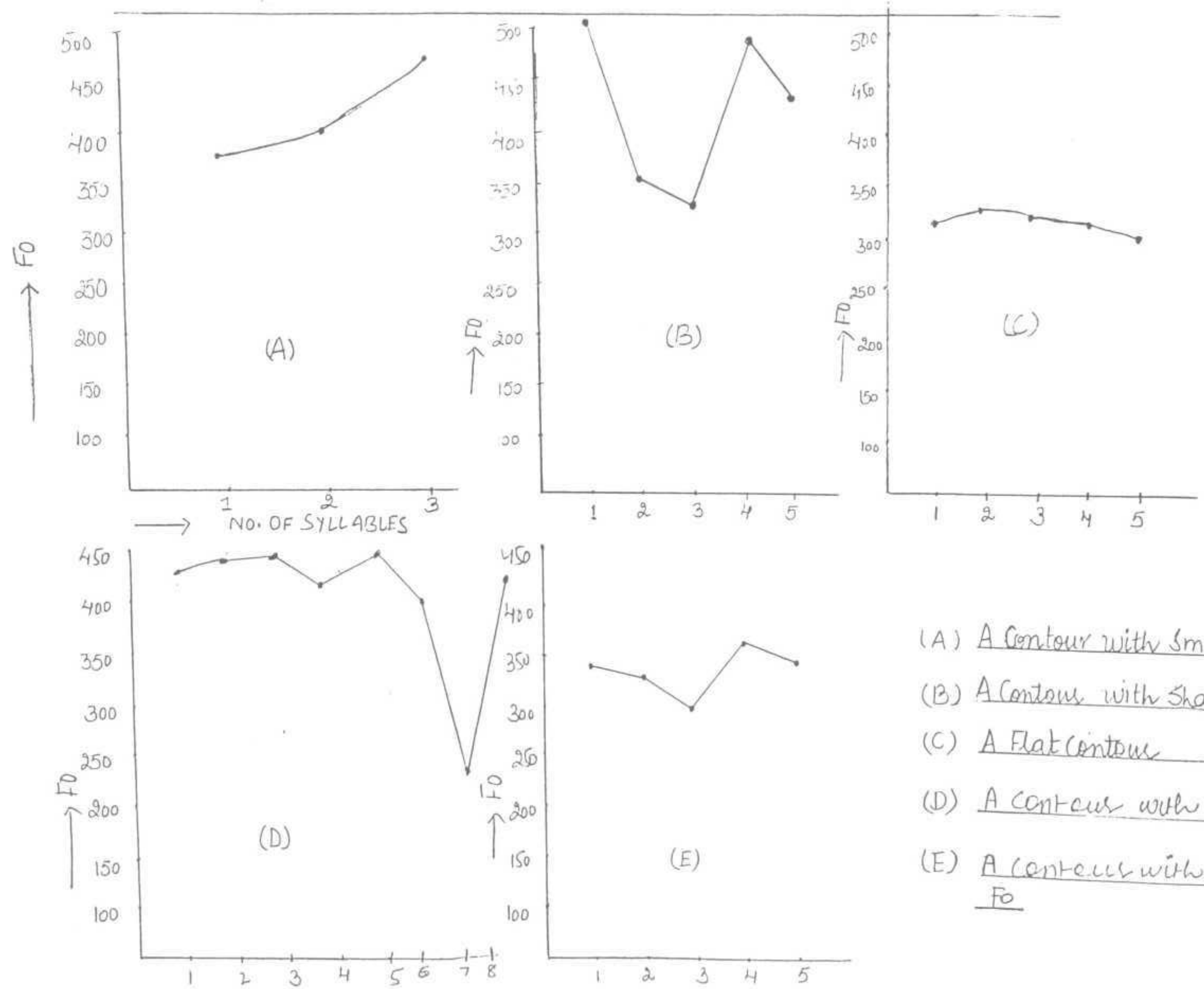
a. Excessive and inappropriate changes in F_0 The F_0 either raises or lowers 100 Hz or more within the same utterance (depicted in Fig. 6).

b. Insufficient or no variation in F_0 (depicted in Fig. 5).

Normal hearing subjects

- In normal hearing subjects no sharp rise or declination was see in intonation contours.

- They have smooth falling or smooth rising patterns.



(A) A Contour with smooth rise in F0

(B) A Contour with Sharp Fall in Fo

(C) A Flat Contour

(D) A Contour with a sharp rise in Fo

(E) A Contour with a smooth fall in Fo

In normal hearing subjects, their intonation contours had positive peaks (the stressed syllable) and these peaks occurred on second syllable of a bisyllabic word. It is not in agreement with the study of Dulai (1989) who observed that in Punjabi language the stress in a disyllabic word normally falls on the first syllable.

- In normals not much variation was seen in the contours. The intonation contours were more or less same across all the subjects.

Figs. 4, 5, 6 and 7 show the comparison of contours between hearing impaired and normal subjects for one of the eight sentences.

The sentence was: karə vitʃ pa:nɨ̊: bɔṱ̂ kʌtsɨ:

Fig. 4 shows the sentence spoken by a normal subject and Figs. 5, 6 and 7 show the same sentence spoken by the hearing impaired subjects.

Figures very clearly depicts the differences between the contours of normal and hearing impaired subjects and the variability found among the hearing impaired individuals as such.

Fig. 5 is the subject which showed flat contour (with very little variations in F_0).

Fig. 6 shows the contour of F_0 by the hearing impaired subject who had exaggerated variations in F_0.

Fig. 7 shows the contour of F_0 for the subject who was in between the two subjects. The subject showed slightly excessive variations as compared to the normal subject and they are not exaggerated variations (which did not serve the purpose of intonation) as showed by the subject in Fig. 6. This subject was the most intelligible subject among the hearing impaired and his intonation contours were more close to normals.

Several investigators have tried to classify the intonation contours of hearing impaired population. Their findings are given below:

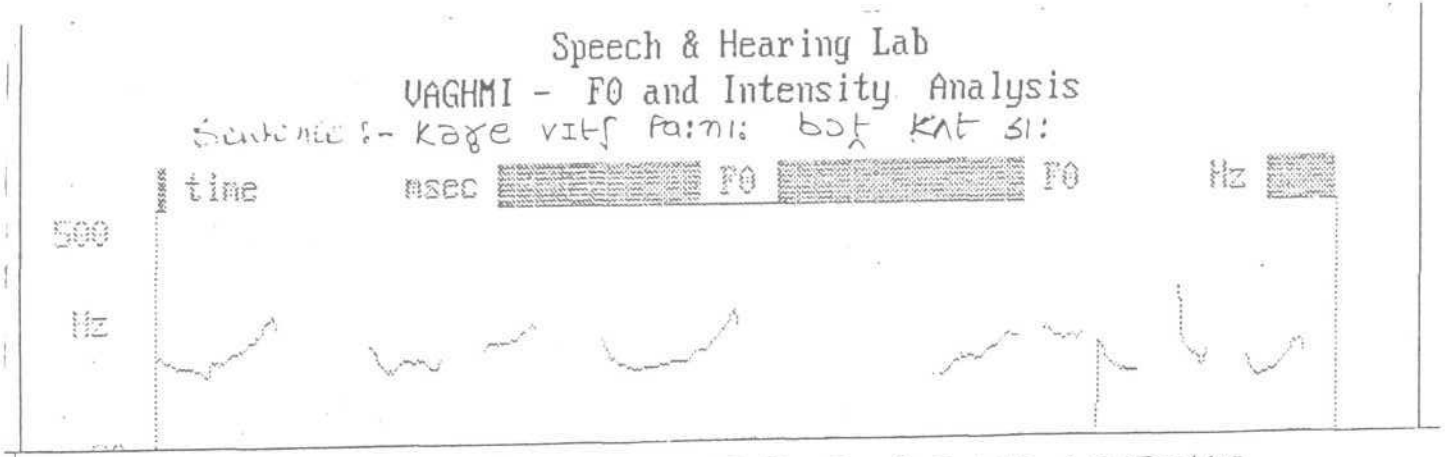


FIG:4 FUNDAMENTAL FREQUENCY CONTOUR FOR ONE SENTENCE READ BY A NORMAL CHILD.

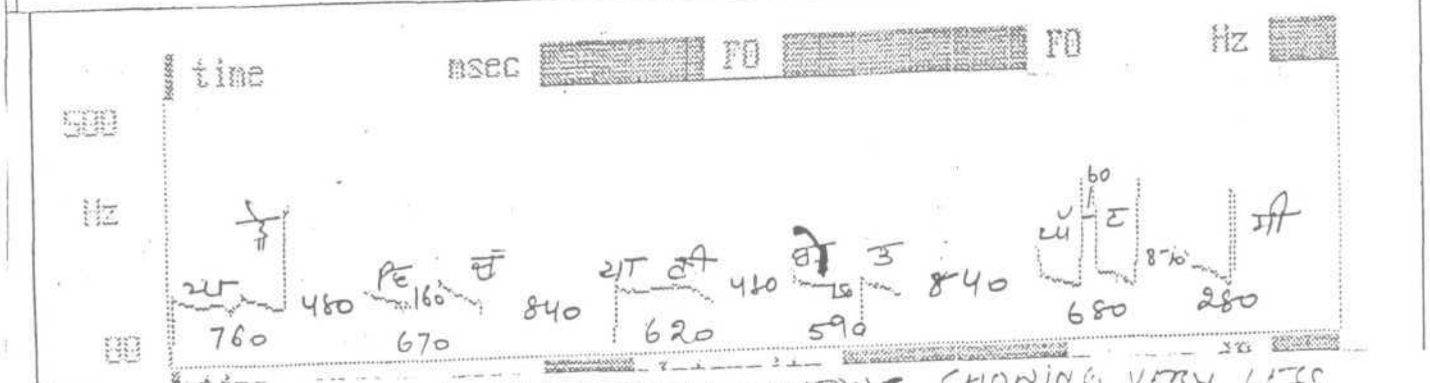


FIG: 5 FUNDAMENTAL FREQUENCY CONTOUR SHOWING VERY LESS VARIATION IN F_0 READ BY A HEARING-IMPAIRED CHILD.

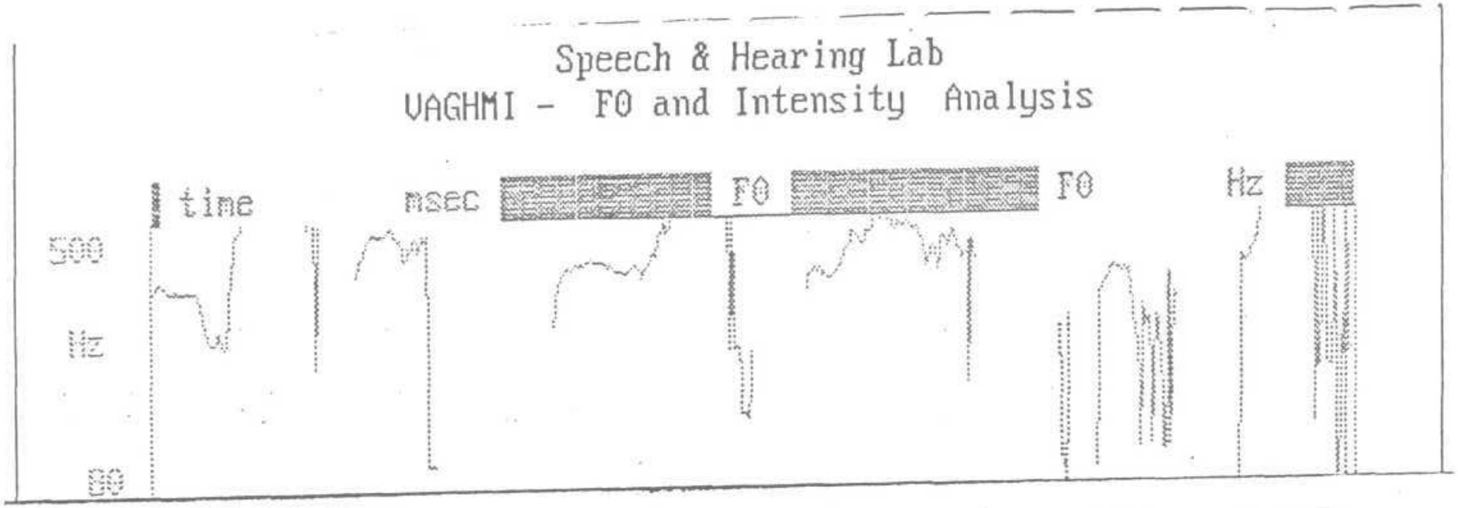


Fig: 6 FUNDAMENTAL FREQUENCY CONTOUR SHOWING EXAGGERATED VARIATIONS IN F0 READ BY A HEARING-IMPAIRED CHILD.

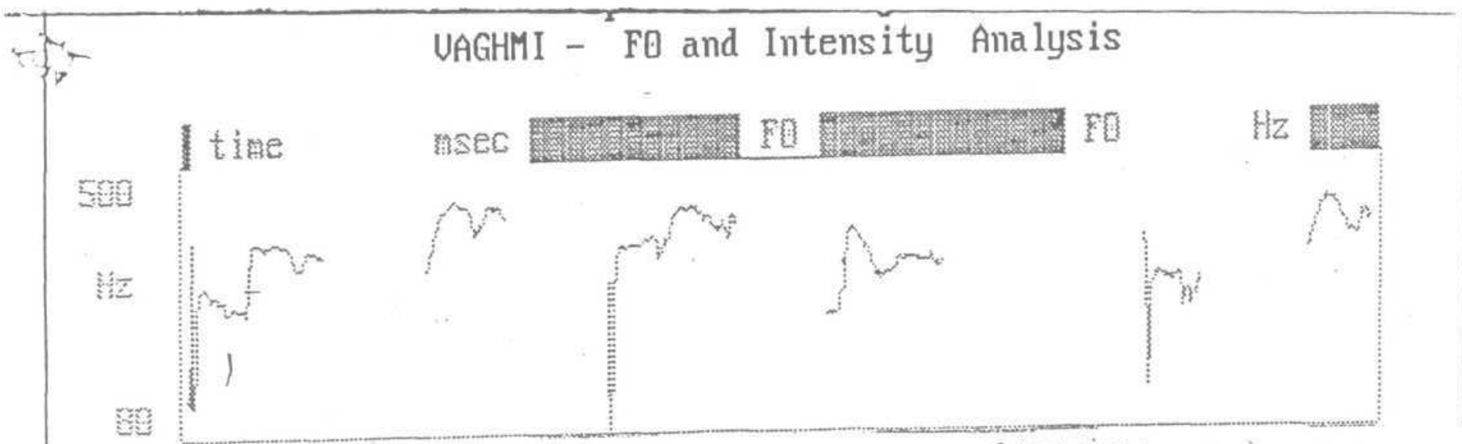


Fig. 7 FUNDAMENTAL FREQUENCY CONTOUR SHOWING SLIGHTLY

Investigator	Findings
Nickerson (1975)	Two types of patterns a. Monotonous b. Excessive or erratic pitch variations
Monsen (1979)	Two types a. Insufficient variation in intonation
Smith (1975) Stevens et al. (1978) and	b. Excessive and inappropriate fluctuations in F_0
Mosen (1979)	Gave quantitative classification of four types of intonation contours: a. a falling contour characterised by a smooth decline in F_0 at an average range greater than 10 Hz per 100 msec, b. a short falling contour, occurring on words of short duration. The F_0 fall may be more than 10 Hz per 100 msec but the total change may be small.

	c. a falling flat contour, characterised by rapid change in frequency at the beginning of the word followed by an unchanging, flat portion,
	d. a changing contour, characterised by a change in frequency, and the duration of which appears uncontrolled, and extends over relatively large segments.
Most and Frank (1991) Enger et al. (1983) Most (1985)	Severely and profoundly hearing impaired children were able to perceive and produce intonation contours.
Green (1956) Hood and Dixon (1969) Williams (1978)	Severe and profound hearing impaired were found to produce correct intonation contours.
Stark and Levott (1974) Smith (1975) Frank,Bergman,Tobin(1987)	Severe and profound hearing impaired had difficulty in producing intonation contours.
Williams and Lee (1971)	Deaf speakers tended to begin a breath group with an abnormally high pitch and then lower the pitch to a normal level.

All these findings support the findings of the present study when individual variations are observed. But one single pattern could not be identified for all the hearing impaired children because each hearing impaired subject differed from another in terms of production of intonation contours. Authors have considered that for these unusual pitch variations may occur from attempts by the speaker to increase the amount of proprioceptive feedback that he receives from the activity of producing speech (Martony, 1968).

Fundamental frequency features and intelligibility

In terms of frequency range, it was seen that the male hearing impaired subjects which were rated intelligible by the judges had overlapping values when compared with the normal group. But their counterparts who were rated as not at all intelligible or very slightly intelligible showed much variations from the normal range, viz. (a) too wide a range or (b) too limited a range (Table I©). In female group this trend was not very obvious. It could be accounted by the fact that female hearing impaired subjects as a group showed overall poor intelligibility score, and best of the subjects was also rated as score 2, i.e. only slightly intelligible. Overall findings also support this fact. Male hearing impaired subjects as a group were rated as more intelligible than female hearing impaired subjects and their average F_0 range corresponded with the normal group and correlation was found to be 0.66 whereas female hearing impaired subjects showed much wonder range as compared to their normal counterparts.

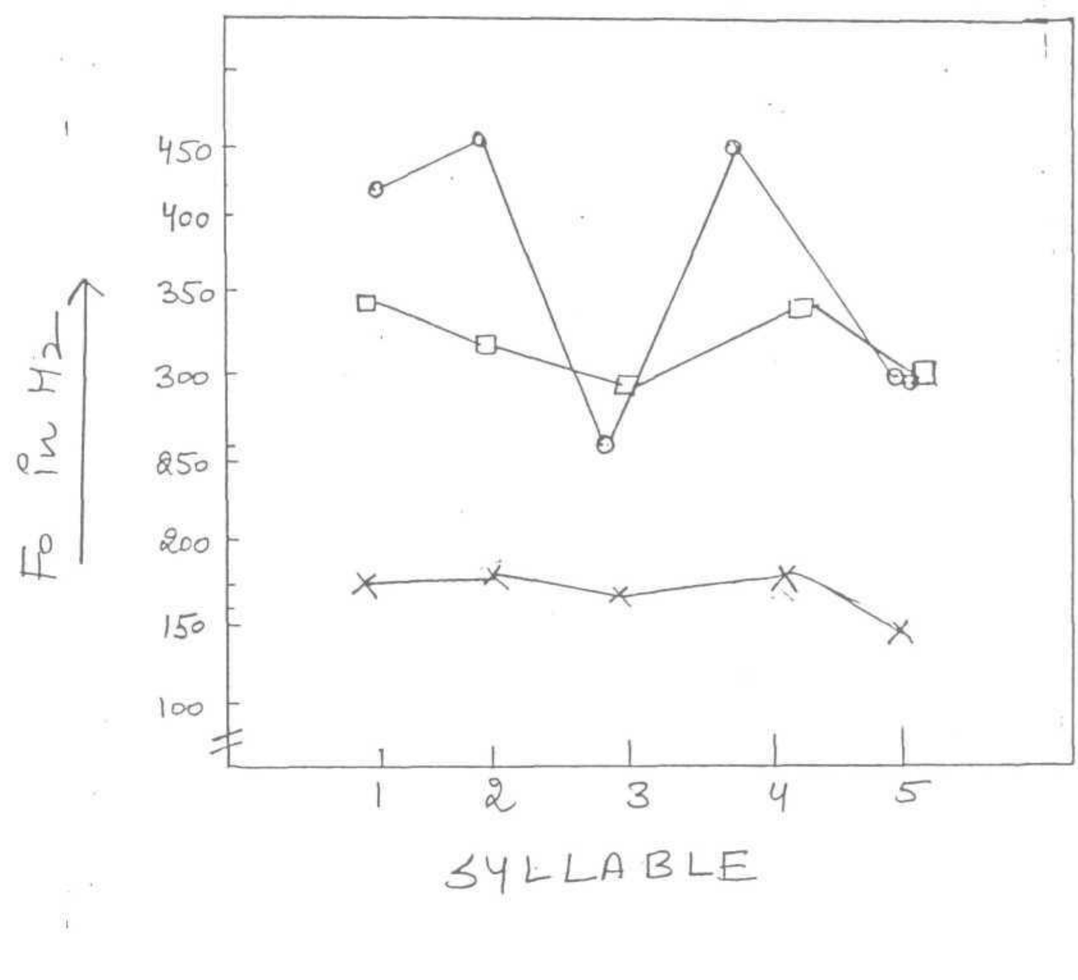
Monsen (1978) measured mean F_Q and mean amount of changes in F_0 in 37 hearing impaired individuals. He found no correlation between speech intelligibility of hearing impaired adolescents with either mean F_Q or mean amount of changes in F_0. The present study deviates slightly from the findings of Monsen (1978). More number of subjects need be studied before generalizing the findings of this study.

In terms of intonation contours very positive results have been found in the literature. According to Monsen (1979) study the correlation coefficient between voice quality and the scores based on quantification of the intonation contours was 0.88, which indicated that approximately 77% of the variations of the voice quality scores was due to this single variable. Thus the type of fundamental frequency contour appeared to be the most general acoustic characteristic which differentiated the better from the poorer voices.

In the present study also this correlation was seen. The unintelligible subjects used extremely large degrees of variation in F_0 while better intelligible subjects varied F_0 over a smaller range for short sentences (upto 5 syllables) and slightly more variations over long sentences (upto 8 syllables or 12 syllables). But their variations were not erratic or inappropriate which did not serve the purpose of intonation. For long sentences intelligible hearing impaired speakers had definite peaks and valleys (which showed stressed syllables) and their excessive variations could be very well differentiated from the variations of unintelligible speaker which had exaggerated variations (see Fig. 8) not serving the purpose of intonation. The intelligible speakers had intonation contours correlating more with the normal group though there were sometimes slightly excessive variations and sometimes change of F_0 was not take into account whether that change was in an appropriate direction when compared with normal speakers.

Stress

To analyze the stress, perceptual analysis was carried out. The investigator and one trained speech and hearing pathologist marked the stress in the speech of the normal speakers and hearing impaired speakers. And the syllables marked as stressed (in normal speech) by both the evaluators were taken for comparison with hearing impaired speech.



Fo in Hz
450
400
350
300
250
200
150
100
1
2
3
4
5
SYLLABLE

The findings were:

1. In Punjabi language, all the three parameters, viz. intensity, duration and fundamental frequency were important markers of stress.

2. For perceptually judged stressed syllables, there was a considerable increase in either fundamental frequency, intensity or duration. Most of the times, for the stressed syllables, there was increase in two parameters it could be any of the two combinations, i.e. frequency and intensity or intensity and duration or frequency and duration but alone also they were capable of marking stress.

3. It was observed that in different persons any of these one combination was dominant.

Stress in hearing impaired speech

- Analysis of stress in hearing impaired revealed that hearing impaired stress more frequently as compared to normal speakers.

- Variability was seen among the individuals. It was seen that the hearing impaired speakers with poor intelligibility stressed significantly more frequently when compared to hearing impaired speakers with good intelligibility. And in poor intelligible speakers, it seems as if every syllable was stressed and that was inappropriate.

Objective analysis of stress revealed that perceptually marked stressed syllables in hearing impaired speech had most of the times durational changes, i.e. hearing impaired individuals use duration as a prominent parameter to mark stress. Though frequency changes were also seen in some syllables to mark stress.

- In certain perceptually marked stressed syllables it was difficult to analyse which parameter they used to mark the stress. It was seen that in such syllables relative values rather than absolute values were considered to mark the stress.

- Whatever parameter was used by the hearing impaired speakers to mark stress, it was seen that there was a drastic change (most of the times duration) in that parameter values when compared with the other values. Whereas such drastic change (increase) in values was not observed in normal speech.

- Hearing impaired speakers did not use intensity as parameter to mark stress.

The present findings support the findings of Reilly (1979) who found larger than normal durational differences seems as if every syllable was stressed and that was inappropriate.

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- Hearing impaired speakers did not use intensity as parameter to mark stress.

The present findings support the findings of Reilly (1979) who found larger than normal durational differences between vowels in primary and weak stressed syllables produced by a group of profoundly hearing impaired children. Nickerson (1975) had also remarked that it was almost as if the deaf speakers produce only stressed syllables and the present study agrees with the fact that hearing impaired speakers put stress very frequently as compared to normal speakers.

So, the hypothesis stating that there is no difference (1) between the normal and hearing impaired subjects in terms of stress is rejected and (2) between normal males and females, and between hearing impaired males and females is accepted.

Thus the results of the present study can be listed as follows:

There is a significant difference between hearing impaired and normal subjects

a. in terms of intelligibility scores
b. in terms of rate of speech
c. in terms of pauses (number, duration and location of pauses)
d. in terms of word duration
e. in terms of F_0 and F_0 range
f. in terms of intonation contours
g. in terms of stress

But variability is seen in hearing impaired group when compared individual subjects. It was found that hearing impaired subjects who have good intelligibility scores approximates more with the normal values. Prosodic aspects which fuond to have good correlation with intelligibility are:

1. Pause duration (subjects with longer pauses had better intelligibility than others)
2. F_0 range
3. Intonation contour patterns
4. Stress

Implications of these results to the therapy and in describing the speech of hearing impaired are many. Few of them are

1. Provides basis for correcting F_0 Intonation and Stress
2. The database of the present study can be used for transformation of speach of hearing impaired.

SUMMARY AND CONCLUSION

The aim of the present study was to compare the speech of normal speaking children and hearing impaired children in terms of prosodic aspects. The children were having "Punjabi" as their native language. The study also aimed at find out role of suprasegmental features toward intelligibility of speech.

The speech samples (a story) from 10 Punjabi speaking impaired (5males"5females) and 10 Punjabi speaking normal subjects matched for age and sex were collected. These were

Analysed using computer programmes and judges ton obtain the following parameters

PsychoAcoustics Parameters

1) Intelligibility rating of hearing impaired speech

2) Perceptual analysis of stressed syllables

Acoustics Parameters

A fundamental frequency features

1)Fundamental frequency of speech

2) Fundamental frequency (f) range

3) Variations of fundamental frequency in sentences to study intonation contours.

4) Mean fundamental of each syllable for stress correlational

B. **TEMPORAL FEATURES**

1) Rate of speech (words/min Syllables/min)

2) interword pause durations

3) Intraword pause durations

4) Between sentence pause durations

5) Word durations

6) Mean duration of each syllable for stress measures

INTENSITY FEATURES

1) Mean intensity of each syllable For stress measures

The results were subjected to statistical analysis using mann whitney U test. The following conclusions were drawn :-

1) There was significant difference between the rate of speech of normal hearing children and hearing impaired children. The normal hearing children speak faster then

hearing impaired. But it was seen that rate as a factor was not contributing much towards intelligibility of hearing impaired children.

2) There was significant difference between the normal and hearing impaired children in terms of pauses and word duration. The following results were seen:

a) The hearing impaired children had longer durations of pauses as compared to normal hearing children. And this is true for all types of pauses (intraword 'interword and between sentence pauses).

b) In terms of number of pauses hearing impaired speakers had significantly greater number of pauses as compared to normal group for interword pauses, the hearing impaired children pause after each word. For intraword" pauses it was seen that normals did not pause at all while hearing impaired subjects showed much variability among themselves.

It was seen that perceptually judged, intelligible subjects had longer durations of pauses as compared to their counterparts who are only slightly intelligible.

c) Hearing impaired subjects showed longer word durations as compared to normal group.

3) There was significant difference between normal and hearing impaired subjects in terms of intonation contours and other fundamental frequency features.

a) Hearing impaired subjects had a higher fundamental frequency as compared to their normal group.

b) In terms of fundamental frequency range male hearing group on average approximated with the normal group range values but showed too much variability when individually compared, depending on their intelligibility ratings. The more intelligible subjects approximated more with normal values.

But on average hearing impaired females showed higher range as compared to normal values. Individual variations are seen in hearing impaired group but did not show any correlations with speech intelligibility scores.

c) In terms of intonation contours hearing impaired differed from normal group.

The normal group showed tendency for falling intonation whereas hearing impaired group showed variability in terms of pattern of intonation contours viz: falling, rising, flat The mean syllabic fundamental frequency variations showed five types of intonation contours in hearing impaired children :

1) A falling contour characterised by a sharp decline in fO

2) A falling contour characterised by a smooth fall in fo

3) A flat contour

4) A rising contour characterised by a sharp rise in fO

5) A rising contour characterised by a smooth rise in fO

So we can say that hearing impaired subjects showed both types of patterns i.e

a) Exaggerated patterns (too much variations in fO)

b) Flat patterns (very less variations in fO)

In terms of intelligibility, hearing impaired subjects who were more intelligible matched more with normal subjects in terms of their intonation patterns.

4) In terms of stress also there was a significant difference between hearing impaired and normal hearing subjects.

- The hearing impaired subjects stressed very frequently whereas normal hearing subjects did not put stress very frequently.

- Analysis of stress revealed that hearing impaired subjects depend more on duration as a parameter to mark stress, whereas in normal group it was marked by either

Frequency intensity or durational parameters. Most of the times it v/as the combination of two of these values which marked the stress in the normal group.

In normal hearing group, absolute values were more important to mark the stress, but hearing impaired depend on relative values also to mark the stress of a syllable.

IMPLICATIONS OF THE STUDY

The present study is helpful in knowing:

1) Which of the prosodic parameters contribute to speech intelligibility.

2) and how the hearing impaired speech differs from the normal speech in terms of prosodic aspects and applying this knowledge in the correction of their speech thus improving the overall intelligibility of speech of the hearing impaired.

RECOMMENDATIONS FOR THE FUTURE RESEARCH

1) Subjects studied in each group is less and further study can be taken up by taking more number of subjects to reveal more definite patterns and role of suprasegmentals in speech intelligibility.

2) In this study only read passages are studied and thus future research can be done in spontaneous speech and to see

how far these results can be generalized to spontaneous speech.

3) Different emotions can be taken to study intonation contours in normals as well as hearing impaired population.

Very less work is done Punjabi language in terms of prosodic aspects so more research should be carried out towards this line.

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APPENDIX-II

Speech sample consisted of eight sentences in a story

1. ik kã: sɨ:

(ਇੱਕ ਕਾਂ ਸੀ)

2. ɔh bɔt pəasa: sɨ:

(ਉਹ ਬਹੁਤ ਪਿਆਸਾ ਸੀ)

3. ɔh ɨ:k ba:g vitʃ gəa:

(ਉਹ ਇੱਕ ਬਾਗ ਵਿਚ ਗਿਆ)

4. ɔne ɨ:k g^hɽa: vek^həa:

(ਉਨੇ ਇੱਕ ਘੜਾ ਵੇਖਿਆ)

5. g^həɽe vitʃ pa:nɨ: bɔt g^hʌt sɨ:

(ਘੜੇ ਵਿਚ ਪਾਣੀ ਬਹੁਤ ਘੱਟ ਸੀ)

6. kã: ne g^həre vitʃ pəθər pae

(ਕਾਂ ਨੇ ਘੜੇ ਵਿਚ ਪੱਥਰ ਪਾਏ)

7. pa:nɨ: ute a: gɔa:

(ਪਾਣੀ ਉੱਤੇ ਆ ਗਿਆ)

8. kã: ne pa:nɨ: pɨ:ta: te k^huʃɨ: k^huʃɨ: ud gəa:

(ਕਾਂ ਨੇ ਪਾਣੀ ਪੀਤਾ ਤੇ ਖੁਸ਼ੀ-ਖੁਸ਼ੀ ਉਡ ਗਿਆ.)

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APPENDIX-I

DEFINITIONS

1. PROSODY is usually defined as a suprasegmental property of the acoustic signal that communicates linguistic, attitudinal, emotional, pragmatic and idiosyneratic information. The physical concomitants of prosody include fundamental frequency, duration intensity, harmonics and spectral energy distribution from which linguistic categories such as (affective) intonation, timbre/tempo and melody are constructed.

2. Intonation: Intonation is the linguistic form in which speaker organises certain kinds of information (Dewes, 1959).

3. Intonation contour: In each language, however, the use of pitch fluctuation tends to become semi-standardized, or formalized, so that all speakers of the language use basic pitch sequences in similar ways under similar circumstances. These abstracted characteristic sentence melodies may be called "Intonation Contours" (Pike, 1945).

Stress: Stress may be defined as air articulatory gesture, related to the degree of force of an utterance. The stress is the prominence produced by means of respiratory effort. Important acoustic correlates of stressed syllables in words are intensity, amplitude and fundamental frequency. The weight given to various perceptual factors will vary from language to language.

Rate: Rate of speech has been defined as the number of words spoken per minute during a complete speech performance. Rate is also defined as the number of syllables uttered per minute.

Tone language: Pitch is principle exponent of intonation. Pitch is used for differentiation of tone in language. A change in meaning is produced. If one tone is exchanged for another on one syllable, while keeping the segmental composition unchanged. Thus sets of words are distinguished only by tone.

APPENDIX-II

Speech sample consisted of eight sentences in a story

1. ik kã: sɨ:
   (ਇੱਕ ਕਾਂ ਸੀ)

2. ɔh bɔt̪ pəasa: sɨ:
   (ਉਹ ਬੋਤ ਪਿਆਸਾ ਸੀ)

3. ɔh ɪk ba:g vitʃ gəa:
   (ਉਹ ਇੱਕ ਬਾਗ ਵਿਚ ਗਿਆ)

4. ɔne ɪk gʰəɽa: vekʰəa:
   (ਉਨੇ ਇੱਕ ਘੜਾ ਵੇਖਿਆ)

5. gʰəɽe vitʃ pa:ɳɪ: bɔt̪ gʰʌt sɪ:
   (ਘੜੇ ਵਿਚ ਪਾਣੀ ਬੋਤ ਘੱਟ ਸੀ)

6. kã: ne gʰəɽe vitʃ pəθər pae
   (ਕਾਂ ਨੇ ਘੜੇ ਵਿਚ ਪੱਥਰ ਪਾਏ)

7. pa:ɳɪ: ut̪e a: gəa:
   (ਪਾਣੀ ਉੱਤੇ ਆ ਗਿਆ)

8. kã: ne pa:ɳɪ: pɪ:ta: te kʰuʃɪ: kʰuʃɪ: ud gəa:
   (ਕਾਂ ਨੇ ਪਾਣੀ ਪੀਤਾ ਤੇ ਖੁਸ਼ੀ-ਖੁਸ਼ੀ ਉਡ ਗਿਆ.)