3.1 Introduction

The current study is taken up with the aim to analyze the speech characteristics of Telugu speaking children with normal hearing, children with hearing impairment using hearing aids and cochlear implants, spectrographically in terms of average fundamental frequency (F0), formant frequencies (F1, F2 and F3), bandwidth characteristics (B1, B2 and B3), vowel duration and word duration of both long and short vowels in VCV syllable production.

3.2. Subjects

The following methodology was adopted for the study

A total number of 48 subjects (24 males and 24 females) participated in the study. The subjects for the study were divided into three groups with 8 males and 8 females in each group. Group I consists of 16 age matched children with normal hearing (males=8, females=8), Group II consists of 16 children (males=8 and females=8) with hearing impairment using hearing aids. Group III consists of 16 children (males =8, females =8) with hearing impairment using cochlear implants. All three groups consist of children with Telugu as native language. The subject selection criteria for each group would be as follows.
3.2.1. Group I Selection criteria

The subjects were selected by keeping the following criteria in mind:

1. No history of any hearing disorder.
2. In age range of 6-12 yrs (mean age-8.09).
3. No other history of neuromotor problems, mental retardation and other systemic disorders.
4. Ability to read simple VCV words in Telugu script.

3.2.2. Group II Selection criteria

The children with hearing impairment using hearing aids were selected based on the following criteria: (For details see appendix-I)

1. The children having bilateral severe to profound sensorineural hearing loss.
2. In the age range of 6-12 yrs (mean age-8.09).
3. Using hearing aids behind the ear (BTE) hearing aid, binaural fitting for at least 2 years.
4. Attending speech language therapy for at least 2 years.
5. Using at least simple sentences at the time of speech sample recording.
6. Ability to read simple VCV words in Telugu script.
7. No concomitant neuro-motor disorder, mental retardation and other systemic disorders.
3.2.3. Group III Selection criterion

The children with hearing impairment using cochlear implants were selected based on the following criteria (For details see appendix-II)

1. The children have bilateral severe to profound sensory neural hearing loss implanted with cochlear implant in one ear.
2. In the age range of 6-12 years (mean age-8.09)
3. Using cochlear implant in monaural fitting for at least 2 years.
4. Prior to use of implant children who had used a hearing aid and those who haven’t used are also considered as subjects.
5. Attending speech language therapy for at least 2 years.
6. Using simple sentences at the time of speech sample recording.
7. Able to read simple VCV words in Telugu script.
8. No concomitant neuro-motor disorder, mental retardation and other systemic disorders.

3.3. Material

The test material consisted of ten bisyllabic Telugu words (VCV) having short vowels, /a/, /i/, /u/, /e/ and /o/ and long vowels /a:/, /i:/, /e:/ and /o:/ . Simple words with VCV syllables were selected for the study so that both normal and children with hearing impairment using hearing aids and cochlear implants can read whichever is written on the
flash cards) (size 6’’X 4’’). The first consonant will always be a plosive. This is to aid in appropriate temporal measures of the first vowel. The vowels analyzed are in the initial position. The full length of the variety can be found in the initial syllable and the shorter one in all initial syllables. The materials used for the study have been enclosed as appendix III.

3.4. Recording Procedure

The speech samples of all the children were recorded in a quiet room of the school building using a tape recorder. Subjects were comfortably seated and the microphone was kept at a distance of 10 cms from the mouth of the subjects. The recording microphone was covered by well foam to avoid capture of air turbulence and other noises. The subjects were instructed to read the word written on the flash card presented to them by the experimenter. The experimenter presented one card at a time to the child. Each child read the card at the comfortable loudness. Three readings of each word by each child have been recorded on a Digital recorder (D.35, Sony). A Sony C300 microphone was used to capture the response samples. But, out of three trails one which was considered to be most intelligible was selected for analysis purpose for each subject of the three groups. Subject was made to repeat after the experimenter whenever the subject had difficulty in reading the target word. A personal computer with CSL-4500/PRAAT, software program and processing unit was used to digitize the sample and analyze the acoustic properties.
3.5. **Acoustical Analysis**

The obtained data was subjected to the acoustical analysis to compare and analyze the speech characteristics of Telugu speaking children with normal hearing, children with hearing impairment using hearing aids and cochlear implants, spectrographically in terms of acoustic parameters such as average fundamental frequency (F0), formant frequencies (F1, F2 and F3), bandwidth characteristics (B1, B2 and B3), vowel duration and word duration of both long and short vowels in VCV syllable production.

3.5.1. **Parameters**

The details of the parameters studied are as follows:

**Fundamental frequency (F0)**

Fundamental frequency is the first harmonic of the voice. It is the physical measure of lowest periodic component of the vocal fold vibration. In the present study Fundamental frequency is directly measured using the PRATT software. The recorded sample i.e. syllable, that was stored on computer using the software PRAAT, was displayed on the monitor of the computer and by visual inspection, the investigator, highlighted the vowel by moving the cursor from the beginning of the vowel i.e., the starting of the signal represented as waveform, to the end of the vowel i.e., end of the
waveform and listened the same by playing the highlighted waveform back to confirm auditory that the vowel was highlighted then the highlighted portion was considered and “show pitch” was clicked to get average fundamental frequency of that vowel. When the highlighted waveform was considered auditory that it was not covering the vowel portion then the cursor was moved forward/backward depending on the position of the cursor and played back again. This procedure was carried out till the investigator was satisfied or confirmed auditorily that the highlighted portion of the waveform was covering the vowel portion and then highlighted portion was considered and show pitch was clicked to get average pitch of that vowel. This was done to obtain average fundamental frequency of the each vowel spoken by each subject of the three groups.

Fig. 3.1. Fundamental frequency of a vowel in a VCV of subject with normal hearing.
Formant Frequencies (F1, F2 and F3)

Formant frequency is the center frequency of the formant. Formant frequencies F1, F2, F3 were noted at steady state for each of the first vowel in a VCV word. The unit used is Hertz. To extract the vowel formant frequencies (F1, F2, F3) the spectrogram of each utterance using the formants programmer of the software “PRAAT” was used. The recoded sample i.e., each word that is stored on computer using the software PRAAT, was displayed on the monitor of the computer and by visual inspection, the investigator, highlighted the vowel by moving the cursor from the beginning of the vowel i.e. the starting of the signal represented as waveform, to the end of the vowel i.e. end of the waveform and listened the same by playing the highlighted waveform back to confirm.
auditorily that the vowel was highlighted then show formants was clicked to get formant frequency of that vowel, when the highlighted waveform was considered auditorily that it was not covering the vowel then the cursor was moved forward/backward depending on the position of the cursor and played back again. This procedure was carried out till the investigator was satisfied or confirmed auditorily that the highlighted portion of the waveform was covering the vowel and then show formants was clicked to get formant frequency value of that vowel. This was done to obtain each of the vowels spoken by each subject of the three groups.

Fig. 3.3. Formant frequencies F1, F2, F3.
Band width (B1, B2 and B3)

Bandwidth is a measure of frequency band of a sound, especially a resonance. Bandwidth is determined at the half-power (3 dB down) points of the frequency response curve. That is both the lower and higher frequencies that define the bandwidth are 3 dB less intense than the peak energy in the band. The bandwidth, B1, B2, B3 of each of the formants F1, F2 and F3 respectively were noted for the first vowel in steady state. The unit used is Hertz.

Fig. 3.4. Formant frequencies F1, F2, F3 and B1, B2, and B3.
Vowel Duration

Vowel duration is the duration of the first vowel in its steady state from onset to offset in the following consonant. The following consonant being a plosive, duration of vowel was measured till the closure duration onset. The unit used is msec.

The “PRAAT” software was used to measure vowel duration also. The vowel duration was considered to extend from the beginning of the periodic marking to the end of the periodicity. This duration was highlighted, through the use of cursors. The highlighted portion was played back through headphones, to confirm that the vowel under study has been marked correctly and thus the duration has been identified correctly. Once this was confirmed, the duration of the highlighted portion was read from the display on the monitor directly. When the highlighted waveform was considered auditorily that it was not covering the vowel duration then the cursor was moved forward/backward depending on the position of the cursor and played back again. This procedure was carried out till the investigator was satisfied or confirmed auditorily that the highlighted portion of the waveform was covering the vowel duration and then it was noted as vowel duration of that vowel. Once this was confirmed, the vowel duration of the highlighted portion was read from the display on the top of the frame directly. This was done to obtain each of the vowels spoken by each subject of the two groups.
Fig. 3.5. Vowel duration for word /atu/.

Word duration

Word duration is the duration of whole VCV word. It is the sum of vowel duration, consonant duration and pause duration. The unit used is msec. The waveform and spectrogram of the word were displayed on the computer monitor using the PRAAT software. The whole word was identified based upon the continuity of the waveform by clinical inspection by the experimenter. The whole word was considered to extend from the beginning of the signal to the end of the signal for the word and it was highlighted through the use of cursors. The highlighted portion was played back through headphones, to confirm that the word under study has been highlighted and then the duration has been marked correctly. Once this was confirmed, the duration of the
highlighted portion was read from the display on the monitor directly. When the highlighted waveform was considered auditorily that it was not covering the word duration then the cursor was moved forward/backward depending on the position of the cursor and played back again. This procedure was carried out till the investigator was satisfied or confirmed auditorily that the highlighted portion of the waveform was covering the word duration and then it was noted as the word duration of that word. Once this was confirmed, the duration of the highlighted portion was read from the display on the top of the frame directly. This was done to obtain each of the words spoken by each subject of the three groups.

Fig. 3.6. Word duration for word /atu/
3.6. Statistical Analysis:

The obtained data was analyzed and compared by computing the mean scores and standard deviations for each of the group. Inter group comparisons were done with appropriate statistical tools. The results are discussed in the next chapter.