COARTICULATION IN THE SPEECH OF PRELINGUALLY PROFOUND HEARING IMPAIRED AND NORMAL CHILDREN

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MAY 2001

Dedicated to

Amma, Appa, Chitra Akka,

Kumar Anna and Jothi

With love

Certificate

This is to certify that the Dissertation entitled *"COARTICULATION IN THE SPEECH OF PRELINGUALLY PROFOUND HEARING IMPAIRED AND NORMAL CHILDREN"* is the bonafide work done in part fulfillment of the degree of Master of Science (Speech and Hearing) of the student (Register No. M 9909).

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Certificate

This is to certify that the Dissertation entitled *"COARTICULATION IN THE SPEECH OF PRELINGUALLY PROFOUND HEARING IMPAIRED AND NORMAL CHILDREN"* has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in any other University for the award of any Diploma or Degree.

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Declaration

This dissertation entitled *"COARTICULATION IN THE SPEECH OF PRELINGUALLY PRFOUND HEARING IMPAIRD AND NORMAL CHILDREN"* is the result of my own study under the guidance of Ms. K. Yeshoda, Lecturer, Department of Speech Sciences, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier in any other University for the award of any Diploma or Degree.

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INTRODUCTION

Speech, a serially ordered stream of complex, articulatory movements consists of predetermined, orderly sequences of actions which are unique for each language (Lashley, 1951). As speech sounds are produced in serial order, the articulators must be moved sequentially from one target to another. The vocal tract moves slowly but continuously from vowel to vowel with periodic interruption caused by consonantal modulations. Consonants and vowels overlap because consonant articulations are superimposed on a continuous steadily shifting vowel articulation pattern. As a result, coarticulation, the label for overlapping properties of speech sounds, is built into the process of articulation.

Coarticulation by definition is the overlapping production of two or more phonetic segments (Fowler, 1981). Acoustically, it refers to the influence due to modifications by certain contextual features on the spectral and temporal characteristics of speech sounds. Physiologically, coarticulation refers to the integration of neural commands to the speech musculature, timing and movement patterns of articulators and aerodynamic forces, which results in spreading of features from one sound to another (Sharf and Ohde, 1981). This integration or coproduction of segments provides the listener, additional cues to phonetic identity in segments surrounding the phoneme in question (Monsen, 1974) and essentially increases transmission rate in speech production (Lieberman and Blumstein, 1988).

The coarticulatory effects are commonly described as anticipatory or forward and perseveratory or backward coarticulation. Anticipatory coarticulation refers to the influence of a given sound segment on a preceding sound (Daniloff and Moll, 1968; Lubker and Gay, 1982; Sereno, Baum, Marean and Lieberman, 1987). The perseveratory or backward coarticulation refers to the influence of a given sound segment on a following segment (Gay, 1977; Fowler, 1981; Recansens,1984; Flege, 1988; Sereno, et al., 1987).

During infancy hearing individuals may learn to restrict the degrees of freedom of articulatory movements and interactions by abstracting information from the speech signal. These learnt articulatory interactions may provide the corner stones for production of connected speech later.

One of the most devastating effects of congenital hearing impairment is the disruption of normal speech development. Consequently, most hearing impaired children have to be taught the speech skills that normal hearing children readily acquire during the first few years of life. Although, some hearing impaired children develop intelligible speech, many do not. Normalcy in terms of timing, rhythm, pitch, intonation, velar control, articulation and voice quality are not achieved.

The individuals with hearing impairment who learn to speak without audition may develop aberrant principles of aiticulatory coordination, thus not blending their gestures together, like hearing speakers. This lack of articulatory coordination or coarticulation in their speech (Calvert, 1961; John and Howarth, 1965; Smith, 1975) may in torn lead to reduced intelligibility (Tye-Murray and Woodworth, 1989).

The distortion in transition of formant frequency is one of the manifestations of lack of coarticulation at the acoustic level. In general, the formant transitions were exceedingly short in duration or missing altogether, and the extent of the frequency range of transitions were limited in part because, the formant frequencies for vowels were greatly neutralized and the transitions varied little with respect to phonetic context (Monsen, 1976c).

In the last two decades, the advances in the study of speech of the hearing impaired are mainly due to the development of sophisticated processing and analyzing techniques in Speech sciences. These technological advances have been applied not only in the analyses of speech of hearing impaired but in the development of clinical assessment and training procedures too (Sharf and Ohde, 1975).

The oral communication skills of hearing impaired children have since long been of concern to special educators, speech language pathologists and audiologists because the adequacy of such skills can influence the social, educational and career opportunities available to these individuals. Identification of the coarticulatory effects in the speech of children with hearing impairment would provide a better insight into the nature of speech production in them. Further, comparison with normal children would help inquire the attributes of coarticulation in the speech of hearing impaired children.

The aims of the study were:

i) To investigate the nature of anticipatory and perseveratory coarticulation in the speech of hearing impaired.

ii) To acoustically compare the coarticulatory effects in the speech of hearing impaired and normal hearing children.

REVIEW OF LITERATURE

Speech articulators do not function individually and independently. The speech sounds are modified by the influence of contiguous phonemes. Thus the acoustic properties of certain sounds are changed under the influence of adjacent sounds. Coarticulation is defined as an influence of a phonetic context on a given segment (Daniloff and Hammerberg, 1973).

These coarticulatory effects are categorized as anticipatory or forward coarticulation and perseveratory or backward coarticulation. Anticipatory coarticulation is said to occur when an articulatory adjustment for one phonetic segment is anticipated during an earlier segment in the phonetic string and this said to result from preplanning. Perseveratory coarticulation is said to occur when an articulatory adjustment for one segment appears to have been carried over to a later segment in the phonetic string. This is attributed to the mechanical-inertial properties of the articulators (Kent and Minifie,1977). Most of the studies have found greater backward effects than forward effects (Ohde and Sharf, 1975). However, there are also few reports of forward effects being greater than the backward effects (Butcher and Weiner, 1976).

Commonly it is assumed that children coarticulate less than adults. This reduction in the extent of coarticulation reflects the underlying general tendency in children to produce speech, segment by segment which decreases with age (Disimoni, 1974; Kent, 1983; Sereno and Lieberman, 1987; Nittrouer, Studdert-Kennedy, Mc Gowan, 1989).

To study the development of coarticulation in normals as well as in disordered population is a topic of great interest now. The speech of the hearing impaired children have also been compared with those of normal hearing children and the results reveal a notable difference in the performance of the hearing impaired children (Baum and Waldstein 1991; Waldstein and Baum, 1991).

Coarticulation in normal hearing children:

It has been debated that whether children exhibit fewer and or less consistent coarticulation that become more precise or adult like with increasing age or whether they demonstrate greater coarticulatory effects that decline with age. Kent (1983) reported that children tend to coarticulate less when compared to adults especially the anticipatory type, as it is the result of preplanning.

Disimoni (1974) studied CVC tokens (C = p, b, s, z, and V = i, a) in 30 children, aged 3, 6, and 9 years. The vowel duration of the vowel, preceding the consonant was measured. Results showed that vowel duration remained constant for voiceless sounds for all children but with voiced sounds, it increased with age. This shows that, contextual effects develop over a long period of time.

Abelin, Landberg and Persson (1980) measured duration of intervocalic consonants and the duration from the onset of the labial EMG activity to the acoustic onset of V_2 in six children (2-10 years) and an adult. VC_nV tokens were recorded, where Vj = unrounded vowels, V_2 = rounded vowels, C_n = non labial consonants. Findings revealed that consonant duration was much greater in children, indicating less coarticulation than adults. The second parameter also showed significant difference between the two age groups indicating less coarticulatory effects in children. In conclusion, the absence of EMG activity when V_2 was preceded by stressed unrounded V_1 in children indicated that anticipatory coarticulation was due to learning or maturation.

Repp (1986) compared the speech of two children aged 4.8 years and 9.5 years with an adult. The subjects were made to produce sea, sand, soup, tea, ten and tooth, five times each in a carrier phrase. The parameters measured were noise spectra, release burst spectra, second formant frequency and VOT. Both children produced prolonged /s/ noises and longer VOT, as well as higher F_2 at constriction noise offset before /i/ than before /u/ and /æ/). The lowered noise spectrum for /s/ before rounded vowels reflected the effects of anticipatory lip rounding due to tongue body position changes which were prominent in children than in adults, suggesting that, fricative vowel coarticulation decline with age unlike for other sounds. The author concluded that earlier in life, speech is produced segmentally and gradually becomes syllabified with development indicating that different sounds follow different developmental patterns.

Turnbaugh, Hoffman and Daniloff (1985) investigated F_2 transitions in three subjects (2 children of 3 and 5 years old and an adult) using CVC tokens [C = (b, d, g), V = (i, u)]. They found no significant difference between the age groups. Results revealed relatively strong lingua-labial coarticulatory shifts for labial and velar stops than alveolar /d/. Therefore, the control of CV lingua-labial coarticulation was more adult like at this stage of development than either formant frequencies or the segmental durations. This indicated that the neuromotor antecedents of stop vowel production may have developed earlier than either temporal control or other kinds of more language specific coarticulation.

Sereno and Lieberman (1987) examined lingual coarticulation through spectral analysis in five adults and 14 children (2.8 years to 7 years) using CV tokens [C=/k/, V= /i/ and /a/]. For adults prominent peak for /k/ preceding /a/ was seen in low frequency region and this was same for children in both vowel contexts which denotes different age levels for the acquisition of individual motor process for speech.

Frication noise for fricative sound, aspiration noise and burst duration for stop consonant in CV utterances (C = s, t, d and V = u and i) of four adults and eight children (3-7 years) were studied by Sereno, Baum, Marean and Lieberman (1987). No significant differences were obtained between both the groups considered. The authors concluded that children's utterances exhibit less precise, more variable coarticulatory effects than adult utterances. Therefore, according to them, the anticipatory coarticulation was not innate but a developmental process involving gradual acquisition and fine tuning of motor patterns.

Flege (1988) analyzed nasalance in ten subjects (aged 5 years, 10 years and adults) for /I/, /i/ /u/ in |d -d| , |n-n| , |n-d| ,and |d-n | contexts. Though, both types of coarticulation were present in /d-n/ and /n-d/ contexts, no significant differences were reported between age groups. The reason for lack of significant difference between children and adults were found to be consistent with the view that anticipatory nasal coarticulation is a natural speech process.

The frequency, amplitude and bandwidth of the second formant were measured for tokens /si si/, /ii, /uu/ and /susu/ in two children each, at 3. 4, 5 and 7 year of age and four adults. The F2 of the fricative preceding /i/ was higher in frequency than the F_2 of the fricative preceding /u/ and was found in all speakers, but was highest in children. This difference was attributed to lip rounding and tongue positioning in expectation to the vowels. The relative F2 amplitude was higher for /s/ than / / in children due to better transmission of back cavity sound to the atmosphere (Mc Gowan and Nittrouer, 1988).

Nittrouer et al. (1989) explored CVCV utterances (C = /s, / /, V = /i, u/ of eight adults and eight children (two each in 4 age groups - 3, 4, 5 and 7 years) for centroids and second formant frequencies. Two different developmental trends were reported i.e., the extent to which speakers differentiated between / / and /s/ increased with age while the extent to which they coarticulated each fricative with its following vowel decreased.

Katz, Kripke, and Tallal (1991) inquired into perceptual analysis, video analysis, frequency and durational analysis of /SV/ productions (V = a. i, u) in ten adults and thirty children (3, 5 and 8 years). Children showed greater variability in their articulatory patterns than adults. The acoustic and video analyses suggested that younger children and adults produced similar patterns of anticipatory coarticulation.

Transition duration, terminal frequency, extent and speed of transition of F2 were traced in six children ranging in age from 4-7 years for their CVCV [C = /p, t, k/, V = /a, i, u/] utterances by Perumal (1991). No specific developmental patterns were obtained for any of the parameter, as the results were highly variable. However, it was noticed that the transition duration, speed and extent of transition duration of F_2 were reduced in the older age group.

Sussman, Duder and Dalston (1999) examined a single child from seven to 40 months for the production of stop consonants and vowels by measuring the second formant at the onset and vocalic center. Labial, alveolar and velar CV productions followed distinct articulatory paths toward adult like norms of coarticulation. For labials, initial rise in coarticulatory effects were found to begin at the end of the first year with progressive increases during first word productions around year two and relatively stabilizing during the third year. In case of alveolars, there was an initial sharp decrease throughout the first year, followed by a prolonged period of undershooting the adult norm throughout year two or three. Most stable slope values were obtained for velars relative to the adult norm.

A review of the developmental research in this area delineates that the results are yet inconclusive in spite of varied methodologies. Although they report of a general difference between children and adult productions, the actual nature of coarticulation has to be probed further.

Coarticulatory abilities of hearing impaired individuals:

The hearing impaired speakers have often been reported to have difficulty in moving their articulators correctly from one phoneme to the next according to Calvert, 1961; John and Howarth, 1965; Smith, 1975. These authors have further reasoned that the above, results in distortion of formant frequency transitions and therefore the speakers with hearing impairment have reduced or absent coarticulatory affects in their speech.

Monsen (1976c) found that formant transitions were exceedingly short in duration or missing altogether and that the extent of frequency range of transition was limited in part because the formant frequencies for vowels were greatly neutralized and that transition varied little with respect to phonetic context, F_2 transition was also found to be reduced both in time and frequency in speech of hearing impaired.

Mc Garr and Lofqvist (1982) inspected glottal activity (by trans-illumination) in three severe to profound hearing impaired adults for their words and cluster productions. For each hearing impaired speaker an inappropriate abduction gesture was often found between words, a pattern never observed for normal hearing speakers.

Vowel and word duration (spectrographic analysis) was quired by Tye-Murray and Woodworth (1989) in four prelingually deaf adults and two normal speakers. The stimuli were three sets of word sequences consisting of three kernel word and their derived forms. It was found that, for normal hearing speakers the word and vowel durations were longer when produced in isolation or at the end of a phrase or sentence than when followed by additional syllables compared to the group of deaf adults.

Waldstein and Baum (1991) sifted consonant duration, centroids and F_2 peak in nine normal and profound prelingually hearing impaired children in the age range of 7-10 years by recording CV and VC utterances (C= / /, t, k/, V=/i, u/). The results revealed a presence of anticipatory and perseveratory coarticulation in the speech of the hearing impaired individuals but, the magnitude of coarticulatory effects was smaller in them.

Ryalls, Baum, Samuel, Larouche, Lacoursiere and Garceau (1993) interrogated CV pronouncements of five male and five female children with normal hearing, moderate to severe and profound hearing impairment. The parameters considered for spectrographic analysis were F_2 and centroid frequency. Coarticulation was reported for all the groups. However, the degree of coarticulation was found to be smaller and less consistent in hearing impaired speakers than the normal hearing speakers.

These studies evinced that hearing impaired children also exhibit coarticulation in their speech but the extent of such an effect is less when compared to normal hearing children. This impaired ability to produce appropriate context effects in speech may contribute to reduced intelligibility of the hearing impaired speech. It is therefore important to examine the extent to which context effects are developed in the speech of the hearing impaired.

Although great strides have been made in understanding the speech of the hearing impaired, the knowledge in this area is far from complete. Further research, delineating the development of coarticulatory effects in their speech would improve the existing remediation programs. In this precinct, the present study was envisaged

METHODOLOGY

The aim of the study was to acoustically compare anticipatory and the perseveratory coarticulatory effects of prelingually profound hearing impaired children with normal hearing children.

SUBJECTS:

The subjects for the study consisted of two groups, experimental and control group. Experimental group comprised of ten Kannada speaking children (five males and five females) with prelingually profound hearing impairment in the age range of 5-10 years (two in each age group). Ten children matched for age, gender and language formed the control group.

SUBJECT SELECTION CRITERIA:

The inclusion criteria were as follows:

EXPERIMENTAL GROUP:

1) Congenital hearing loss with a pure tone average of 90 dBHL or greater at speech frequencies and no other associated problems (mental retardation, orofacial abnormalities or other sensory deficits).
2) Amplified in infancy/early childhood and trained using the aural-oral approach.
3) Age appropriate reading skills.

CONTROL GROUP:

1) Age and gender appropriate speech and language skills.
2) Average intelligence as reported by teachers and parents.
3) Normal hearing sensitivity as ascertained by audiometric screening at speech frequencies.

TEST MATERIAL:

Eighteen nonmeaningful words (C_1 V_1 C_2 V_2) with the vowels (a, i, u) and consonants (p, t, k, b, d, g) were selected for the study. Each word was orthographically depicted on a card sized 4"x6". The word list is given in the appendix.

PROCEDURE:

Prior to the recording, the experimenter initiated conversation with each subject for rapport building. The subjects were seated comfortably and were asked to read the words aloud, presented one after the other. All the 18 words were recorded thrice in a random order on to the module of Computerized Speech Lab 4300B (CSL 4300B) with an high fidelity unidirectional external microphone positioned approximately 5cms from the subjects' mouth. The recordings were done in a quiet room in a single sitting. The response which was perceptually adequate and "on-target" production as judged by the examiner was considered for further analysis.

ANALYSIS:

The selected samples were analyzed using CSL 4300B. All the utterances were digitized at 20 kHz sampling rate with 12 bit quantization and were displayed as broadband spectrograms. The following parameters were extracted from the spectrograms:

1) Transition duration of F_2 in ms (TDF_2):

For perseveratory coarticulation, TDF_2 was measured as the time duration between the onset of the second formant for the vowel (V_2) to the steady state of the same. For anticipatory coarticulation, it was calculated as the time duration from the end of the steady state to the offset of the second formant, following the vowel (V_1).

2) Terminal frequency of F_2 in Hz (TF_2):

The frequency at the onset of the second formant for the vowel (V_2) following the consonant (C_2) was measured as TF_2 in perseveratory coarticulation. In case of anticipatory coarticulation, it was measured as the frequency of second formant at the offset of F_2 following the steady state of the vowel (V_1).

3) Extent of transition of F_2 in Hz (ETF_2)

This was measured as the frequency difference between the terminal frequency of the second formant and the frequency at the onset of steady state vowel (V_2) for perseveratory coarticulation. ETF_2 was calculated as the difference in frequency at the end of the steady state to the offset of the second formant of the vowel (V_1) in anticipatory coarticulation.

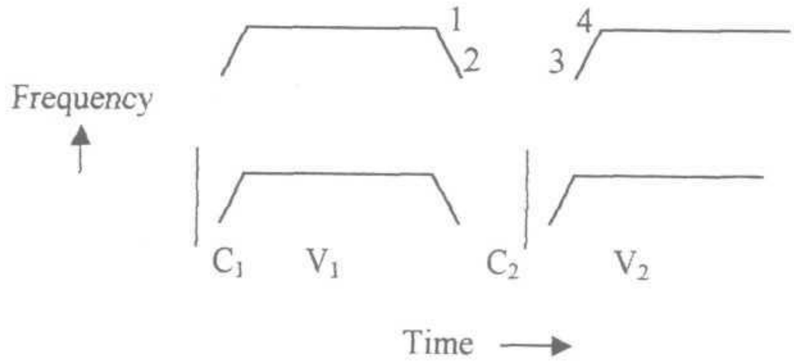
4) Speed of transition of F_2 in Hz/ms (STF_2):

Speed of transition of F_2 is the rate at which the F_2 moves and was calculated separately for both anticipatory and perseveratory coarticulation using the formulae

$$STF_2 = \frac{ETF_2}{TDF_2}$$

5) Second formant and third formant frequencies in Hz (F_2 and F_3):

F_2 and F_3 are the frequencies of second and third formants of the steady state portion of the vowelsV_2 and V_1 for perseveratory and anticipatory coarticulation respectively.



Transition duration of F_2 for perseveratory coarticulation = duration at 4 - duration at 3 (msecs)

Transition duration of F2 for anticipatory coarticulation = duration at 2 - duration at 1 (msecs)

Terminal frequency of F_2 for perseveratory coarticulation = frequency at 3 (Hz)

Terminal frequency of F_2 for anticipatory coarticulation = frequency at 2 (Hz)

Extent of transition of F_2 for perseveratory coarticulation = frequency at 4 - frequency at 3 (Hz)

Extent of transition of F_2 for anticipatory coarticulation = frequency at 1 - frequency at 2 (Hz)

$$\text{Speed of transition of } F_2 = \frac{ETF_2}{TDF_2}$$

STATISTICAL ANALYSIS:

The data obtained for both the groups were tabulated. The independent samples 'T' test was used for comparing the above mentioned parameters in both prelingually profound hearing impaired and normal subjects.

RESULTS AND DISCUSSION

All the responses of normal subjects and the hearing impaired subjects which were perceptually "on-target" in terms of voicing, place and manner of articulation were considered for final analysis. From each response, frequency of the second formant (F_2), Frequency of the third formant (F_3), Transition duration (TDF_2), Terminal frequency (TF_2), Extent (ETF_2) and Speed of transition (STF_2) of the second formant frequency were extracted and tabulated.

The tabulated data were subjected to independent samples 'T' test. Each vowel was compared separately for both anticipatory and perseveratory coarticulation across the two groups. The results are tabulated in the tables given below and 'A' represents anticipatory coarticulation and 'P' represents perseveratory coarticulation.

TABLE 1: Mean, SD and 'T' values of F_2, F_3, TDF_2, TF_2, ETF_2 and STF_2 for the vowel /a/ in normal and hearing impaired subjects during anticipatory coarticulation.

Parameter	Normals		Hearing impaired		'T ' value
	Mean	S.D.	Mean	S.D.	
AF_2	1738.0	218.4	1819.0	281.4	1.480
AF_3	3593.0	263.7	3395.7	472.0	2.530*
$ATDF_2$	34.8	14.2	37.9	20.4	0.832
ATF_2	1851.2	502.2	1973.5	367.7	0.551
$AETF_2$	590.8	213.6	518.6	188.5	1.552
$ASTF_2$	19.4	11.5	17.8	13.1	0.592

* Significant at 0.05 level.

TABLE 2: Mean, SD and ' T' values of F_2, F_3, TDF_2, TF_2, ETF_2 and STF_2 for the vowel /a/ in normal and hearing impaired subjects during perseveratory coarticulation.

	Normals		Hearing impaired		' T' value
Parameter	Mean	S.D.	Mean	S.D.	
PF_2	1710.7	226.0	1820.5	299.0	1.928
PF_3	3603.9	282.0	3514.0	727.0	0.839
$PTDF_2$	34.1	15.8	37.2	21.2	0.766
PTF_2	1848.7	436.8	1760.6	415.3	0.905
$PETF_2$	607.3	233.3	645.0	178.2	0.769
$PSTF_2$	23.2	25.8	21.5	11.8	0.329

The mean F_2 for the hearing impaired speakers was higher than the normals for both anticipatory and perseveratory coarticulation and was not statistically significant. This is in agreement with the results of Angelocci et al., 1964.

Hearing impaired subjects revealed significantly lower F_3 values for anticipator}' coarticulation compared to the normals. Angelocci et al 1964 found increased F_3 values for hearing impaired. The reason for reduced F_3 could be inappropriate constriction in the oral cavity during production of /a/ in the hearing impaired speakers. This again indicates that the anticipation is absent. Mean F_3 values during perseveratory coarticulation were found to be lower in hearing impaired children which was not significant.

Significance was not found for the following parameters even though the mean values varied considerably in hearing impaired when compared to normals.

- Higher TDF_2 was observed for both types of coarticulation in hearing impaired.
- In anticipatory coarticulation TF_2 was increased, but it decreased during perseveratory coarticulation in the hearing impaired.

- Hearing impaired subjects showed reduced ETF_2 in anticipatory coarticulation but the same increased during perseveratory coarticulation.
- In hearing impaired, the STF_2 decreased during both anticipatory and perseveratory coarticulation.

Lack of significance for the above parameters indicates that the hearing impaired speakers produced the vowel /a/ similar to the normals. Geffner (1980), Smith (1975) and Nober (1967) also reported that hearing impaired speakers produced the low vowels correctly. Although hearing impaired speakers are said to have slow articulatory movements, the present study confirmed the presence of the context effects for the vowel /a/. This may be because, /a/ is a neutral vowel and the required articulatory movements are less complex compared to other vowels.

TABLE 3: Mean, SD and' T ' values of F_2, F_3, TDF_2, TF_2, ETF_2 and STF_2 for the vowel /i/ in normal and hearing impaired subjects during anticipatory coarticulation.

Parameter	Normals		Hearing impaired		'T' value
	Mean	S.D.	Mean	S.D.	
AF_2	3181.00	432.4	2634.0	472.1	5.091*
AF_3	3956.7	252.5	3558.8	474.0	4.986*
$ATDF_2$	30.3	11.6	41.6	21.4	3.074*
ATF_2	3029.4	427.5	2434.0	491.5	5.447*
$AETF_2$.	635.4	223.4	523.1	245.5	1.993*
$ASTF_2$	23.5	10.6	14.8	13.0	3.116*

* significant at 0.05 level.

TABLE 4: Mean, SD and ' T' values of F_2, F_3, TDF_2, TF_2, ETF_2 and STF_2 for the vowel /i/ in normal and hearing impaired subjects during perseveratory coarticulation.

Parameter	Normals		Hearing impaired		'T' value
	Mean	S.D.	Mean	S.D.	
PF2	3259.0	206.0	2564.0	401.0	10.36*
PF3	3995.0	278.4	3552.2	473.1	5.27*
PTDF2	29.5	11.7	45.2	17.8	4.70*
PTF_2	2954.1	563.2	2288.3	486.9	4.99*
$PETF_2$	704.1	301.0	654.0	314.6	0.670
$PSTF_2$	27.5	15.1	24.6	40.7	0.484

* Significant at 0.05 level.

The mean F_2 values were significantly lower for hearing impaired speakers compared to normals for both types of coarticulation. This finding is in consonance with the results of Angelocci et al., 1964 who found reduced mean F_2 for /i/ embedded in words and sentences. Baum and Waldstein (1991) reported reduced mean F_2 for /i/ in /t/ and /k/ contexts.

The reduced F_2 could be because of the fact that, hearing impaired speakers have residual hearing only in the frequency range of F_1 and not in the range of F_2. Also this may be due to the relative invisibility of tongue constriction from front to back which is primarily responsible for the second formant (Monsen, 1976a).

Compared to normals, significantly lowered mean F_3 values were observed in the hearing impaired speakers for both anticipatory and perseveratory coarticulation. Angelocci et al., 1964 reported similar results. The possible explanation for this could be the reduced constriction in oral cavity due to inappropriate tongue movements in hearing impaired speakers.

In hearing impaired, the TF_2 values were reduced significantly for both types of coarticulation. This may be due to the changes in front cavity volume.

The TDF_2 values were significantly higher in hearing impaired than normals for both anticipatory and perseveratory coarticulation. This finding is on par with the findings of Rothman (1976). But this contradicts the results of Monsen (1976c) who found exceedingly short transition duration. Increased transition duration as observed in hearing impaired subjects may be due to their inability to move the articulators appropriately from one phoneme to the next according to Martony, 1965; and Smith, 1975.

ETF_2 and STF_2 were reduced significantly only during anticipatory coarticulation in the hearing impaired speakers when compared to normals.

Sluggish movements of the tongue and imprecision in attaining actual articulatory target could explain the reduced ETF_2 and STF_2 in hearing impaired. This also suggests that they do not anticipate the articulatory movements during speech production.

In general, the results of the present study, supports the notion that hearing impaired speakers have difficulty in producing the vowel /i/, as it is difficult to visualize the movement of articulators. This confirms with the findings of Nober (1967), Smith (1975) and Geffher (1980). Therefore, it can be speculated that coarticulation is iess precise pertaining to vowel /i/.

TABLE 5: Mean, SD and 'T' values of F_2, F_3, TDF_2, TF_2, ETF_2 and STF_2 for the vowel /u/ in normal and hearing impaired subjects during anticipatory' coarticulation.

Parameter	Normals		Hearing impaired		'T' value
	Mean	S.D.	Mean	S.D.	
AF_2	1084.9	145.6	1450.1	257.6	8.125*
AF_3	3661.3	313.4	3275.0	665.5	3.622*
$ATDF_2$	33.6	12.3	42.08	16.1	2.578*
ATF_2	1222.0	531.4	1485.9	400.5	2.193*
$AETF_2$	521.9	205.0	521.6	228.3	0.007
$ASTF_2$	17.7	9.8	14.0	9.1	1.566

* Significant at 0.05 level.

TABLE 6: Mean, SD and 'T' values of F_2, F_3, TDF_2, TF_2, ETF_2 and STF_2 for the vowel /u/ in normal and hearing impaired subjects during perseveratory coarticulation.

Parameter	Normals		Hearing impaired		'T" value
	Mean	S.D.	Mean	S.D.	
PF_2	1084.4	171.6	1487.7	274.0	8.122*
PF_3	3691.7	286.0	3284.3	733.3	3.683*
$PTDF_2$	34.14	16.3	39.1	17.4	1.24
PTF_2	1261.3	582.7	1478.9	395.4	1.678
$PETF_2$	591.8	215.4	622.9	223.9	0.590
$PSTF_2$	20.0	10.5	19.5	12.1	0.170

* Significant at 0.05 level.

In comparison to normals, the hearing impaired subjects revealed significant increase in F_2 values for both types of coarticulation and is in consensus with the reports of Angelocci et al. (1964) and Baum and Waldestein (1991). But, Waldstein and Baum (1991) found reduced F_2 for /u/ in /k/ and /t/ context during anticipatory coarticulation. The hearing impaired speakers exhibit inaccurate articulatory movements which results in the reduction of volume of the front cavity which explains the increased F_2.

F_3 significantly decreased for anticipatory and perseveratory coarticulation in hearing impaired speakers compared to normal speakers. Angelocci et al., 1964 also reported similar results. This reduction in F3 may be due to the increase in volume of the constriction area as a result of inaccurate tongue movements.

TF_2 was also significantly higher for anticipatory coarticulation in hearing impaired than in normal subjects. This can be attributed to the changes in front cavity volume in hearing impaired compared to normal children.

Hearing impaired subjects revealed significantly prolonged TDF2 for anticipatory coarticulation indicating that, the anticipation of lip rounding is absent in them. Hence the articulators might take a longer time to move from one phoneme target to the next. In perseveratory coarticulation, this significance was not present.

The mean ETF_2 values of hearing impaired subjects were similar to the normals in anticipatory coarticulation, but it increased dunng perseveratory coarticulation in hearing impaired. The difference in mean values might indicate that hearing impaired speakers were not able to move their articulators to the desired extent which is a perquisite for correct production of speech.

The means of STF_2 in hearing impaired speakers were less than the normal speakers for both types of coarticulation referring to slow movements of articulators to their target positions. However, this difference was not statistically significant. Significant differences observed only for few parameters when the vowel /u/ was considered in hearing impaired subjects, could be an indicator of presence of contextual effects to some extent.

Many of the hearing impaired subjects produced a great number of substitution errors and such samples were not considered for final analysis. Ryalls et al. (1993) also reported of substitution errors. The younger subjects exhibited more errors when compared to their older counterparts. With increase in age, the errors also reduced and the same could be attributed to the effect of training, resulting in better speech intelligibility.

To summarize, the results indicated the following:

1) For the vowel /a/ the considered parameters were not significantly different between the normal and hearing impaired children.
2) For the vowel /i/, many parameters were significantly different in hearing impaired and normal subjects.
3) For the vowel /u/, only few parameters differed significantly.

Thus, the contextual effects involving the vowel /i/ was affected greatly in hearing impaired than the vowels /u/ and /a/.

SUMMARY & CONCLUSIONS

Coarticulation is overlapping production of two or more phonetic segments (Fowler, 1981). The coarticulatory effects are categorized as anticipator}' and perseveratory coarticulation.

Hearing impaired speakers have often been described as having difficulty in moving their articulators correctly from one phoneme to the next (Calvert 1961; John & Howarth, 1965; Martony, 1965; Smith, 1975). Changes in formant frequencies, particularly the direction, extent and duration of the second formant transition, have found to be important acoustic cues for the continuous speech production. The consonant-vowel transitions have been reported to be longer and more restricted in range in hearing impaired when compared to the normals (Rothman, 1976). Waldstein & Baum (1991) and Baum & Waldstein (1991) found that hearing impaired subjects exhibited both anticipatory and perseveratory coarticulation, although they did so, to a lesser degree.

The aim of the present study was to compare the anticipatory and perseveratory coarticulation in hearing impaired and normal children. Twenty Kannada speaking children, 10 normals and 10 prelingually profound hearing impaired formed the subjects. The stimuli were $C_1V_1C_2V_2$ sequences with the vowels /a, i, u/ and consonants /p, t, k, b, d, g/. There were 18 words totally and were recorded thrice in random order.

The perceptually adequate and "on target" responses were subjected to spectrographic analysis. From the spectrograms, frequency of the second formant (F_2), frequency of the third formant (F_3), transition duration (TDF_2), Terminal frequency (TF_2), extent of transition (ETF_2) and speed of transition (STF_2) of the second formant were obtained. The results indicated that, as the visibility of the sound being produced became obscured, the nature of coarticulation in the hearing impaired varied and this was revealed by the significant differences in the values obtained for the vowel /i/, compared to the other two vowels /a/ and /u/. It can be deduced that coarticulatory effects may be more limited in hearing impaired speakers in the production of certain sounds.

Thus the combination of less adequate preplanning and greater articulatory imprecision attributes to the decreased anticipatory and perseveratory coarticulation present in the speech of hearing impaired individuals. Hence, incorporating the concept of coarticulation or context effects in training the hearing impaired speakers would enhance intelligibility of the speech of the hearing impaired.

Further research on coarticulation in the speech of hearing impaired children may inquire into the developmental trends, the effect of severity of hearing loss and nature of coarticulation for different consonants. This will enable the speech and language pathologists to understand the coarticulatory effects across sounds, which may improve the existing remediation programs for hearing impaired children.

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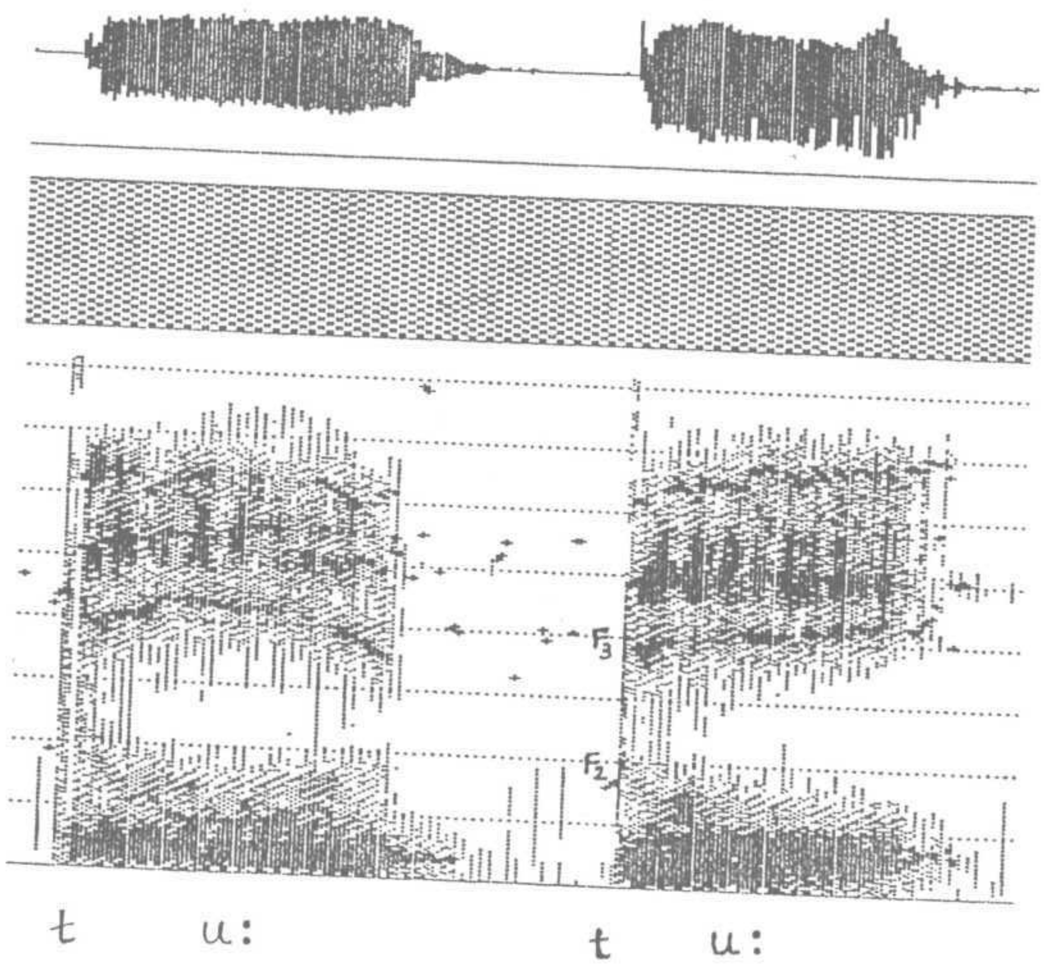
APPENDIX I

Test material:

೧. ಪಾಪ	೭. ಪೀಪೀ	೧೩. ಪೂಪೂ
೨. ಟಾಟ	೮. ಟೀಟೀ	೧೪. ಟೂಟೂ
೩. ಕಾಕ	೯. ಕೀಕೀ	೧೫. ಕೂಕೂ
೪. ಬಾಬಾ	೧೦. ಬೀಬೀ	೧೬. ಬೂಬೂ
೫. ಡಾಡಾ	೧೧. ಡೀಡೀ	೧೭. ಡೂಡೂ
೬. ಗಾಗಾ	೧೨. ಗೀಗೀ	೧೮. ಗೂಗೂ

Appendix II: Waveform and spectrogram of the word /tu: tu:/ in a normal hearing male subject.



Appendix III: Waveform and spectrogram of the word /tu: tu:/ in a hearing impaired male subject.