A COMPARISON OF ACOUSTIC CHARATERISTICS OF SPEECH IN YOUNG COCHLEAR IMPLANT AND BTE USERS WITH NORMAL HEARING AGE MATCHED INDIVIDUALS

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Abstract

A major consequence of hearing impairment in children appears to be a reduced repertoire of sound segments mainly consonants which results in place, manner and voicing errors leading to poor communication. With advancement in technology (cochlear implants and programmable digital behind the ear devices), significant progress have been made by children with profound hearing impairment. Cochlear implant (CI) aims to improve the speech perception and production abilities in individuals who receive limited gain from the conventional amplification devices. The primary aim of the present study was to compare selected acoustic speech parameters (lead and lag Voice Onset Time, word and vowel duration and second formant frequency) of children with hearing impairment using cochlear implants, Behind The Ear (BTE) hearing aids with those of age matched normal hearing peers. Results indicated that, the mean lead Voice Onset Time (VOT) in CI and BTE users was longer compared to normal hearing individuals, though not statistically significant. Results of lag VOT indicate that mean values for the CI and BTE groups were shorter than normal hearing individuals. Measures of F2 revealed that CI group had higher F2 where as the BTE users had lower F2 values compared to normal hearing individuals. Among the duration measures only vowel duration was significantly different between normal hearing individuals and CI. Though several studies report that acoustic measures of the speech of cochlear implantees approximate normal values, similar findings were not obtained in the present study, probably because the cochlear implantees in this study were implanted only six months prior to data collection.

Key Words: Voice Onset Time (VOT), word and vowel duration, fundamental frequency (F2)

A major consequence of hearing impairment in children appears to be a reduced repertoire of sound segments mainly consonants leading to poor communication. The speech of children with profound deafness is characterised by numerous segmental errors, including vowel neutralisation, omission of word-final consonants, confusion of voiced voiceless cognates and errors of manner and place of articulation (Levitt & Stromberg, 1983 and Smith, 1975). Speech of children with deafness has been studied for many years (Tobey, Geers & Brenner, 1994) and continues to be studied. These reports have examined aspects such as, errors in their speech production; differences in their speech as a function of hearing loss and /or perceptual abilities; differences in their speech as a function of hearing device used and; deviations in their speech acoustics.

Voicing, place and manner of articulation errors are common in individuals with hearing impairment. Perceptually consonant errors include substitution and omission and vowels include substitutions, neutralisation and diphthongization. Acoustically, voicing errors (Calvert, 1961); reduced VOT (Gilbert & Cambell, 1978); prolongations of vowels (Calvert, 1961; Shukla, 1987); and abnormal formants (Angelocci, Kopp & Holbrook, 1964; Vasantha, 1995; Nataraja, Sreedevi & Sangeetha 1998) have been reported.

Children who make proficient use of hearing aids develop a predominantly auditory/vocal style and go on to acquire good understanding and use of spoken

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language (Tait & Lutman, 1994). Speech language pathologists are trying their best to increase the verbal productions of the child with hearing impairment who have been rehabilitated with either digital hearing aids or more recently cochlear implants. Cochlear implants have made a tremendous influence in the last decade not only on individuals with profound deafness but on the entire Health care profession. Many factors have contributed to the rapid growth and success of cochlear implants. The most significant factor is the benefit received by the hearing impaired individual. They have obtained high levels of word recognition without lip reading (Dorman, Hannley, Dankowski, Smith & Mc Candless, 1989). Children who receive cochlear implant by 5 years of age are presented with auditory information at the crucial time for speech and language development. Children vary in the amount of speech information they obtain from a cochlear implant. Duration of deafness and age of implantation might be expected to have an influence (Fryauf-Bertschy, Tyler, Kessay, Gantz & Woodworth, 1997).

Children using cochlear implants, who have good speech perception skills, may be the ones who are able to use auditory feedback effectively to assist in the development of their speech production skills. Multichannel cochlear implants are the products of recent technology in the field of assistive listening devices. The primary aim is to improve speech perception abilities in children who have limited gain from the conventional amplification method. It promotes the speech production skills in mainly prelingually impaired individuals and improves their capacity to produce vowels, consonants and supra segmental aspects of spoken language

A clinically significant increase in the size and diversity of imitative and spontaneous phonetic repertoires after one to two years of CI use has been reported (Osberger, Robbins, Berry, Todd, Hesketh & Sedey.1991; Tobey & Hasenstab.1991). Others have reported improved production of vowels (Ertmer, Kirk, Todd & Riley, 1997) and consonant features (Kirk & Osberger, 1995) after 24 to 36 months of implant experience. Tait and Lutman (1997) say that the benefits of implantation appeared to be showing one year after implantation in the prelinguistic measures.

Dawson et al. (1995) and Sehgal, Kirk, Svirsky, Ertmer and Osberger (1998) indicated that children who use cochlear implants produced labial consonants correctly more often than consonants with other places of articulation. Affricates were produced correctly less often than consonants with any other manners of articulation. Osberger et al. (1991) found that children who had used cochlear implants for one year produced bilabial stops and nasals /m/ often followed by velars and alveolar stops, then fricatives, liquids and lastly glides.

As the acoustic features in the speech of the hearing impaired are characterized by several segmental and suprasegmentals errors, speech and language clinicians increasingly have been confronted with children who exhibit hearing impairment and are not clear about the parameters that should be manipulated in order to improve their speech intelligibility. Literature is abundant with studies on the acoustic characteristics of speech of analog hearing aid users, whereas such studies on subjects using cochlear implants and digital BTE hearing aids is relatively sparse at least in the Indian context. Therefore the present study is planned to compare a few acoustic parameters of speech across CI users, digital BTE users and age matched normal hearing individuals.

Method

Subjects: Subjects considered were divided into three groups: cochlear implant users, BTE users and normal-hearing age-matched children. Each of the above three groups consisted of three participants, (total number of subjects were 4 males and 5 females) and all of them were in the age range of 4 to 4.5 years with Kannada as their native language. Inclusion criteria for normal hearing age mates were normal speech, language, hearing, cognitive, neurological and physiological development, and that for the hearing impaired group was that they have congenital hearing loss and normal developmental domains except for speech and language. The language age of these children were also matched using a screening tool, Receptive Expressive Emergent Language Scale (REELS) and their language age was of 42 to 48 months for both reception and expression. The children wearing BTE were rehabilitate for two years on an average and those using CI (Freedom Nucleus with ACE coding strategy) had been implanted six months ago with two of the children having used digital BTE amplification device (Electone

Eclipse 2SP) in both the ears for a period of two years prior to implant. Their aided performance was 10 – 15 dB below the speech spectrum. Only one child had not been using conventional amplification device prior to implantation. All the rehabilitated children with hearing impairment were attending listening training for a duration of 45 minutes thrice a week.

Speech stimulus: Three meaningful simple bisyllabic Kannada words were considered incorporating the phonemes /k/ and /g/ and vowels /a/ /i/ and /u/.All the children were able to produce the selected phonemes at word level. The target words were /kannu/ (eyes), /kuri/ (sheep) and /gili/ (bird). The parameters measured from the waveform display are:

1. VOT (for the plosives /k/ and /g/ in the initial position of words (/gili/ and /kuri/)

   (VOT is defined as the time difference between the articulatory release and the onset of vocal fold vibration (Lisker & Abramson, 1964)

2. Word duration (measured as time difference between the onset and offset of the target word) for all the three words.

3. Vowel duration (measured as time difference between the onset and offset of target vowel in a word) of /a/, /i/, and /u/ in the above three words respectively.

4. The single spectral parameter considered is the second Formant Frequency (F2) of vowels /a/, /i/ and /u/. F2 was measured at the centre of the steady portion of the target vowel.

Procedure : The speech sample was recorded in quiet room for one subject at a time. Recording was done using COOL EDIT PRO VERSION 2. The speech utterances were digitized at a sampling rate of 44100 Hz with 16 bit resolution. The subjects uttered the target words into a microphone (Smart-Stereo headphones SH-03). For all the three groups speech was elicited with the help of colourful, average sized flashcards or by imitation. Three productions of each word were obtained and the best production was for further acoustical analysis which was carried out using speech analysis software PRAAT (Ver.5114).

Statistical Analysis: A non parametric test, Kruskal Wallis was applied to compare the parameters across the cochlear implantees, BTE users and normal hearing age peers. All statistical analysis was carried out using “SPSS” (Ver. 16).

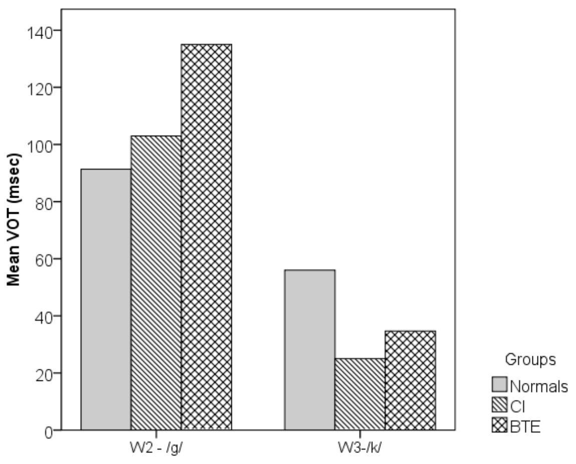
Results and Discussion

Descriptive statistics consisting of mean, standard deviations, minimum and maximum values were obtained for all the parameters as depicted in Table 1. The statistical analysis revealed some salient features of interest (Table 2). The results of lead VOT indicated that the mean values for the cochlear implantees and BTE users were longer as compared to normal hearing subjects as shown in Graph 1. This finding can be explained on the basis that there is an increase in VOT values as the place of articulation moved back in the oral cavity as also explained by Lisker and Abramson (1964) and Gilbert and Cambell (1978). Similar finding was reported by Ravishankar (1981) in Kannada citing the same reason. It is highly probable that for producing a velar sound the children with hearing impairment would have possibly made a much more posterior place of articulation because of the exaggerated visual demonstrations to them during training. The standard deviation was the highest in the BTE group followed by CI and then normal hearing individuals as shown in Table 1.

The results of lag VOT indicate that there was no significant difference between the mean values of all three groups with the mean value for the hearing impaired group (CI and BTE) being shorter than normal hearing individuals as seen in Graph 1. The reduced positive VOT value in the speech of the hearing impaired may be attributed to the reduced oral breath pressure in them (Gilbert, 1978; Hutchinson & Smith, 1976). Standard deviation for the normal hearing individuals was comparatively higher as compared to the hearing impaired group as depicted in Table 1.

Parameters	Normal Mean(SD)	CI Mean (SD)	BTE Mean (SD)
Temporal parameters			
VOT (in ms)			
Lead VOT for /g/	91.33 (16.86)	103 (21.37)	135 (56.82)
Lag VOT for /k/	56 (41.67)	25 (13.11)	34.67 (20.03)
Word and vowel duration (in ms)			
/kannu/ (W1)	460.66 (166.4)	765.33 (193.14)	755.67 (70.5)
/gili/ (W2)	431.67 (52.93)	695.33 (113.07)	655 (77.17)
/kuri/ (W3)	389.66 (72.05)	677.66 (231.53)	642 (76.54)
/a/ (V1)	99.33 (26.72)	290 (105.35)	94 (29.46)
/i/ (V2)	82 (19.46)	328 (60.1)	170 (69.29)
/u/ (V3)	82 (7.81)	263.33 (221.32)	127.33 (17.9)
Spectral parameters			
Formant frequency (F2) in Hz			
/a/	1955 (296.5)	2032 (369.26)	1498 (184.27)
/i/	2684 (124.5)	3343 (453.24)	2628 (319.67)
/u/	1568 (123.92)	1791 (420.29)	1091 (365.44)

Table 1: *Mean and Standard deviations for lead and lag VOT, F2, word and vowel duration for the three groups.*

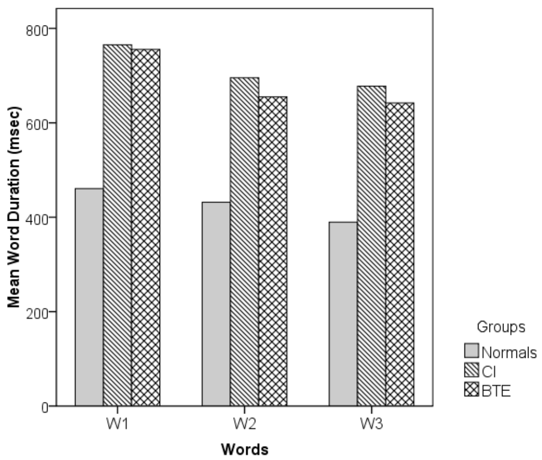


Graph 1: Mean lag and lead VOT values for the three groups.

Parameters	
VOT1	.288
VOT2	.193
WD1	.113
WD2	.066
WD3	.066
VD1	.066
VD2	.027 *
F2-/a/	.561
F2- /i/	.957
F2-/u/	.105

Table 2: Results of Kruskal Wallis Test
*: significant at 0.05 level

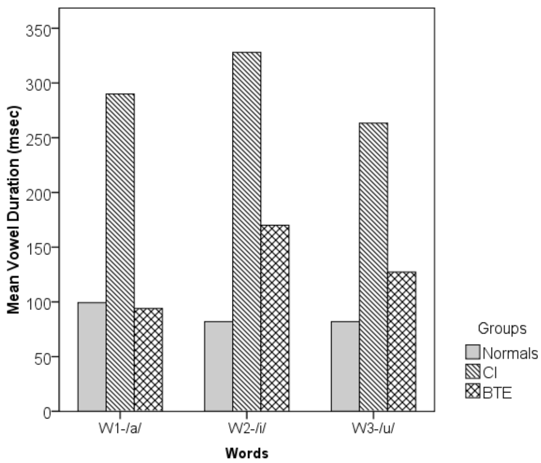
The present study indicates that both CI and BTE groups had word duration almost twice that of the normal group as shown in Graph 2.



Graph 2: Mean word duration values for the three target words.

Many earlier studies have reported similar results in the hearing aid users (Shukla, 1986 & Vasantha, 1995; Calvert, 1961; Monsen, 1974 and Osberger & Levitt, 1979). Monsen (1974) states that deaf subjects production of vowels were longer by one and a half times when compared to normal hearing individuals.

The standard deviation for word duration was maximum for the CI group followed by normal hearing individuals and lastly BTE group as seen in Table 1. A puzzling finding was that the CI group had longer vowel duration as compared to BTE users and normal hearing individuals.



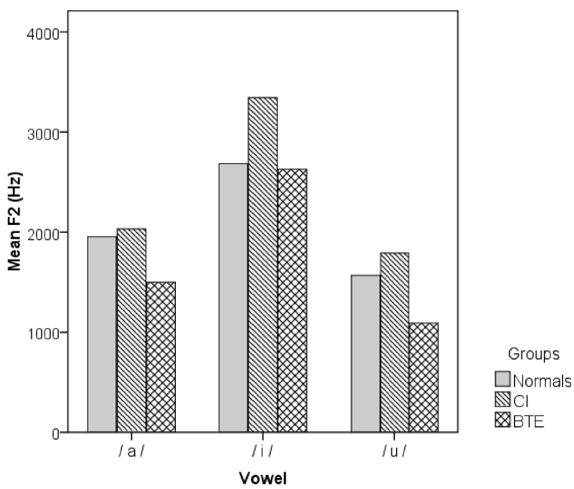
Graph 3: Mean vowel duration in the three groups

Vowel duration is found to be longer in the CI and BTE group and one possible reason for the prolongation of vowels and consonants is that they heavily depend on vision and vision simply does not operate in as rapid a time frame as audition. Another possibility is that auditory feedback is necessary for rapid smooth production of complex motoric sequences of speech and hearing impairment limits the required information too severely. It could also be reasoned out that vowels are much easier to produce as compared to the consonants and hence the hearing impaired group compensate for the inability of producing a consonant by prolonging the vowel. One more probable reason is that training given to the hearing impaired group is exaggerated to obtain a better production from the client which in turn leads to a prolongation of vowels in them.

Several studies (Uchanski & Geers, 2003; Dawson et.al, 1995) have reported that the acoustic measures of the speech of the CI users are expected to approach normal values compared to the BTE users. However in the present study, the CI values did not vary significantly with those of the BTE users. It can be supported by the fact that the cochlear implantees taken up for this study have been implanted for duration of 6 months only at the time of data collection.

With respect to vowel duration, the results illustrate a significant difference between normal hearing individuals and the CI group at 0.05 level of significance using Mann Whitney test. Vowel duration of the CI group is thrice that of the normal hearing individuals and that of the BTE group is twice that of normal hearing individuals.

The second formant frequency (F2) pattern of vowels is an important acoustic correlate of the vowels phonetic quality and its phonemic identity. It was observed that the CI group had higher F2 for the vowels /a/, /i/, /u/ as compared to normal hearing age matched individuals, whereas the BTE users had lower values than the normal hearing individuals for these vowels as depicted in Graph 2. The finding is in consonance with the study done by Angelocci et.al, 1964; Monsen, 1976 who report that deaf talkers formant frequencies often deviate from those of normal hearing talkers. It has also been supported by Monsen (1976) who reported that in the speech of the hearing impaired subjects (using BTE) the second formant transitions may be reduced both in time and frequency. BTE users probably had lower F2 formant values because of the neutralisation of the vowel and also tongue raising is insufficient in contrast to what is required for the accurate production of /i/ and the hearing impaired children usually produce vowel /i/ with an open jaw which lowers F2. The front back position of the tongue is primarily responsible for the second formant, which is not easily visible and hearing impaired individuals have difficulty in maintaining proper position of the tongue (Monsen, 1976) during vowel production.



Graph 4: Mean F2 values for the vowels /a/, /i/ and /u/.

A salient observation was that F2 for /i/ is relatively higher for the cochlear implant user compared to the BTE users. Except for the formant frequency for the vowel /i/, the values of the CI users are approximating that of the normal hearing individuals as opposed to the BTE users. The F2 of the CI group is approaching the normal values probably because the former have a better speech perception in the F2 region which can be one of the important advantages of CI implantation.

Also one of the CI subject was directly implanted without any prior amplification. The present finding is also in consonance with the report of Tait and Lutman (1997) which states that the benefits of implantation appears only one year after implantation in the pre linguistic measures.

Conclusions

Describing the speech of the individuals with hearing impairment acoustically not only has the advantage of an objective measurement but it also sheds light on the probable reasons for the poor intelligibility in them, which in turn may help in developing effective therapeutic procedures. The present study made an attempt to compare a few acoustic parameters across cochlear implantees, BTE users and normal hearing subjects. The findings revealed that there was significant difference only for vowel duration across CIs and normal hearing subjects where as no evident difference was seen in lead and lag VOT, second formant frequency and word duration across the three groups. This is probably because the cochlear implantees in this study were implanted only six months prior to data collection. In view of the small group studied, findings need to be ascertained by expanding the study on a larger number of cochlear implantees and BTE users.

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