DEVELOPMENT OF PRODUCTION
OF
COARTICULATION IN CHILDREN

Register Mo. : M 3107

A Dissertation submitted as part fulfilment for

Final Year M.Sc, (Speech and Hearing)

to the University of Mysore

ALL INDIA INSTITUTE OF SPEECH AND HEARING
MYSORE - 570 006
MAY 1333

To all those who spend

their lives battling against

the odds - that dark

world of science, shame and

ugly stigma ....

the speech & hearing disabled,

... is the work dedicated

C E R T I F I C A T E

This is to certify that the dissertation entitled "DEVELOPMENT OF PRODUCTION OF COARTICULATION IN CHILDREN" is the bonafide work in part fulfilment for the degree of Master of Science (Speech & Hearing), of the student with Register No. M 9107.

Director
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Mysore - 570 006

C E R T I F I C A T E

This is to certify that the dissertation entitled "DEVELOPMENT OF PRODUCTION OF COARTICULATION IN CHILDREN" has been prepared under my supervision and guidance.

Savithri. S.R

Dr.S.R. SAVITHRI
GUIDE

D E C L A R A T I O N

This dissertation is the result of my own study undertaken under the guidance of Dr.S.R. Savithri, Lecturer, Department of Speech Science, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any University for any other Diploma or Degree.

MYSORE

MAY 1993 Reg. No. M 9107

A C K N O W L E D G E M E N T

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CHAPTER 1 : INTRODUCTION

Speech is a serially ordered stream of complex articulatory movements which is smooth, temporally integrated, and coarticulated (Lashley 1951). This stream of sounds consists of phrases, words, and even smaller units such as morphemes, syllable & phonemes.

The basic sound unit phoneme was believed to have invariant acoustic cues and hence each speech sound has got specific acoustic properties in speech. Later, with the development of and assistance of spectographs, and synthesizers the concept of invariance of sound units was put in question. This lack of invariance (Liberman, Cooper and Studdert - kennedy 1967) and lack of segmentation (Fant 1962) faced during synthesis seeked for different explanations. This lack of invariance is because of the simultaneous movements of the articulators used to produce different neighbouring segments, a phenomenon known as "coarticulation".

The term coarticulation was contributed in the 1930's by Menzerath, who argued against the view that successive speech sounds consist of discrete steady states and transitions (invariant cues). Coarticulation may be defined as a speech production processs in which the articulatory characteristics,features or properties of one sound are modified by another sound. Coarticulatory effects thus eliminate extreme articulatory movements, & hence are linked with ease of articulation.

Evidence for the presence, different types, and extent of coarticulation have come from physiological, acoustical and perceptual studies. Since speech sounds are usually preceded and followed by other sounds, coarticulation occurs in both directions. The influence of the articulatory characteristics of one sound on the production of a preceding sound is known as R to L or anticipatory or forward coarticulation & when the influence is on the preceding sound then it is named L to R, backward or carryover coarticulation.

Studies reveal differences in the strengths of the directional influence in childern's speech. Some studies in adults show R to L to be greater than L to R (Soli, 1981 Gelfer et al 1981 & Amerman & Daniloff 1977). On the other hand, there are studies in which L to R was shown to have greater influence (Ohde & Sharf 1975 , Bell- Berti 1978).Yet some findings in adults reveal that there was a difference between these two types (Bladen & Nolan 1977, Liberman, Cooper & Gerstman 1954 and Ohde & Sharf 1977).

Another important issue is the extent or magnitude of these two types of coarticulation in childern (Studdert - Kennedy 1985). It has been proposed that higher levels of structures, such as syllables, words, or phrases may be involved in coarticulation, but these coaricülatory effects are not equal among all phonemes. Certain sounds, both in terms of consonants and vowels always produce greater amount of coarticulation than others, and certain sounds produce coarticulatory effects depending on the context. These contextual - coarticulatory inconsistencies are also shown in the studies of childern with articulatory disorders and during various stages of language acquisition by childern. Although some remediation occurs naturally as a result of coarticulatory - contextual facilitation, application of this is not made use of effeciently as there are no research evidences.

Since most individuals with articulatory disordes are childern we need to have research evidences from normal childern. Unfortunately very few studies have been carried out with regard to developmental aspects of coarticulatory ability in childern.

Disimoni (1974), Abelin et al (1980), Repp (1986), McGowan & Nittrouer (1988) have conducted acoustical and physiological studies on coarticulation in childern and the results show decreased variability with increasing age, reflecting a general development of speech skills. In general, speech of childern show less precise productions and more variable spech motor patterns (Sereno & Liberman 1987, sereno et al 1987). On this basis, one might expect that the speech of childern will also show more variable effects on coarticulation compared with adult speech. In this context, the present study is planned.

An attempt has been made to delinate the development of coarticulatory abilities by examining the patterns of articulatory organization as evidenced in the acoustic patterns of young children's speech. Specifically, the coaticulatory abilities will be studied by measuring the acoustic parameters :

1) Transition duration of F2 (m.sec)
2) Terminal frequency of F2 (Hz)
3) Extent of transition of F2 (Hz) and
4) Speed of transition of F2 (Hz/m.sec).

CHAPTER 2 : REVIEW OF LITERATURE

Physiologically, coarticulation refers to the integration of neural commands to the speech musculature timing and movements patterns of articulators and aerodynamic forces, which results in the spreading of FEATURES from one sound to another. Acoustically, it refers to the influence due to modifications by certain contextual features on the spectral and temporal characteristics of speech sounds, and perceptually it refers to the listening effects of the contextual cues for consonants and vowels, in the perception of sounds (Sharf & Ohde 1981).

Studies that were carried out on adults's speech were primarily to see the amount and extent of coarticualtion (ohde & sharf 1975, Fle ge 1988, Repp & Mann 1981).

Coarticulation is found to vary in its effects for different consonants differently. Nasal sounds, round vowels /u/, fricatives were found to have their effect well before the preceding sounds (Soli 1981, Amerman & Daniloff 1977, Bell-Berti et al 1982). However, all sounds coarticulated with each other to some extent in order to maintain the fluency in continuous speech.

Explanations for the presence of coarticulation in speech have two views :

1) Coarticulation as a central phenomemon i.e transitional properties are planned like that of any phonemes (Whalen 1990, Gelfer & Harris 1981, Hertz 1991) and

2) Coarticulation as a peripheral phenomenon i.e difference in transition duration, formant frequencies are due to the mechano - inertial properties and sluggishness of the

articulators & not due to any planning (Sharf & Ohde 1981).

Studies on coarticulation in child's speech are summarised in table 1.

	AUTHOR'S NAME	MATERIAL/SUBJECTS	TASK	RESULTS AND DISCUSSION
1.	Disimoni, 1974	CVC token was taken where c= |p,b,s,z| & v = |i,a| . 30 subjects of 3, 6 & 9 year old children were taken. Carrier phrase "Say the word - again" was used.	Vowel duration was measured when it was preceded by voiced and voiceless plosives and sibilants in English.	Vowel duration remained constant for voiceless sounds for all children but not so with voice sounds where it increased as age increased. This indicates that observed durational vowel effects due to consonant environment deverlop over a long period of time. Although durational differences begins at the age of 3, the most rapid rates of change occur between 3 to 6 years, statistical significance was found only after 6 6 years of age.
2.	Abelin, Landberg & Persson, 1980.	6 children (2 - 1 0 years old, 3 - 8 years old and 1 - 7 years old) of Swedish speaking population were taken and compared with one adult speaker. Both meaningful work and phrases and non-meaning ful words taken. V1 Cn V2 token was recorded where V1 = |a, i| unrouonded vowels V2 = all rounded Swedish vowels Cn = non labial consonants.	Measurements were: (1) the duration of the intervocalic consonants. (2) The duration from the onset of the labial EMG activiy to the acoustic onset of V2.	Results are: (1) Consonant duration was much greater in children indicating less coarticulation than adults. (2) Second parameter also showed significant difference between two age groups indicating less coarticulation in children. Results indicated that the anticipatory labial coarticulation was not due to peripheral constraints rather there was gradual development with age in the direction of the adult model. This was so gradual that no precise cross-over age was predictable. Producing non-sense words children exhibited more adult like results due to stretching of

				their capacity more toward the adult behaviour. The absence of reduced emg activity when V2 preceded by stressed unrounded V1 was absent in children which again indicates that the anticipatory coarticulation was related to learning or maturation.
3.	Turnbaugh, Hoffman, & Daniloff, 1985.	3 subjects each in 3 age groups. 3,5 and adult speaker group was taken. CVC tokens were prepared C = |b, d, g| V = |i,u|	F2 transitions in CVC syllables were measured.	Results show that labial and velar stops showed relatively strong lingua-labial coarticulation shifts than alveolar |d|. They also found, no difference between age groups. Therefore, control of CV linguo-labial Coarticulation was more adult like at this stage of development than either formant frequencies or segmental durations. This indicated that neuromotor antecedents of stop-vowel production may be developed earlier than either temporal control or other kinds of more language-specific coarticulation.
4.	Repp, 1986.	2 Children of 4.8 and 9.5 years and an adult speaker was taken. They were asked to produce "sea", "sand", "soup" "tea", "ten" and "tooth" five times each in a carrier phrase "I like the ____".	<u>Parameters measured were:</u> 1. Noise spectra 2. Release burst spectra 3. Second formant frequency 4. VOT The influence of vocalic context on various temporal	<u>Findings:-</u> 1. The Young child's speech showed a systematic lowering of |s| noise |t| release burst spectra before |u| as compared to |i| & |æ|. 2. The old child's speech showed an orderly relationship of the f2 in |æ| to the transconsonatal vowels. 3. Both children tend to produce

<table>
<tr><td></td><td></td><td></td><td>and spectral properties of preceding segments were studied</td><td>longer noises and VOT as well as higher F2 at constriction noise effect before |i| than before |u| and |e|.

F2 in younger children showed no observable coarticulation but in older children there was systematic decrease in F2 as the vowel in the following syllable changed from |i| to |æ| to |u| as well as higehr F2 preceding |t| than |s|.

A lowered noise spectrum for |s| before rounded vowel reflects an effect of anticipatory lip rounding due to tongue body position changes are prominent in children than adults. This means that fricative-vowel coarticulation decline with age unlike for other sounds.

It is concluded that speech is produced segmentally first and gradually become syllabified and different sounds follow different developmental patterns.</td></tr>
<tr><td>5.</td><td>Sereno and Liberman, 1987.</td><td>Front & back vowels |i|& |a| in velar stop (|k|) consonant context were taken. 3 tokens of each CV syllables (Ki & Ka) were produced by five adults and 14 child speakers (2 years 8 months to 7 years).</td><td>Subjected to spectral analysis.

Lingual coarticulation was examined in which a velar stop consonant was influenced by the</td><td>Children's speech found to be more variable than adults. For adults predominant peak for |k| preceding |a| was seen in low frequency region which was same for children in both vowel contexts. This indicates different age levels for the acquisition of individual motor process for speech and hence development process involves gradual acquisition and fine tuning of</td></tr>
</table>

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<tr><td></td><td></td><td></td><td>subsequent
vocalic environment.</td><td>speech motor patterns.</td></tr>
<tr><td>6.</td><td>Sereno et al,
1987.</td><td>CV syllables (Si, Su, ti, tu, di & du) tokens were given to 4 adults & 8 children of 3-7 year old.</td><td>Parameters were:
1. Fricative noise spectra of fricative sounds.
2. Aspiration noise and burst duration for stop consonants.
a. F2 region and
b. prominent frequency regions were the points where both of the above values were measured.</td><td>No difference between 2 groups eventhough more variability was observed in children. Among consonants |t| yield better coarticulatory effect than |s| &|d| in both children and adult for F2 region. Difference between consonants indicate that coarticulation was in par with phonological development i.e. first voiceless consonent then voiced, and then fricatives etc. This indicates that the realization of the motor programmes that underline anticipatory coarticulation was innate, and was a developmental process involving gradual acquisition and fine tuning of speech motor patterns.</td></tr>
<tr><td>7.</td><td>FLEGE, 1988.</td><td>CVC syllables were taken where
V = |I,i,u|, C = |d_d|,
|n_d|, |n_n|, |d n|.
Three groups of 10 subjects each were formed.
I group - 5 years old
II group - 10 years old
III group - adults.</td><td>Nasalance was calculated</td><td>Results indicated no difference between age groups but found both types of coarticulation from |d-n| and |n-d| context. He found only 7% of vowels were nasalized in (|d-n|) context and approximately 33% of vowels were nasalized in the (|n-d|) context. Hence, 'look ahed' model was ruled out and he concluded that the anticipatory coarticulation was because of "natural speech process" and the later one was because of inertial properties of the speech production.</td></tr>
</table>

8.	McGowan & Nittrouer, 1988.	2 children each at 3,4,5 & 7 year old age groups and 4 adults were studied. Tokens were |SiSi|, | i i| , | u u | | SuSu|. Samples were acoustically analyzed.	1. F2 measurements 2. Relative F2 amplitude 3. Formant frequency bandwidth	Results were:- In first parameter, the F2 fricative preceding |i| was higher in frequency than fricative F2 preceding |u| and was found in all speakers, but considerably more in children. This difference was due to lip rounding and tongue positioning in expectation to the vowels. 2. Relative F2 amplitude was higher for children than adults and it was higher for | | than |s| due to better transmission of back cavity sound to the atmosphere in | | in children and more sub-glottal pressure in children.
9.	Nittrouer, Studdert-Kennedy & McGowan, 1989.	Eight adults and four groups of 8 children each at ages 3, 4, 5 and 7 years were taken Tokens were |SiSi|, | i i| | u u| |SuSu|. Samples were acoustically analyzed.	Parameters measured were 1. Centroid, which is the first moment of the spectral distribution that is the mean frequency weighed by amplitude 2. Second formant frequencies	Results indicated two different independent developmental trends: 1. 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. Hence, at each point in language development the child has the phonology that its perceptuomotor skills permit and assure. These result support the hypothesis that children initially organise their speech gestures over a domain at least the size of the syllable and only gradually differentiates the syllable into patterns of gestures more closely aligned with its perceived segmental components.

Table :1 Studies on Coarticulation in children.

The results of these studies indicate a developmental trend of coarticulation in children. Though these sources of data are useful thera is pressing need to study the developmental trend of coarticulation in children across various age groups. In this context, the present study aimed at tracking the development of coarticulation in Kannada speaking normal children in the age range of 4 to 7 years.

CHAPTER 3 : METHODOLOGY

SUBJECTS : Six Kannada speaking normal childern one each in the age range of 4 to 4.6, 4.6 to 5, 5 to 5.6, 5.6 to 6, 6 to 6.6 and 6.6 to 7 years participated in this study. Table 2 shows the subject details.

Age Range	Number of Subjects	Sex
4 to 4.6	1	F
4.6 to 5	1	M
5 to 5.6	1	M
5.6 to 6	1	M
6 to 6.6	1	F
6.6 to 7	1	F

Table 2 : Subject details of the study.

All these childern had no known speech and hearing disorders as tested by the experimenter. All the childern were from middle socio-economic groups and had normal speech development. No attempt was made to classify them according to sex. All of them were exposed to kannada at home and surrondings and were attending schools.

MATERIAL: The consonants /p/ (bilabial voiceless plosive), /t/ (dental voiceless plosive), and /k/ (velar voiceless plosive), and vowels /a/ (low back), /i/ (high front) and /u/ (high back) were selected for the present study. A total of 17 meaningful kannada words consisting of the key plosives in the initial and medial positions were selected. Two sets were made of these words which consisted of words as shown in table 3.

SET ONE CONSTANT FINAL SYLLABLE	SET TWO CONSTANT INITIAL SYLLABLE
1. pata	1. pa:ta
2. kata	2. pa:ka
3. t̲ata	3. pa:pa
4. puta	3. pa:ka
5. kuta	5. pa:t̲u̲
6. t̲uti	6. pa:pu
7. pi:ta	7. pa:t̲i̲
8. t̲i:ta	8. pa:pi
9. ki:ta	

Table 3: Showing the details of speech materials of the study

In the first set containing nine words, (t̤a) was the constant final syllable except for (tuti) & the initial CV strings varied & had different vowel combinations. In the second set containing eight words, /pa/ was the constant initial syllable and the final CV strings varied. The plosives in the final CV were combined with the three vowels. In the first set, the final syllable (t̤a) was kept constant to avoid any influence fron the final syllables onto the initial syllable (which is under observation) and vice versa. The 17 words were randomized to make five sets and thus a total of 85 words formed the material.

METHOD : Childern were tested individually. They were seated comfortably and were instructed to repeat the word after the experimenter into a microphone (cordiode unidirectional) kept at a distance of 10 cms from the mouth. Initially a conversation was made with the child and a trial was given prior to the recording.

Repetitions of all the 85 words were recorded onto a spool at a high speed (7 l/2"/min) by using the internal tape recorder of the sound spectograph VII 700. Bar type wide-band expanded (0-4kHZ) spectrograms were obtained for all the words. Thus, a total of 510 spectrograms were obtained. All the spectrograms were analyzed for four parameters as follows:

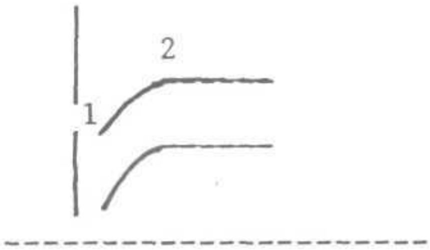
I) Transition duration (TD) of F2 (m.secs) : T.D of the first vowel in the first set and the second vowel in the second set was measured. TD was measured as the time duration between the onset of the second formant for the vowel to the steady state of the same. In case of short vowels, where the steady state was not visible, T.D was measured from the onset of the F2 frequency for the vowel to the end of the vowel.

II) Terminal frequency of F2 stops (TF in Hz) : Terminal frequency of the initial stop in the first set and the second stop in the second set was measured. TF2 was measured as the frequency of F2 at the onset of the vowel following the stop.

III) Speed of transition of F2 (HZ/m. Sec) : Speed of transition of F2 is the rate at which the F2 moves and was calculated by the following formulae.

F2 at the steady state - F2 at the onset of the voweel (Hz)/ Transition duration (m.sec).

IV) Extent of transition of F2 (Hz) : It is the frequency difference between the terminal frequency of F2 and the onset of the steady state vowel (end of the transition). Extent of transition of F2 of the first vowel in the first set & the second vowel in the second set was measured.



Transition duration = 1 to 2

Terminal Frequency = 1

Extent of transition = Frequency at 2 - 1

Speed of transition = $\frac{\text{Frequency at 2-1}}{\text{TD}}$

Fig 1 : Spectogram depicting various measurements.

The data was tabulated and averaged across subjects for each consonant in initial and medial positions. Repeated measures of ANOVA with Fisher's LSD weve performed to findout the significant diference and interactions of age, consonant and vowel.

CHAPTER 4 : RESULTS AND DISCUSSION

1) TRANSITION DURATION (TD) : Figures 2 to 10 depict the average transition duration and the interaction of vowels and consonants. In general, there was no definite increasing or decreasing trend observed. Significant difference was noticed between the age groups. However, no significant differences were observed between the T.D of initial and the medial positions. Vowel /a/ had greater effect on the consonants in that the transition duration from the consonant to the vowel /a/ was the longest followed by that from the consonant to /i/ & /u/. T.D from all consonants to all the vowels increased from the age of 4 years to 6 years and from /k/ & /p/ to vowels /a/ & /u/ in the age range of 5.6 to 7 years.

The consonants did not seem to have similar interactions in both the positions. While in the initial position T.D from /p/ to vowel was the longest followed by /k/ & /t̲/ in the medial position, T.D from /t̲/ to vowel was the longest followed by /p/ and /k/. Also, it was noticed that the T.D from consonants /t̲/ & /k/ increased from 4 years to 6 years. The significance of difference between the T.D of various age groups with vowel & consonant interactions are in table 4.

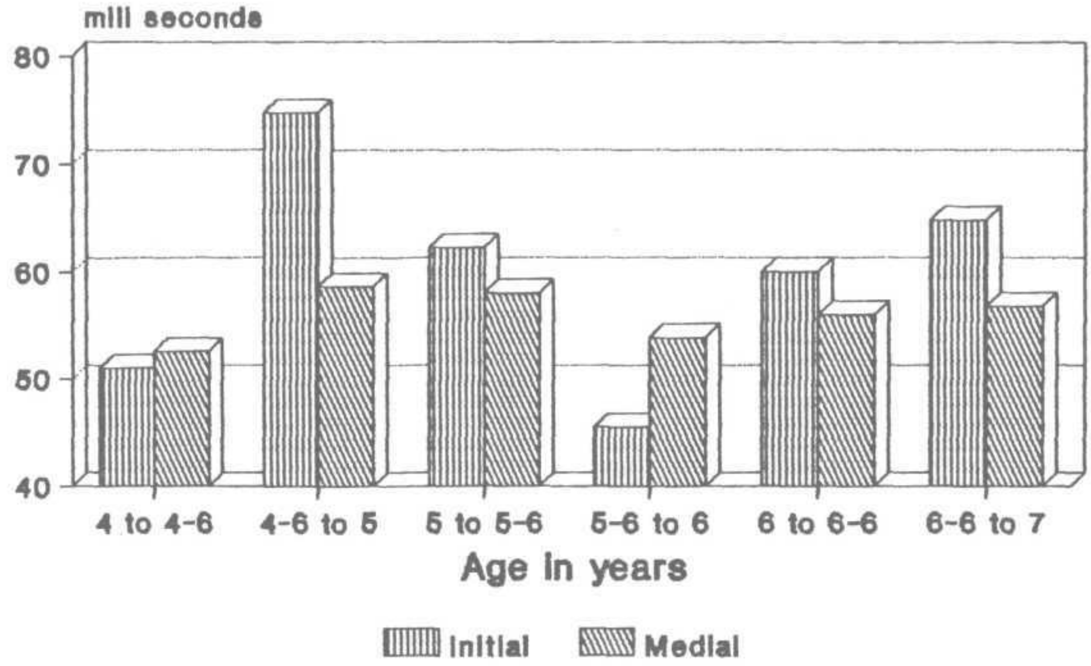


Fig.2: Mean transition duration in various groups.

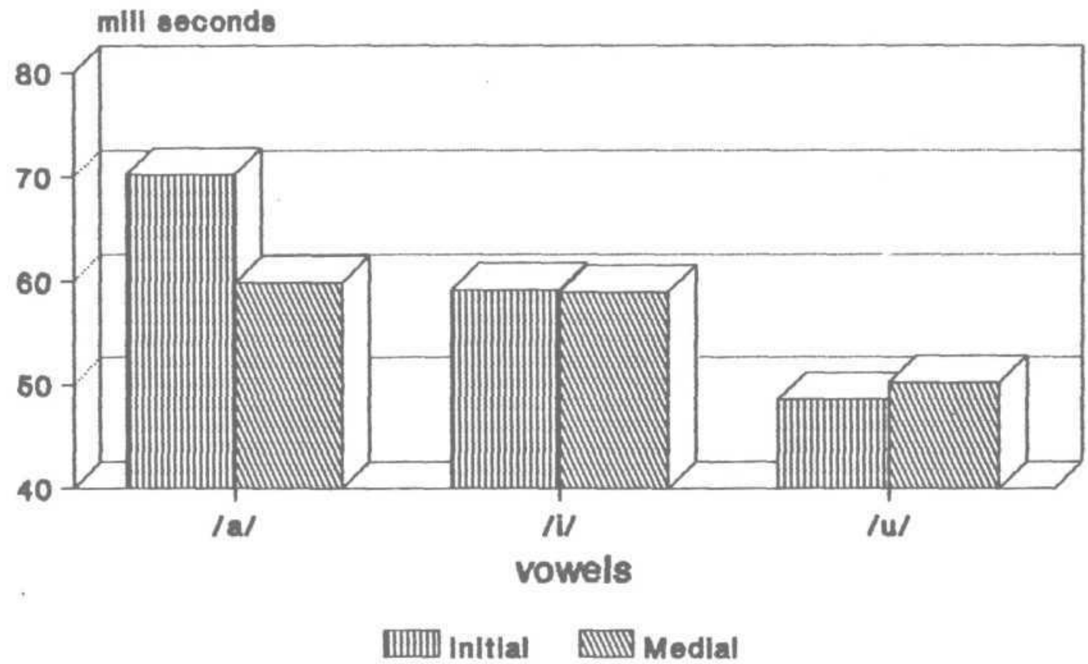


Fig.3 : Mean transition duration of various vowels.

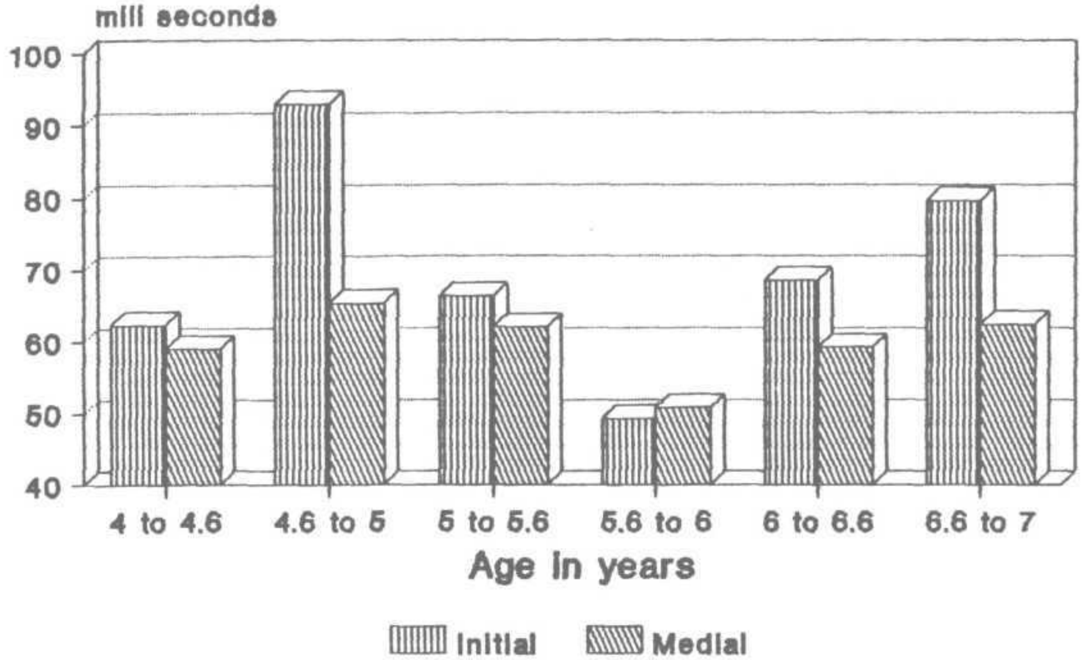


Fig.4 : Mean transition duration of consonant preceeding vowel /a/.

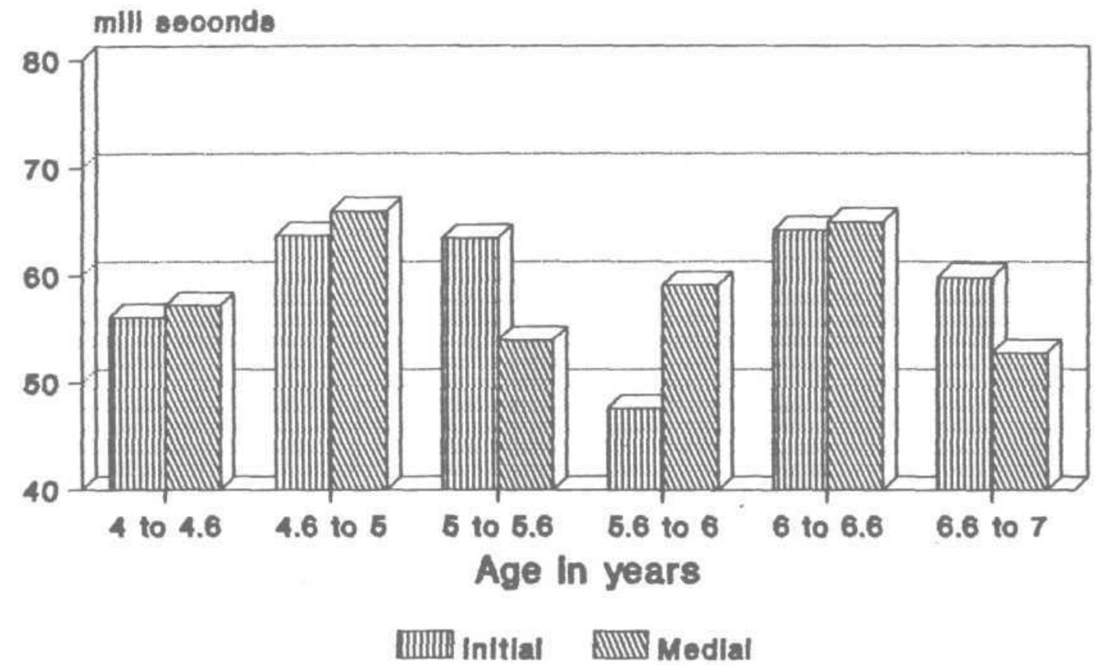


Fig.5 : Mean transition duration of consonants preceeding vowel /i/.

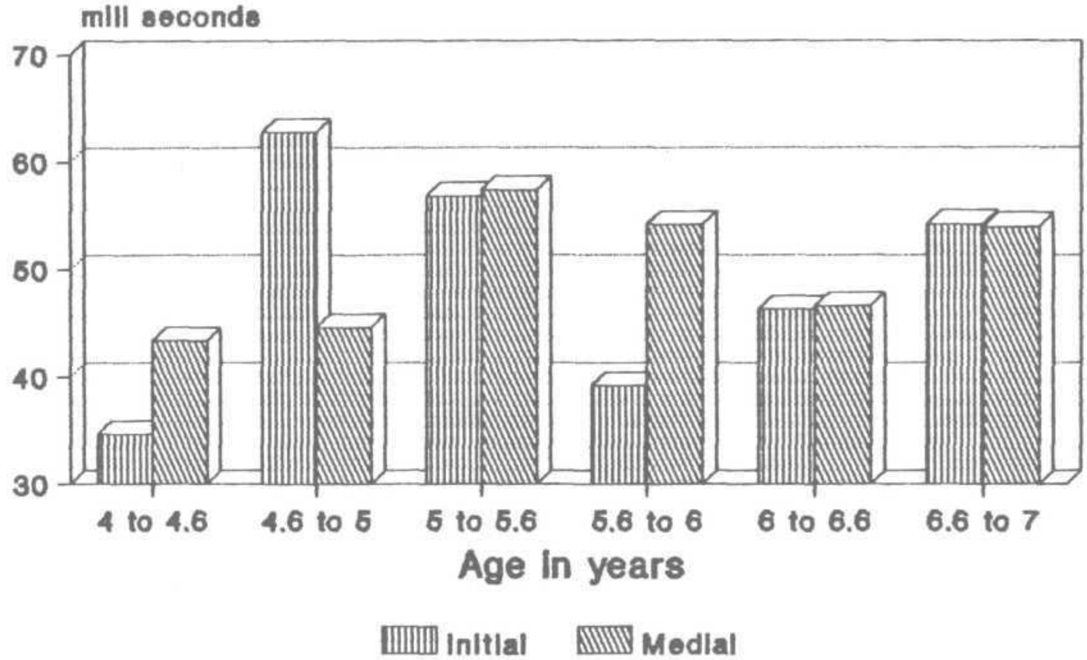


Fig.6 : Mean transition duration of consonant preceeding vowel /u/.

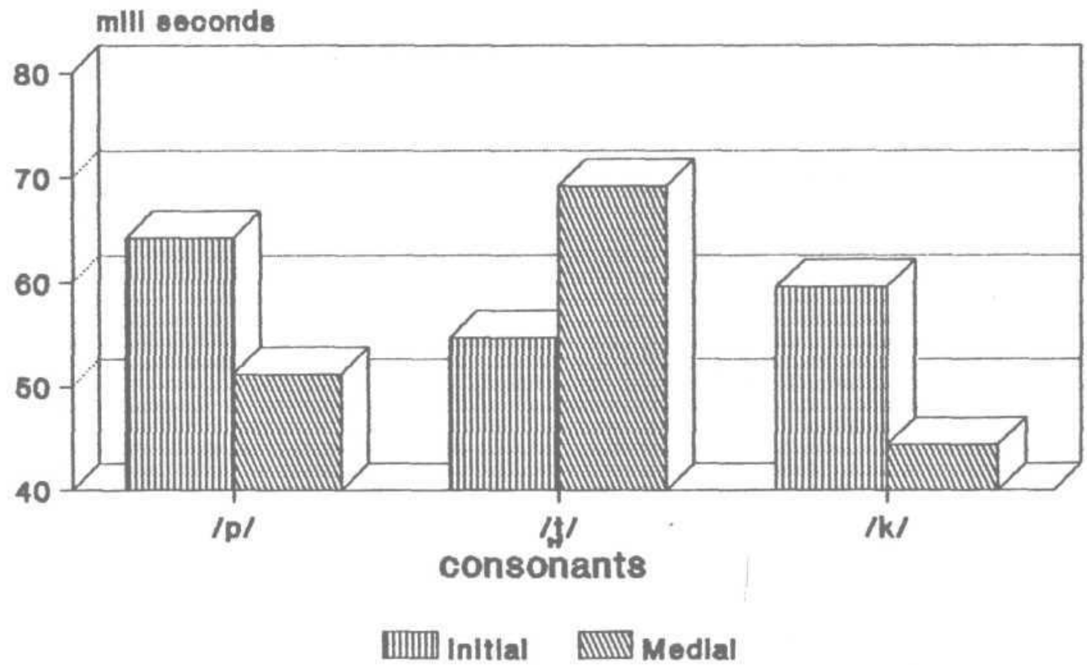
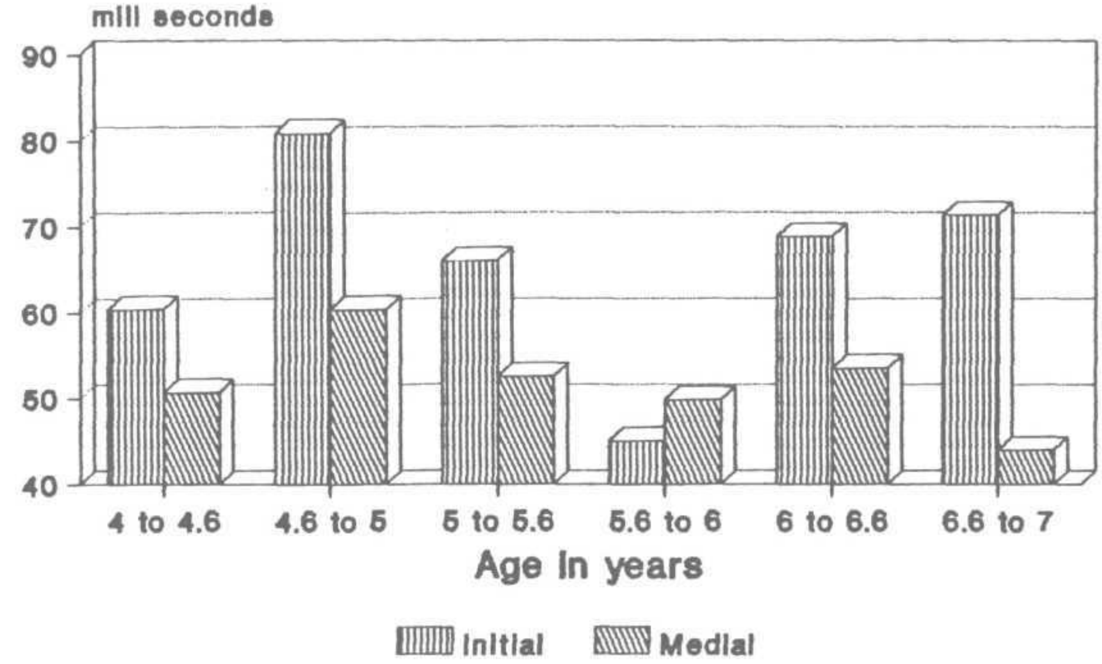


Fig.7 : Mean transition duration of various consonants.



Fig, 8 : Mean transition of consonant /p/.

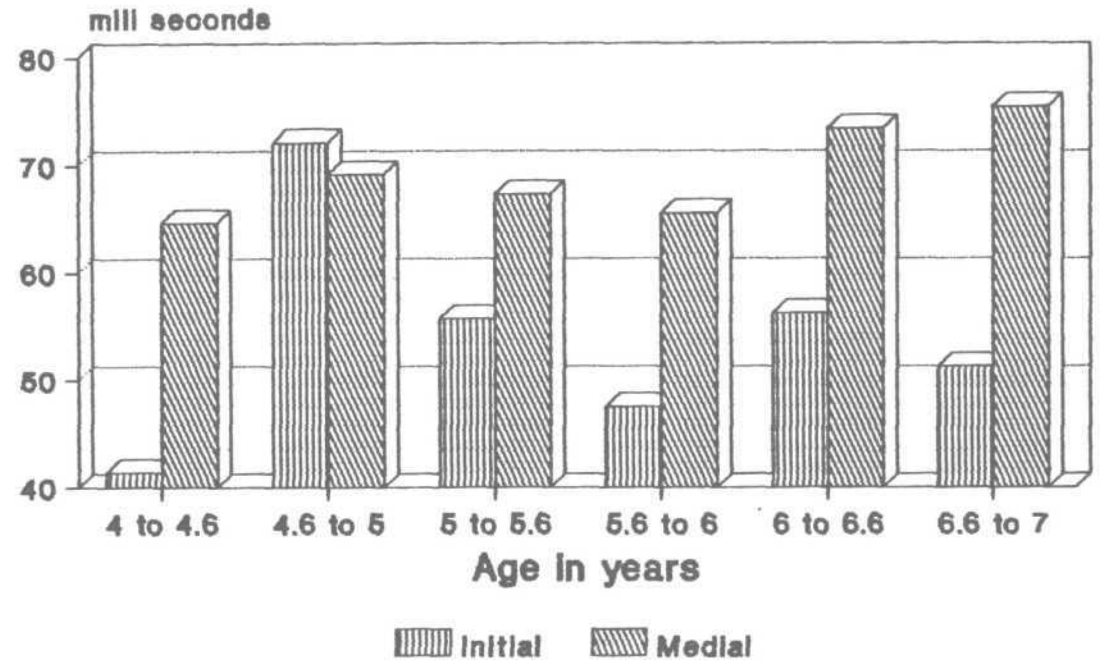


Fig.9 : Mean transition duration of consonant /ṭ/.

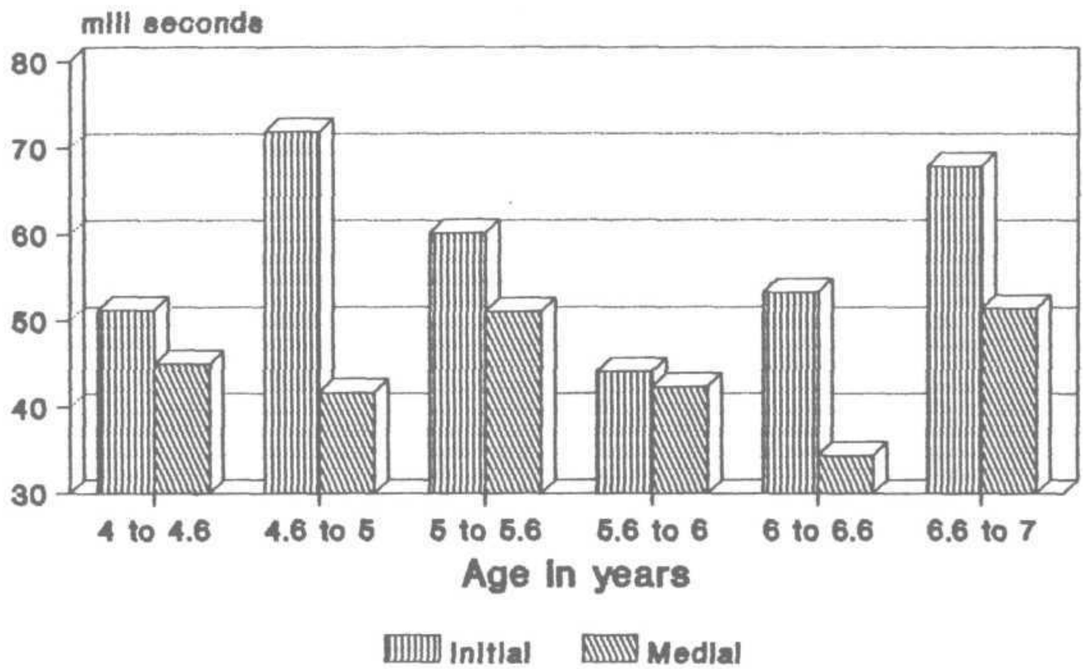


Fig.10 : Mean transition duration of consonant /k/.

		INITIAL 1 2 3 4 5 6	MEDIAL 1 2 3 4 5 6
VOWELS /a/	1 2 3 4 5 6	. S . . . S S . S S S . . S . . . . . S . . S . . S . S . . . . . S . .	. . . .
	ALL AGE GROUPS	NS	NS
/u/	1 2 3 4 5 6	. S S . . S S . . S . . S . . . . . . S . . . . S	NS
CONSONANTS /p/	1 2 3 4 5 6	. . . . S . . . . . S . . . S S . S S . . . S . . . . . S . .	NS
/t/	1 2 3 4 5 6	. S . . . . S . S S S S . S . . . . . S . . . . S	NS
/k/	1 2 3 4 5 6	. S . . . S S . . S S . . . . S . . . S . S . . . . S . . S . .	NS
POSITION	1 2 3 4 5 6	. S S . . S S . S S S . S S . S . . . S S . S S . S . S . . S . . S . .	NS

Table 4. Significance of difference between age groups FOR TRANSITION DURATION

* NS - No significant difference.

II) TERMINAL FREQUENCY OF F2 (TF2) :Figure 11-19 show the average TF2 and the vowel and consonant interactions. The TF2 varied largely and no definite trend was noticed. However, significant differences between the age groups were present. The TF2 in the two positions were not significantly different. Vowel /i/ exerted greater effect on TF2 in that the TF2 of consonants preceeding Vowel /i/ were the highest followed by /a/ & /u/. TF2 decreased from 4 to 5.6 years for the consonants preceeding vowels /a/ & /u/ in the initial position.

The TF2 of /t/ was the highest followed by /k/ & /p/ in the initial position and /p/ & /k/ in the medial position. The significance of difference between the TF2 of various age groups with interactions of vowels & consonants are in table 5.

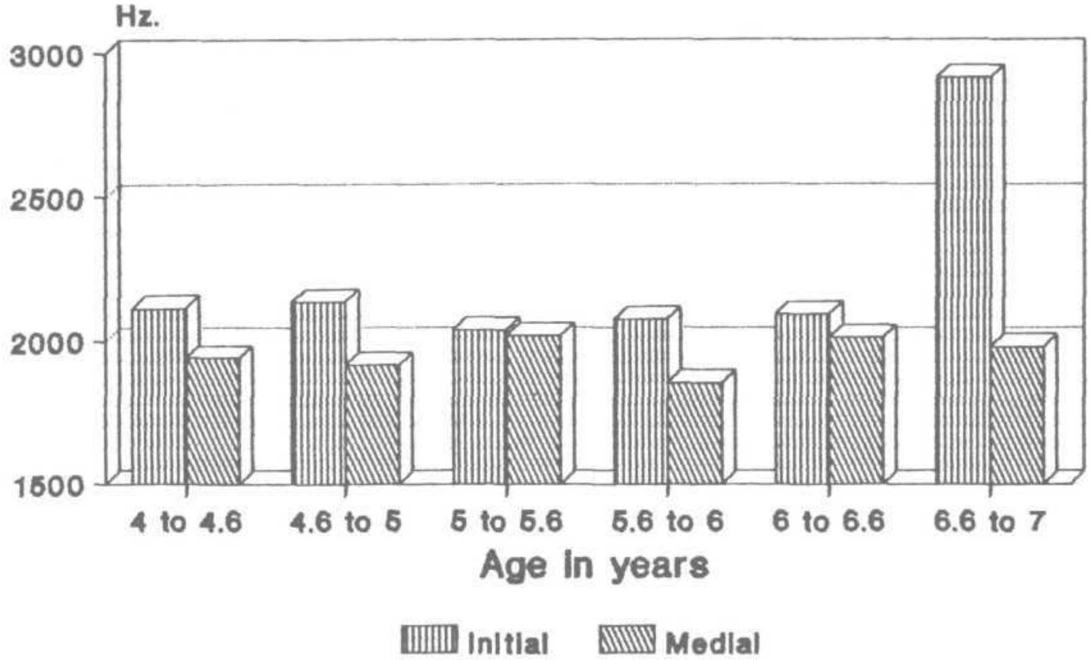


Fig.11 : Mean terminal frequency of various groups.

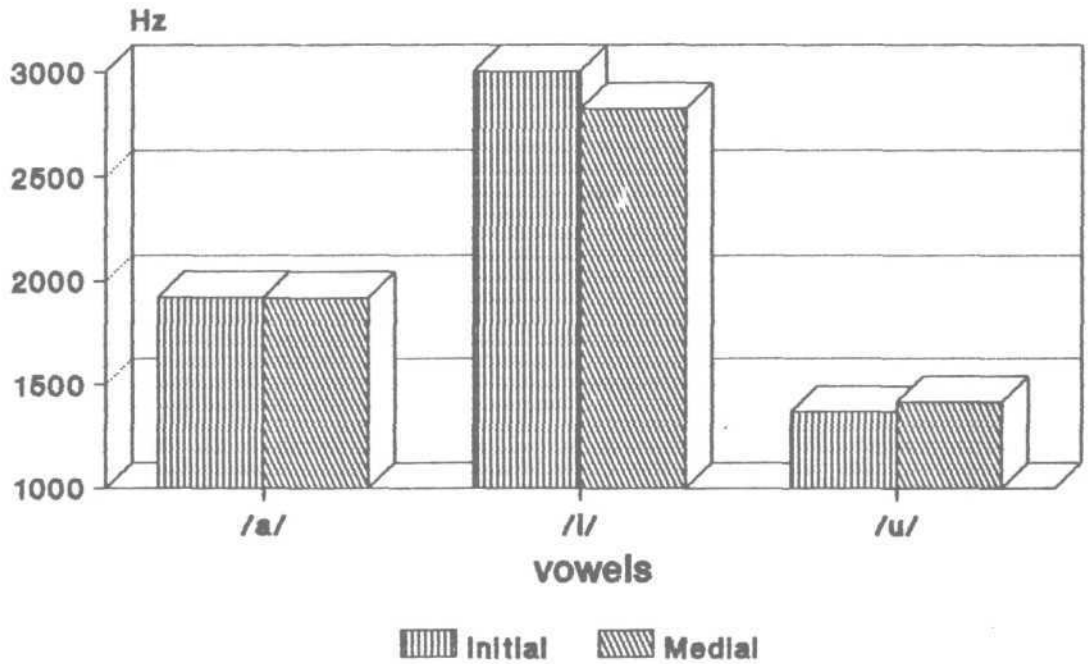


Fig.12 : Mean terminal frequency of various vowels.

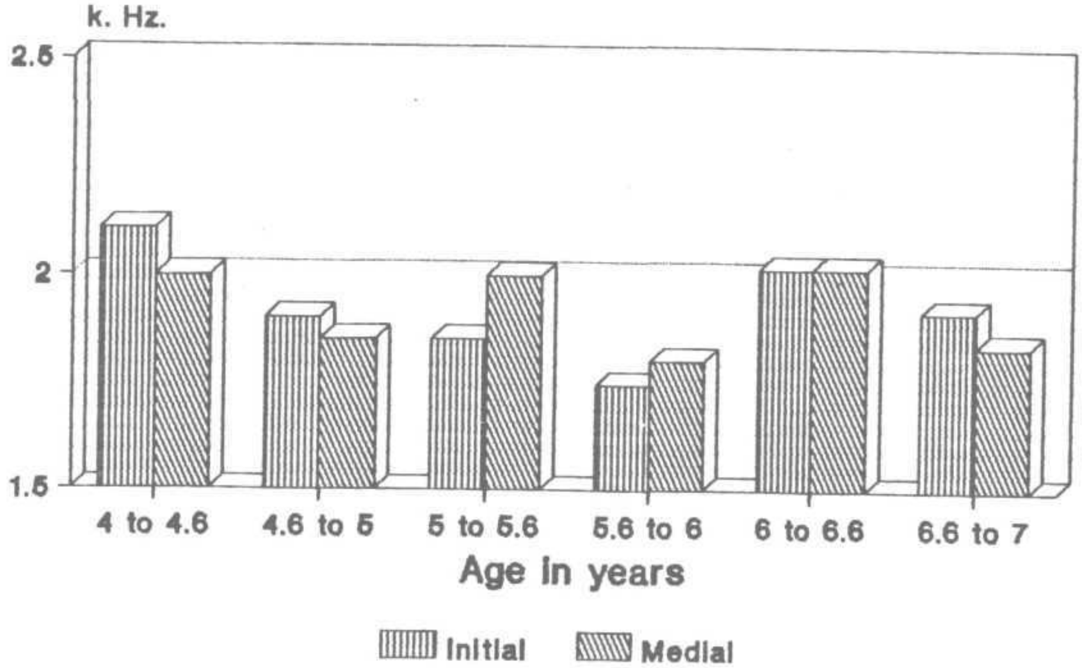


Fig.13 : Mean terminal frequency of consonant preceeding vowel /a/.

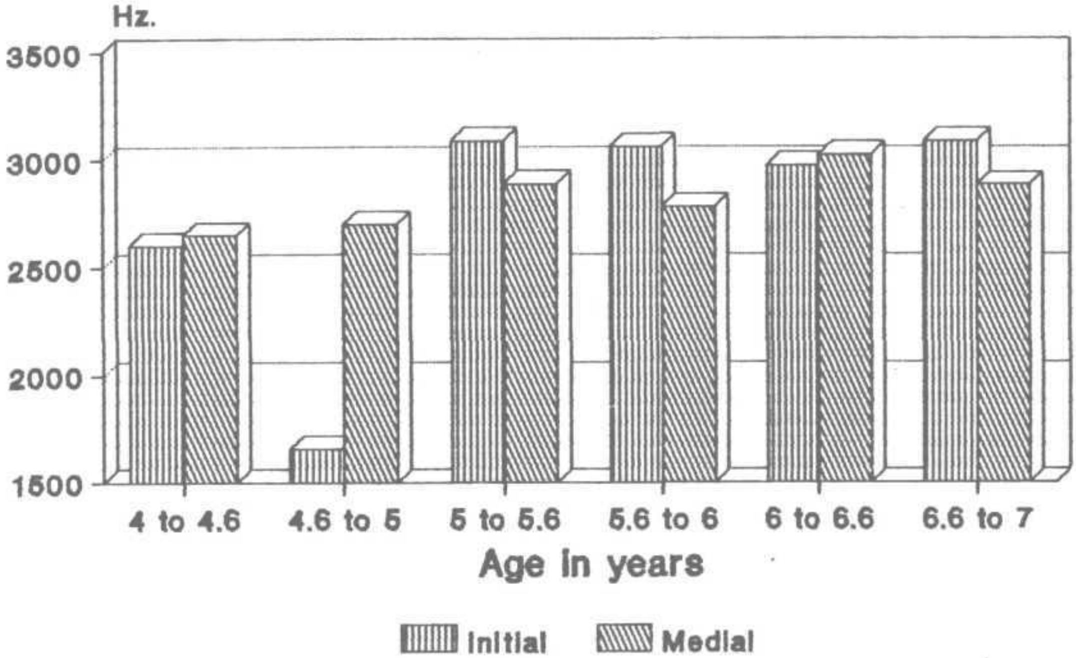
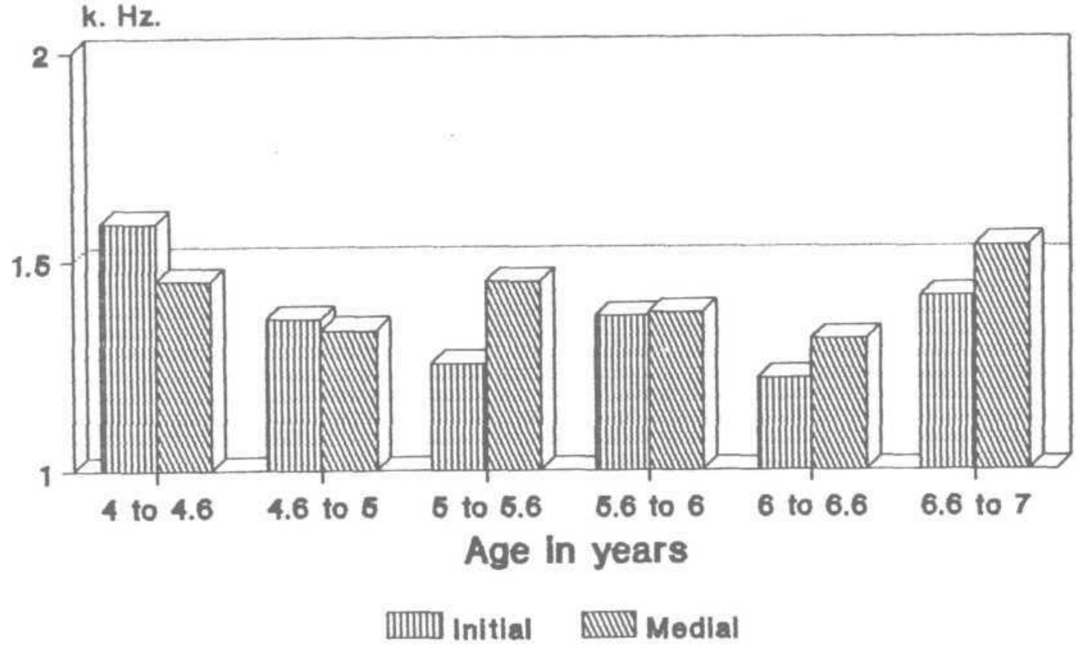
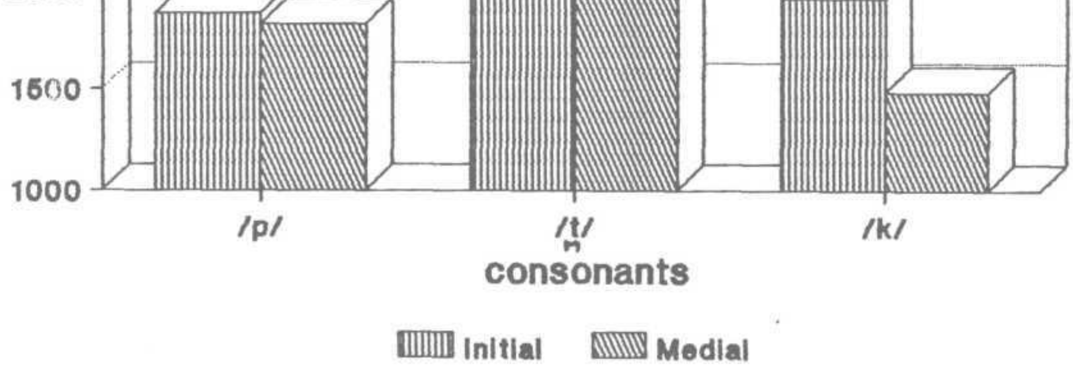


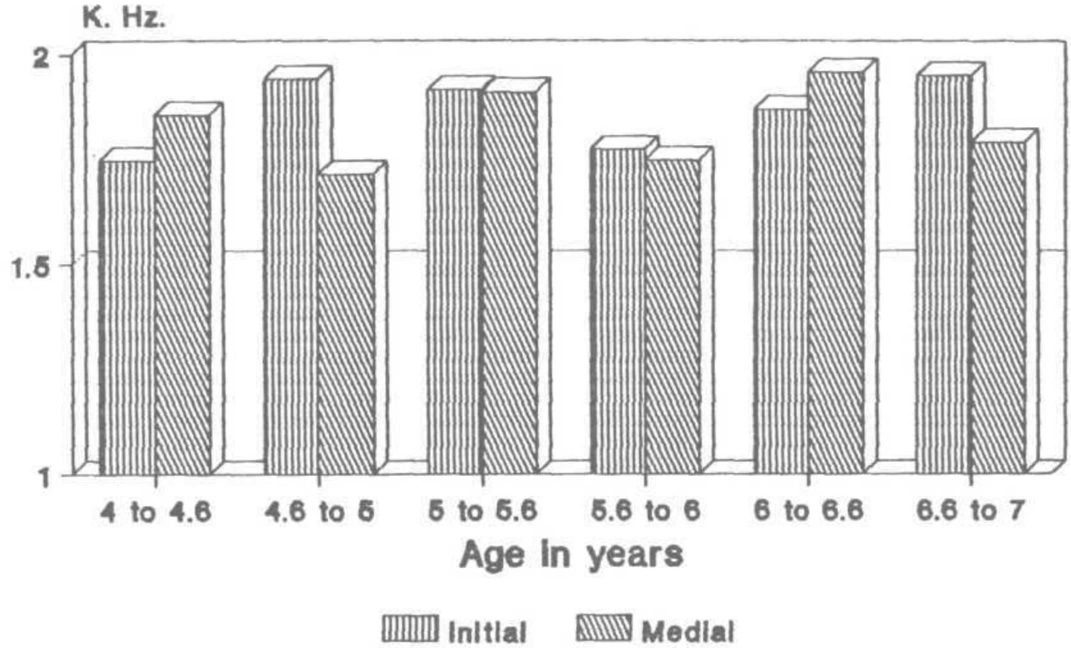
Fig. 14 : Mean terminal frequency of consonant preceeding vowel /i/.



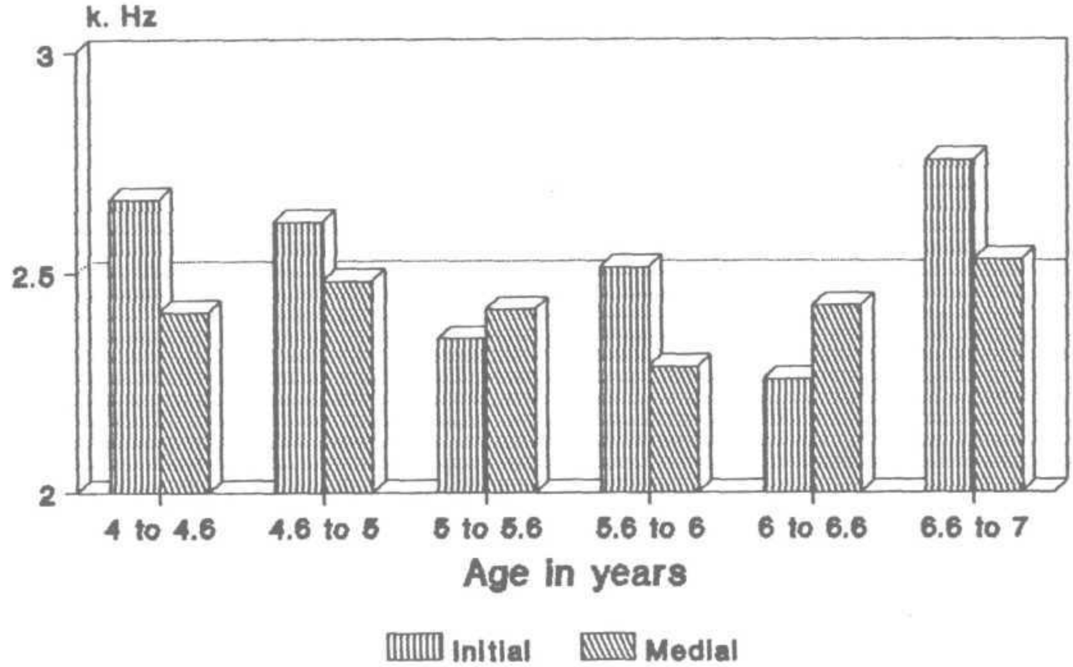
Fig,15 : Mean terminal frequency of consonant preceeding vowel /u/.



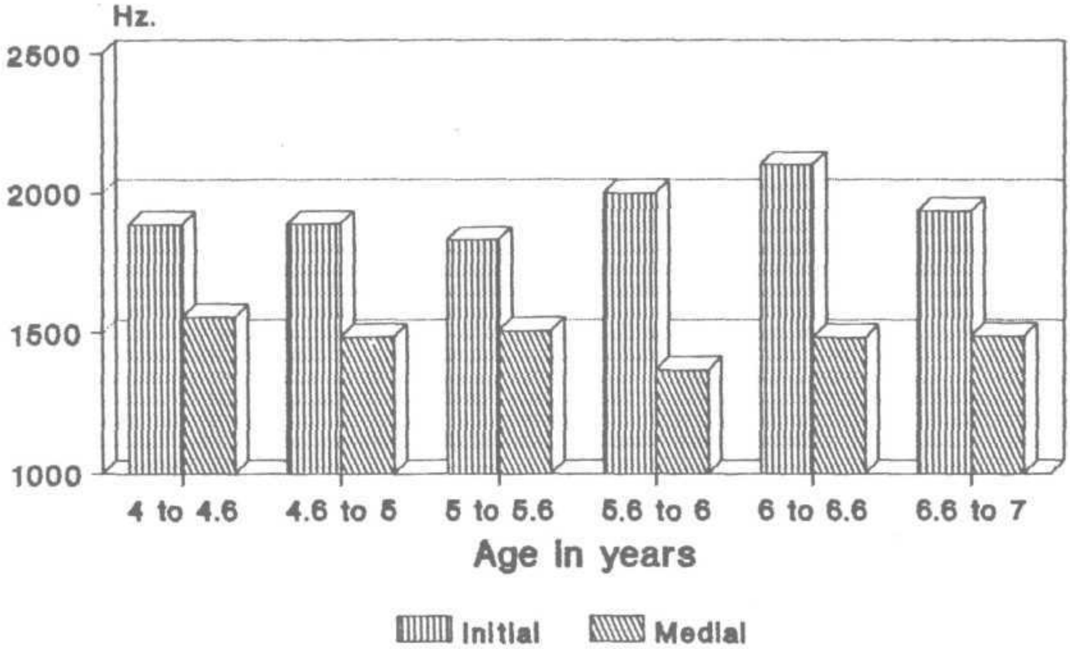
Fig,16 : Mean terminal frequency of various consonants.



Fig, 17 : Mean terminal frequency of consonant /p/.



Fig, 18 : Mean terminal frequency of consonant /t/.



Fig,19 : Mean terminal frequency of consonant /k/.

		INITIAL 1 2 3 4 5 6	MEDIAL 1 2 3 4 5 6
VOWELS /a/, /u/	ALL AGE GROUPS	NS	NS
/i/	1 2 3 4 5 6	. S S S S S S . S S S S S S . . . . S S . . . . S S . . . . S S	NS
POSITIONS	ALL AGE GROUPS	NS	NS
CONSONANTS /p/, /t/ & /k/	ALL AGE GROUPS	NS	NS

Table 5. Significance of difference between age groups for TERMINAL FREQUENCY (f2)

III)EXTENT OF TRANSITION OF F2 (ETF2) :Figures 20 to 28 depict the average values of ETF2 for various vowel and consonant interactions. No definite developmental trend was noticed. However, significant differences existed between both the age groups and positions ETF2 was greater when the vowel was /a/ in the initial position and /i/ in the medial position. It seemed that the ETF2 decreased from 5.6 years for the vowels /a/, /i/ in the initial position and for the vowels /i/ & /u/ in the medial position from 4.6 to 5.6 years.

While the bilabial plosives /p/ had greater extent of transition of F2 followed by /k/ & /t/ in the initial positions, the dental plosive /t/ had greater ETF2 in the medial position followed by /p/ & /k/. Table 6 shows the significant difference between the ETF2 of various age groups with vowel and consonant interactions.

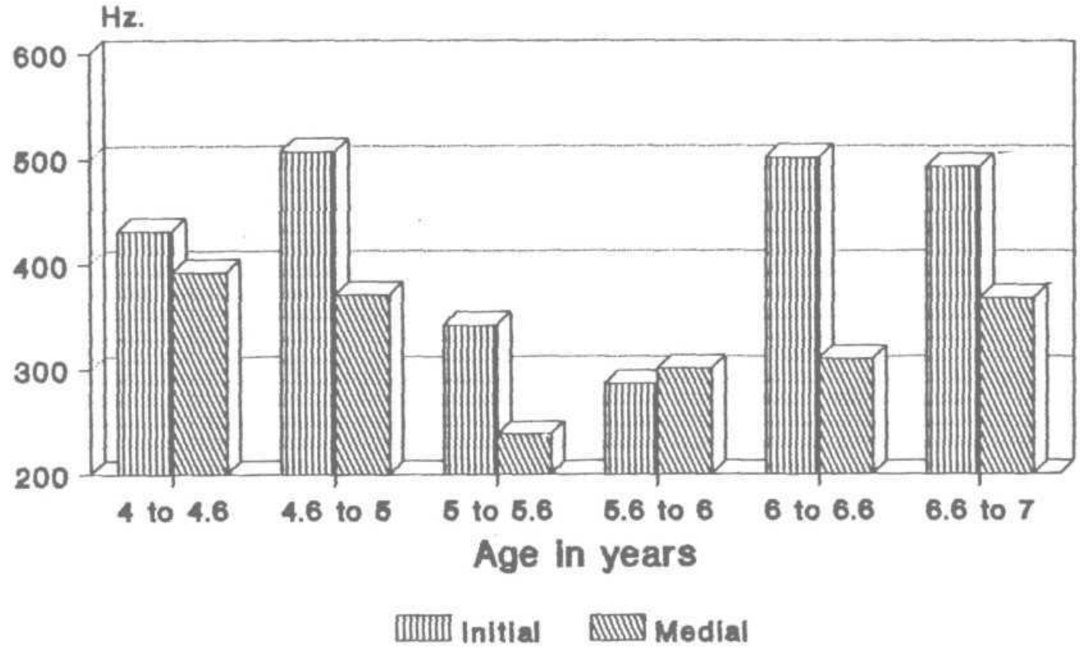


Fig. 20 : Mean extent of transition of various groups.

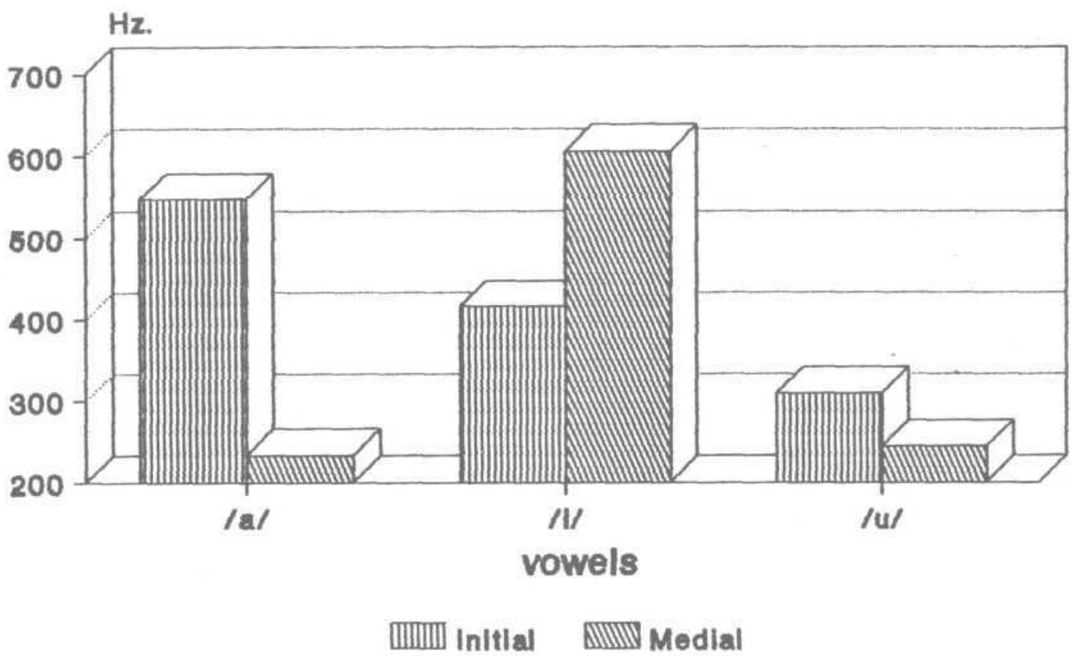
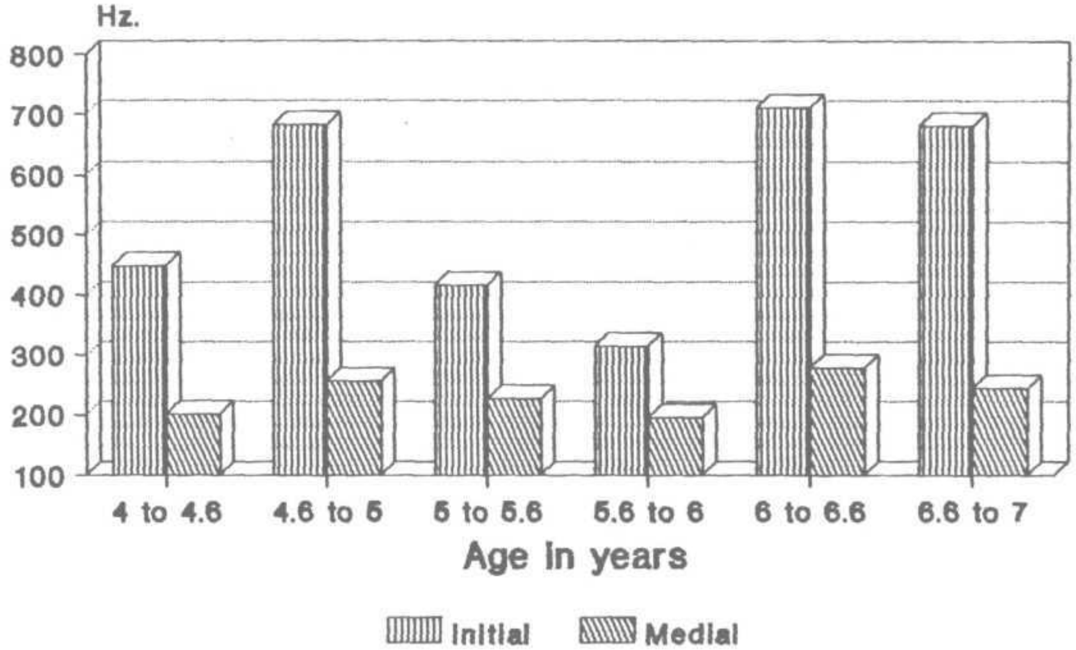
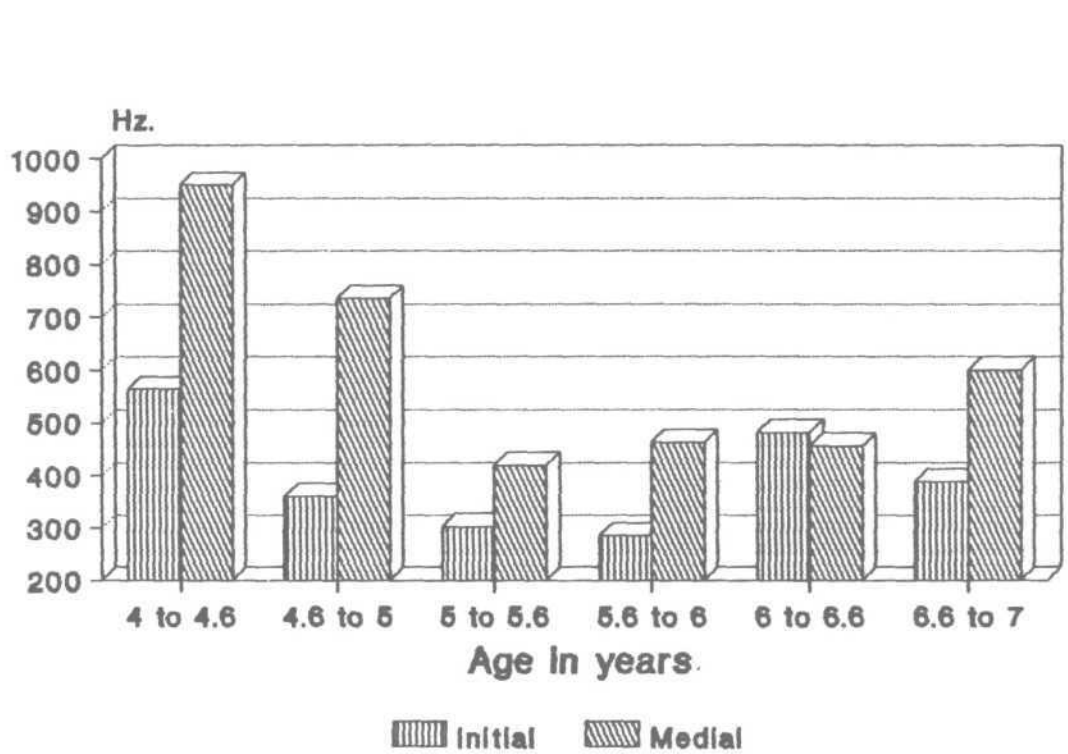


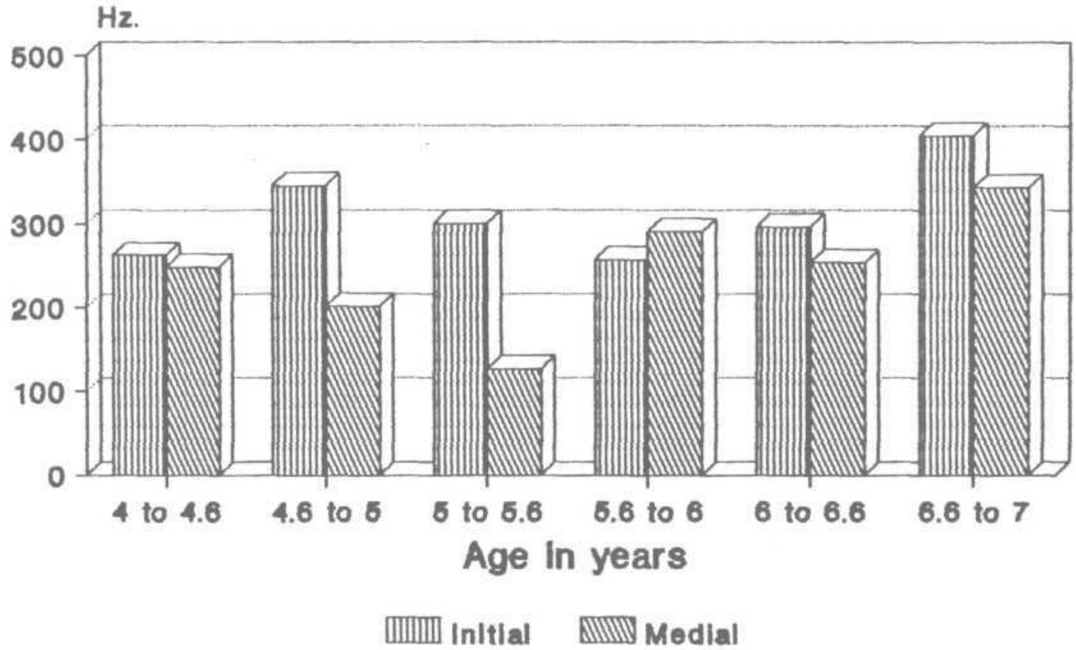
Fig. 21 : Mean extent of transition of various vowels.



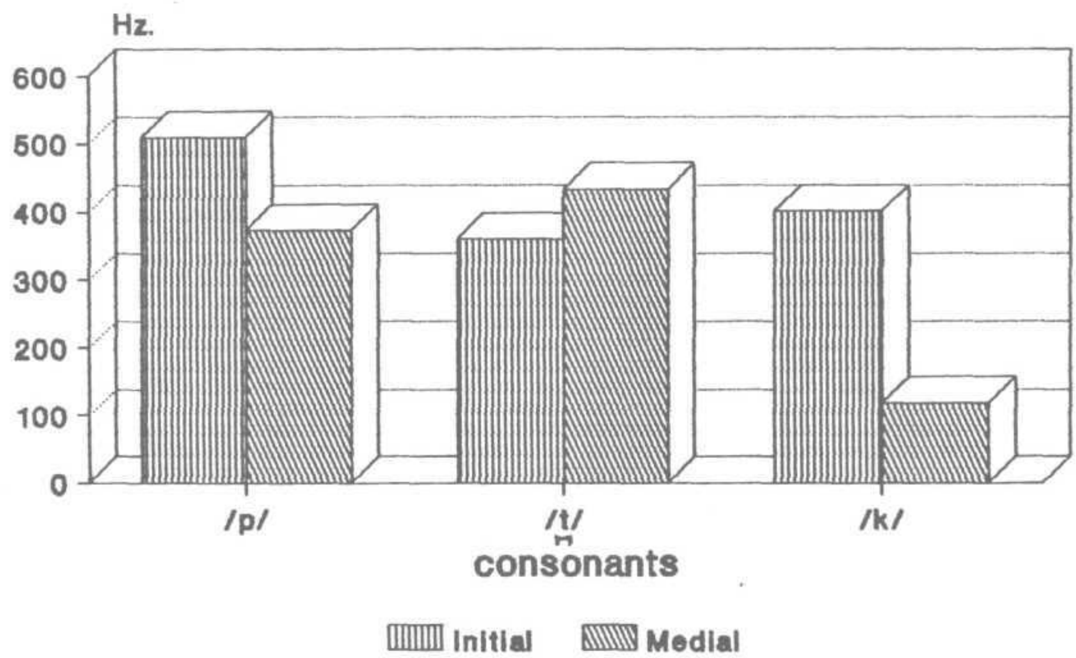
Fig, 22: Mean extent of transition of consonant preceeding vowel /a/.



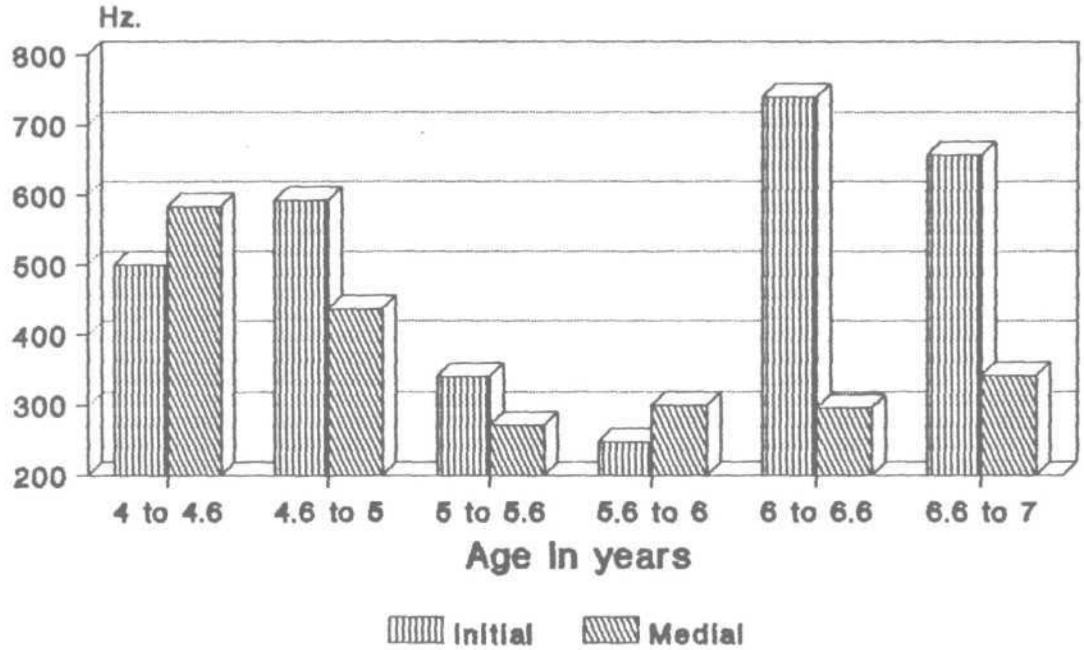
Fig, 23 : Mean extent of transition of consonant preceeding vowel /i/.



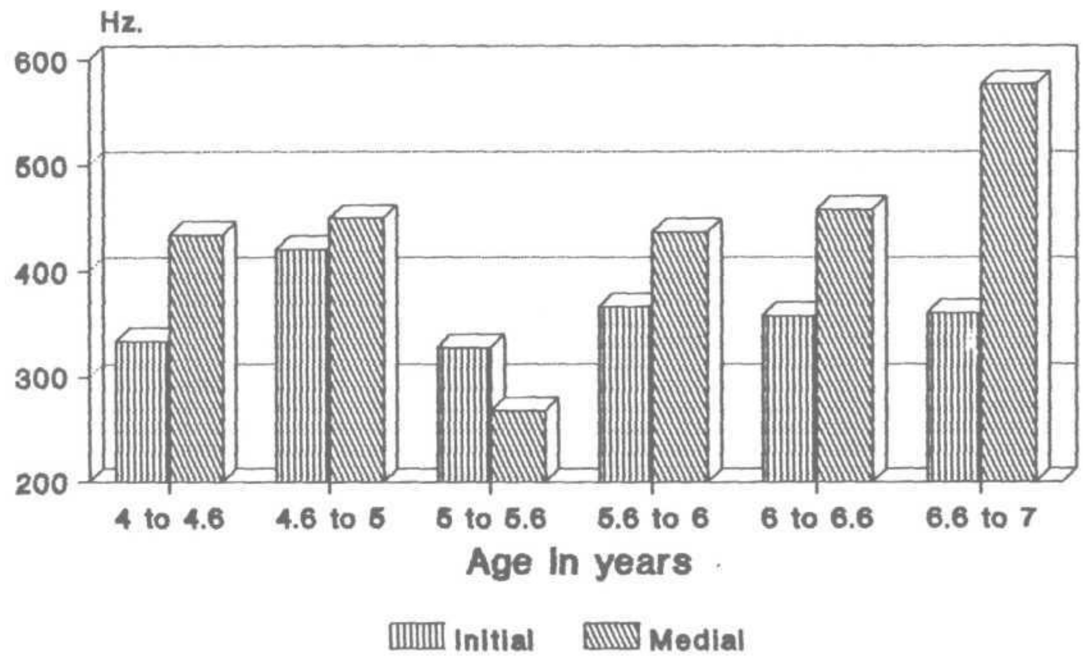
Fig, 24 : Mean extent of transition of consonant preceeding vowel /u/.



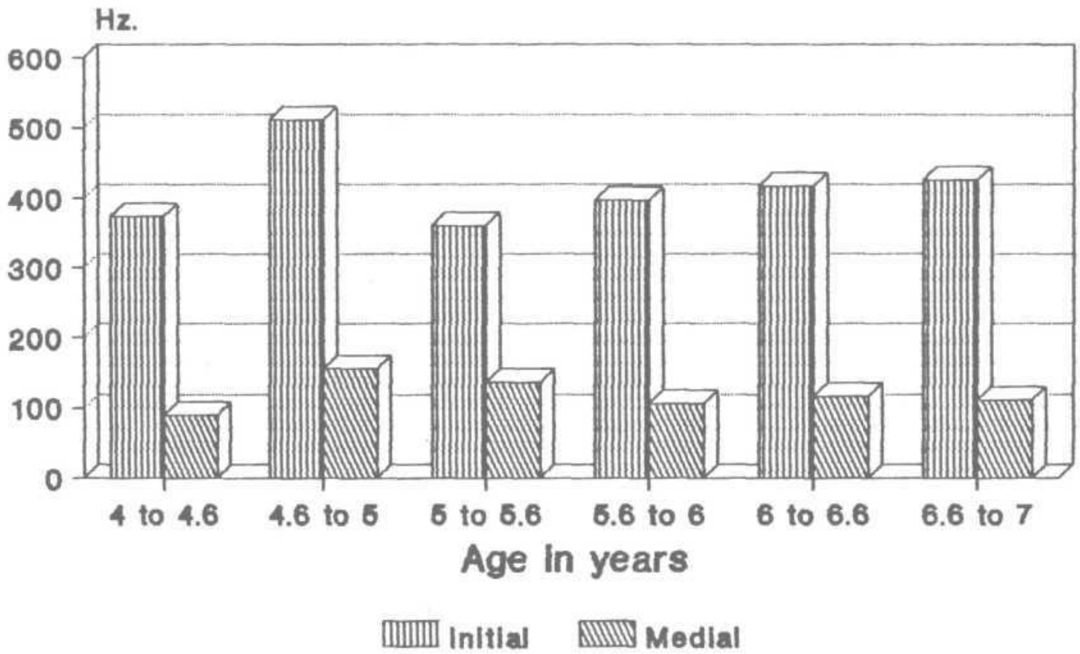
Fig, 25 : Mean extent of transition of various consonants.



Fig, 26 : Mean extent of transition of consonant /p/.



Fig, 27 : Mean extent of transition of consonant /t/.



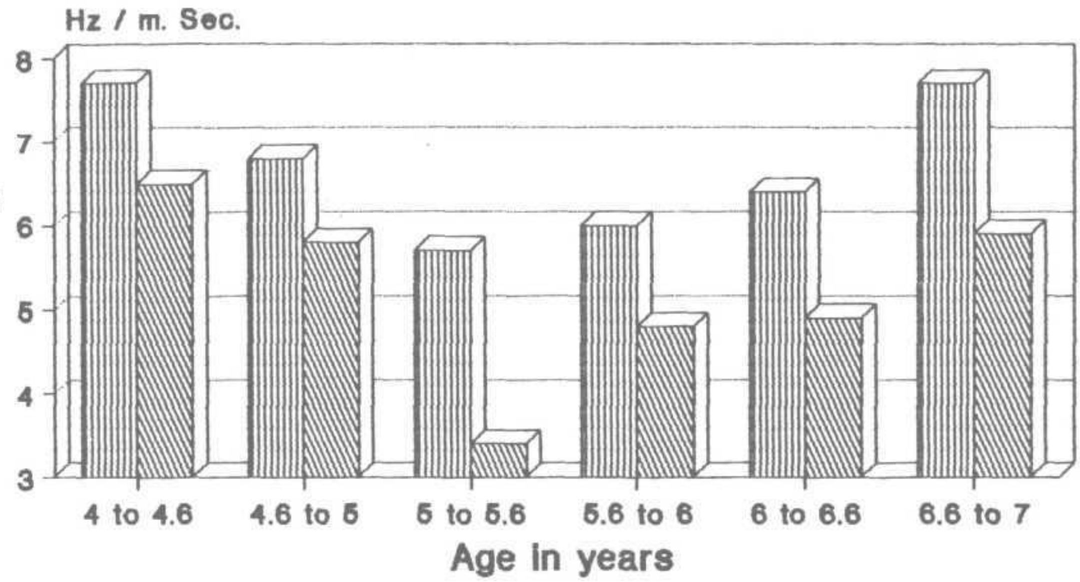
Fig, 28 : Mean extent of transition of consonant /k/.

		INITIAL						MEDIAL					
		1	2	3	4	5	6	1	2	3	4	5	6
VOWELS													
/a/	1	.	S	.	.	S	S	NS					
	2	S	.	S	S	.	.						
	3	.	S	.	.	S	S						
	4	.	S	.	.	S	S						
	5	S	.	S	S	.	.						
	6	S	.	S	S	.	.						
/i/	1	.	S	S	S	.	.	.	.	S	S	S	S
	2	S	.	.	.	.	.	.	.	S	.	.	.
	3	S	.	.	.	.	.	S	S	.	.	.	.
	4	S	.	.	.	S	.	S	.	.	.	.	.
	5	.	.	.	.	S	.	S	.	.	.	.	.
	6	.	.	.	.	.	.	S	.	.	.	.	.
/u/	ALL AGE GROUPS	NS						NS					
CONSONENTS													
/P/	1	.	.	S	S	.	.	NS					
	2	.	.	S	S	.	.						
	3	S	S	.	.	S	S						
	4	S	S	.	.	S	S						
	5	.	.	S	S	.	.						
	6	.	.	S	S	.	.						
/t/	1	NS						.	.	.	.	.	.
	2							.	.	S	.	.	.
	3							.	S	.	.	S	S
	4							.	.	.	.	.	.
	5							.	.	S	.	.	.
	6							.	.	S	.	.	.
/k/	ALL AGE GROUPS	NS						NS					
POSITIONS	1	.	.	.	S	.	.	NS					
	2	.	.	S	S	.	.						
	3	.	S	.	.	S	S						
	4	S	S	.	.	S	S						
	5	.	.	S	S	.	.						
	6	.	.	S	S	.	.						

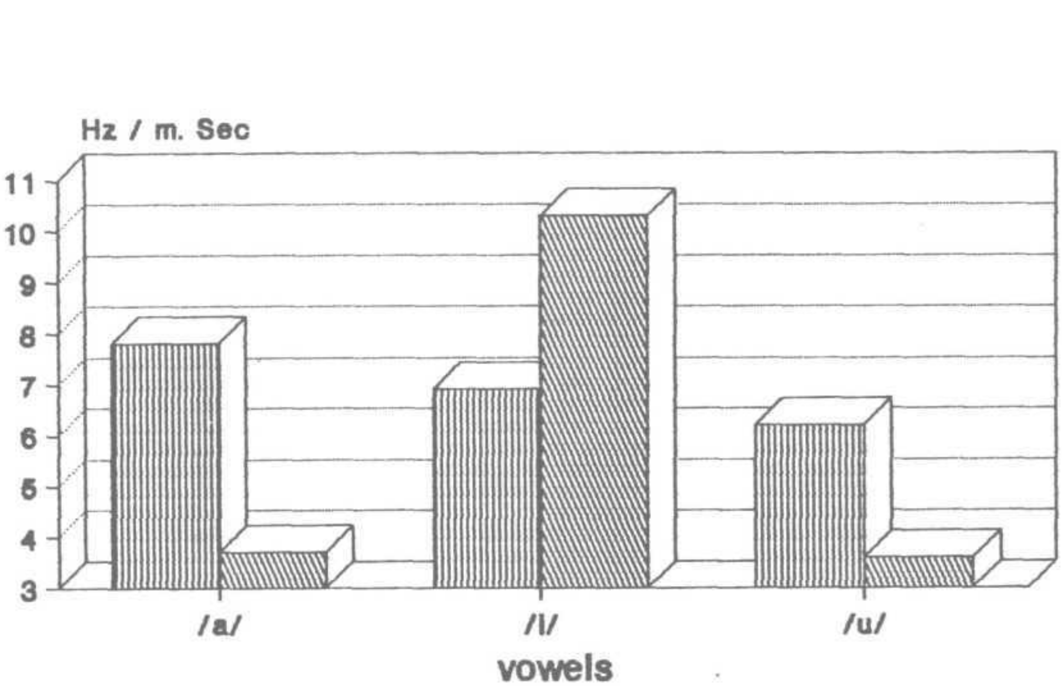
Table 6. Significance of difference between age groups for EXTENT OF TRANSITION (f2)

IV)SPEED OF TRANSITION OF F2 (STF2) : Figures 28-36 indicate the mean STF2 for various vowels and consonants. It appeared that the STF2 increased linearly from 5.6 to 7 years in both the positions. No significant difference were found between the initial and the medial position.

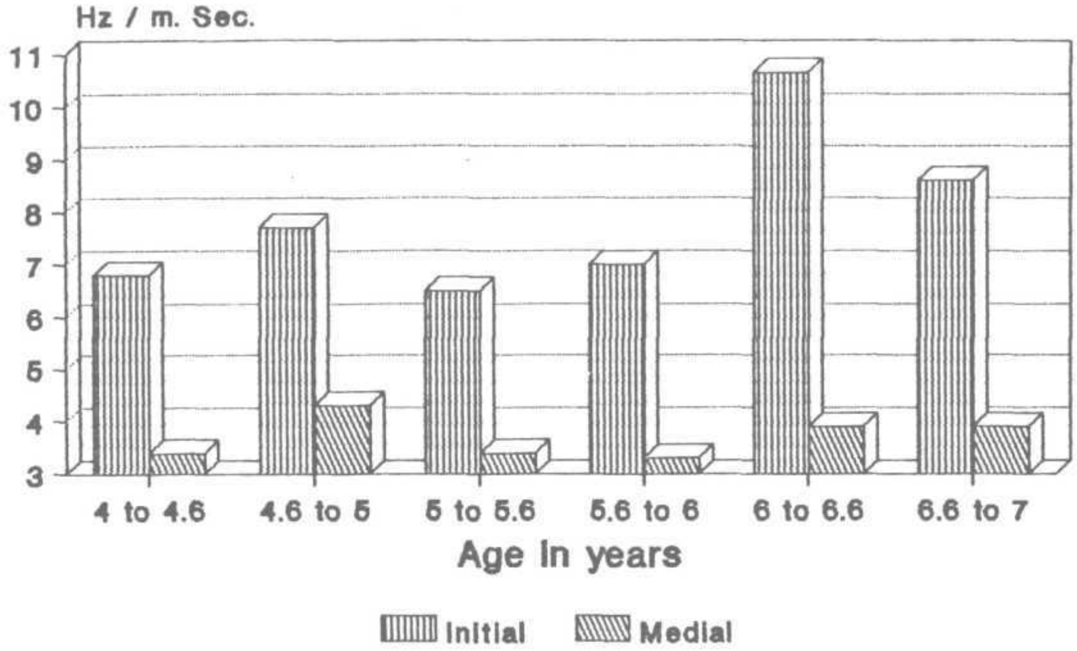
In the initial position STF2 was greater for /a/ followed by /i/ & /u/. However, in the medial position STF2 was greatest for /i/ followed by /a/ and /u/. STF2 of the vowels /i/ & /u/ decreased from 4 to 5.6 years in the initial position. Also, STF2 was greatest for /p/ followed by /t̲/ & /k/. The STF2 of /t̲/ & /p/ decreased from 4 years to 5.6 years in both the positions. The significant difference between the STF2 for various age groups are in table 7.



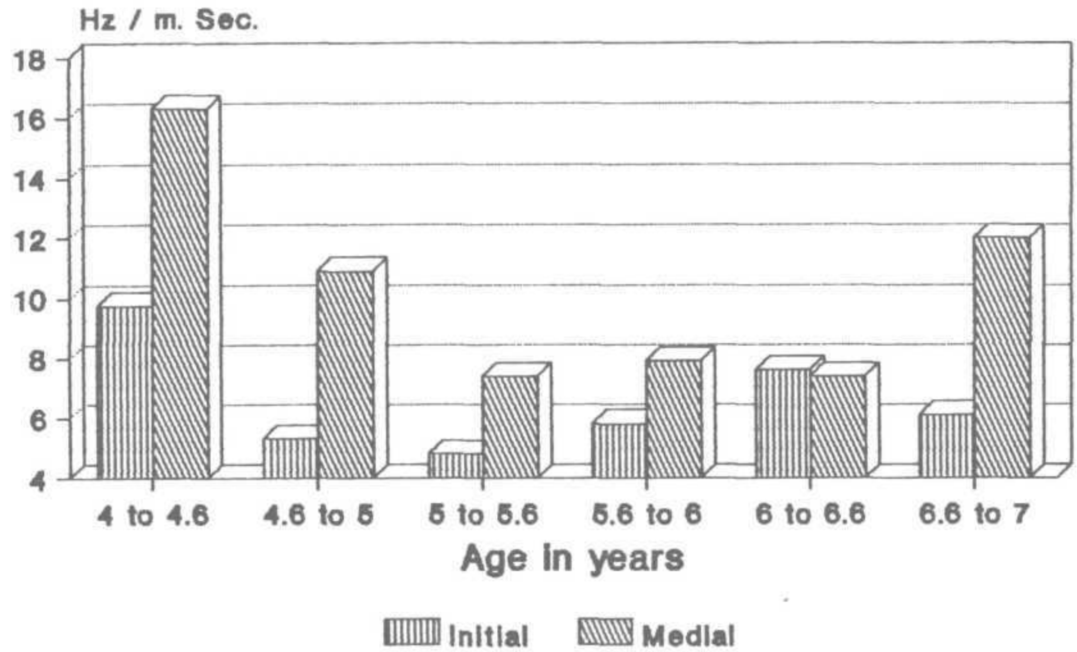
Fig, 29 : Mean speed of transition of various groups.



Fig, 30 : Mean speed of transition of various vowels.



Fig, 31 : Mean speed of transition of consonants preceeding vowel /a/.



Fig, 32 : Mean speed of transition of consonants preceeding vowel /i/.

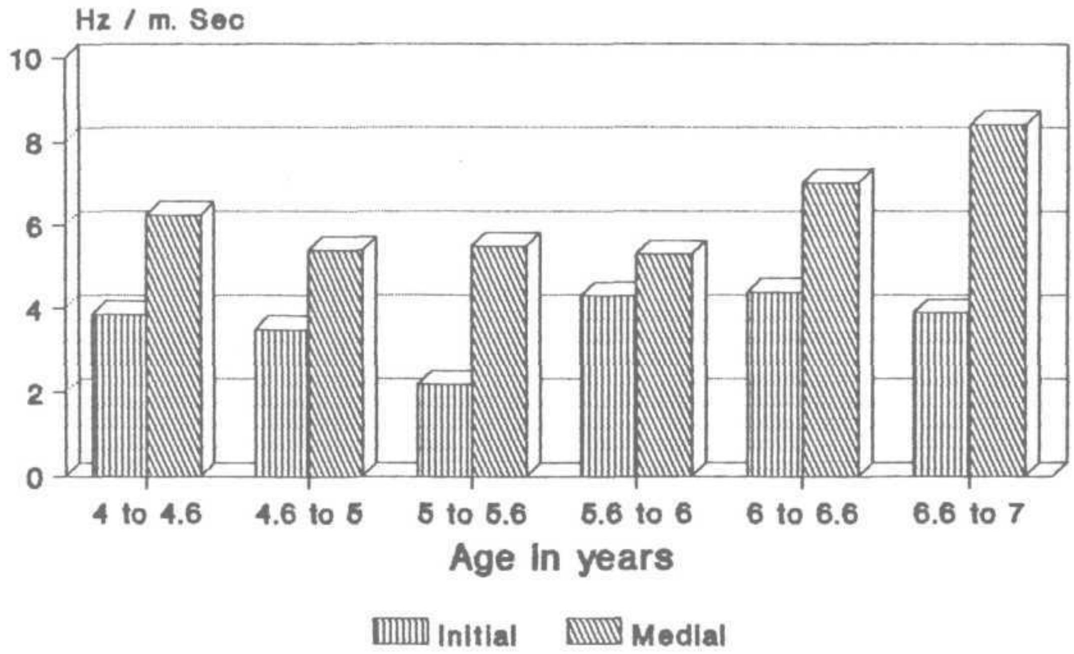


Fig. 33 : Mean speed of transition of consonants following vowel /u/.

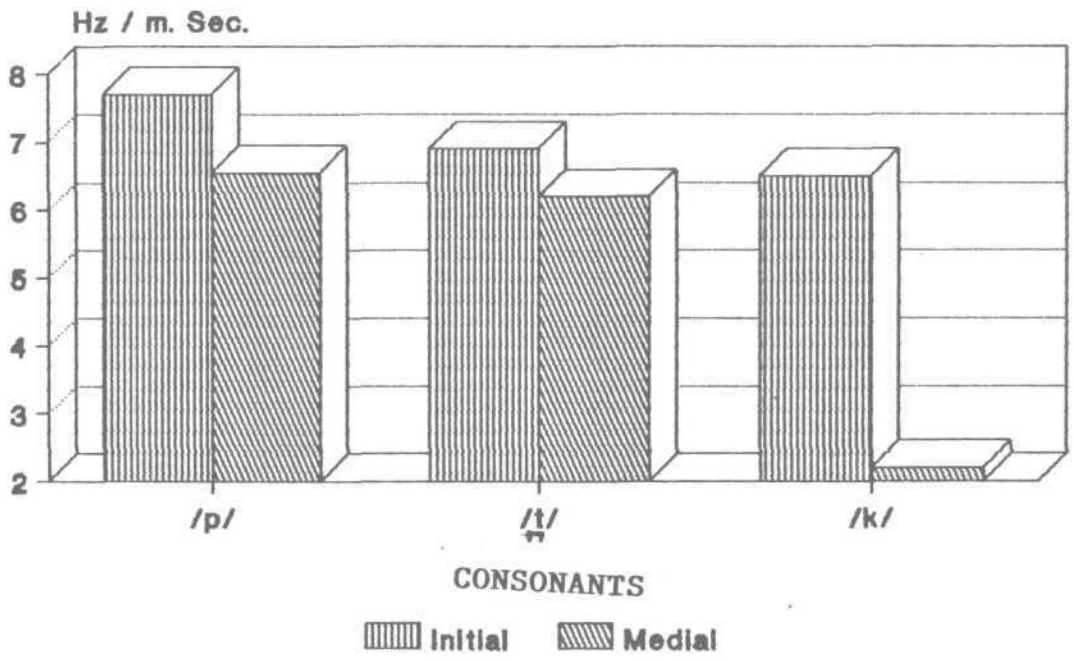
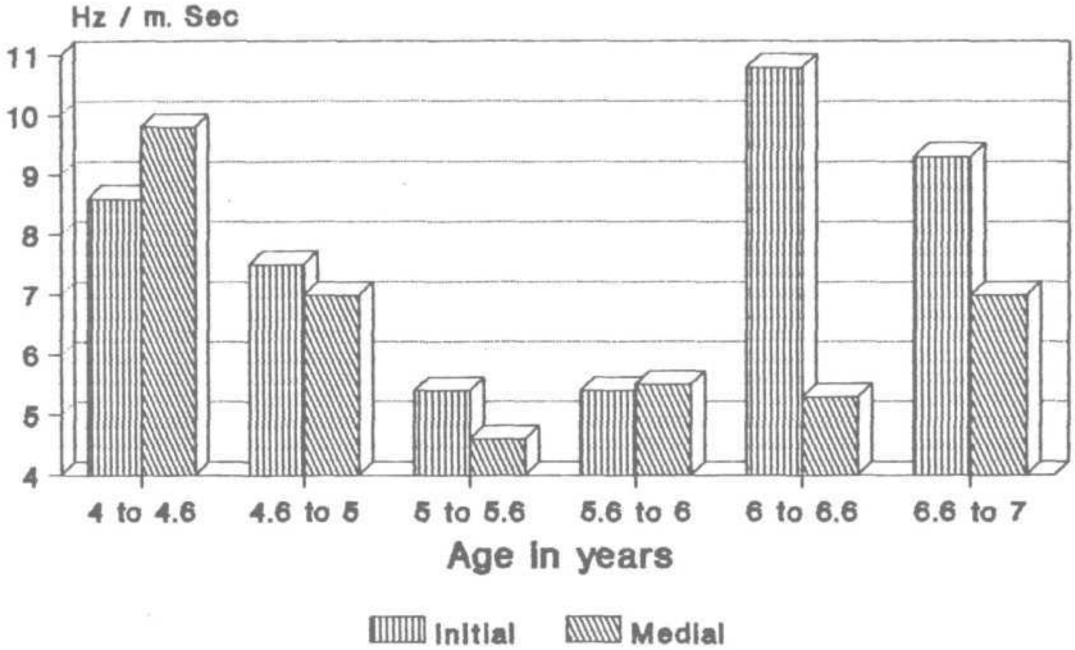
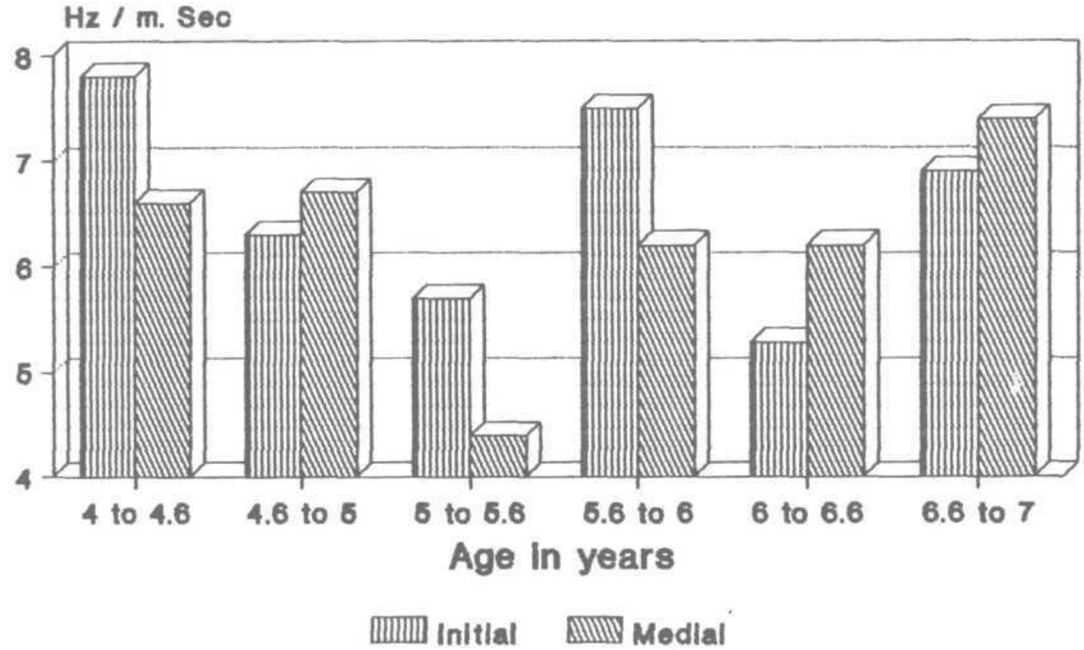


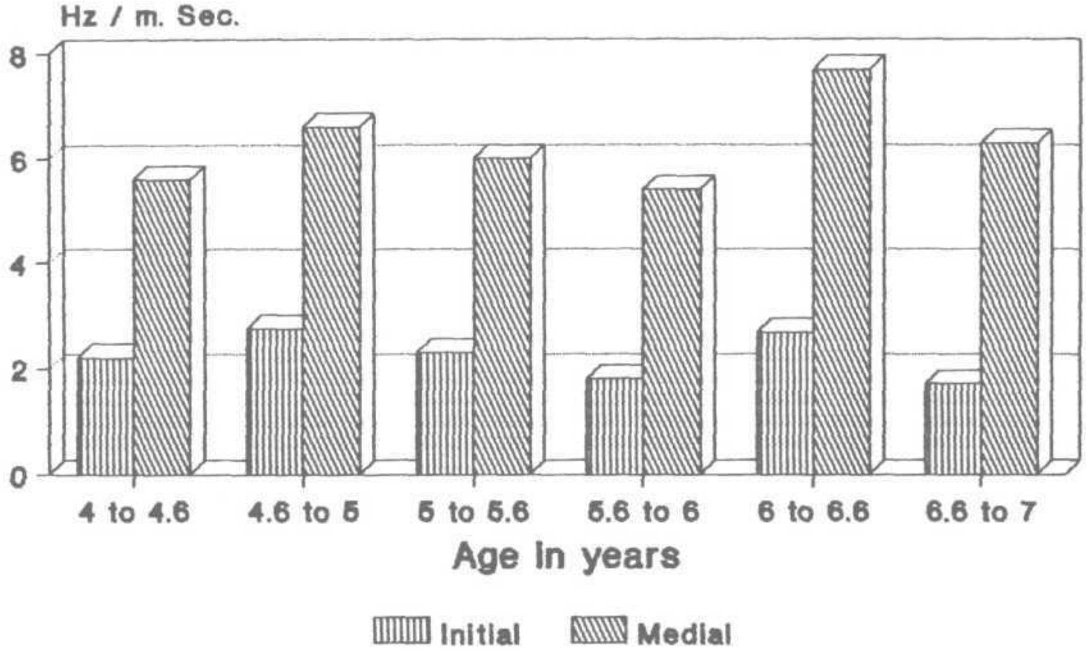
Fig. 34 : Mean speed of transition of various consonants.



Fig, 35 : Mean speed of transition of consonant /p/.



Fig, 36 : Mean speed of transition of consonants /t/.



Fig, 37 : Mean speed of transition of consonant /k/.

		INITIAL	MEDIAL
		1 2 3 4 5 6	1 2 3 4 5 6
VOWELS /a/	ALL AGE GROUPS	NS	NS
/i/	1 2 3 4 5 6	. S S S S . S . . . . . S . . . . . S . . . S . . . . S	. S S S S . S . . . . . S . . . . . S . . . . . S . . . . . S . . . . .
/u/	ALL AGE GROUPS	NS	NS
POSITIONS	ALL AGE GROUPS	NS	NS
CONSONANTS /p/, /t/ & /k/	ALL AGE GROUPS	NS	NS

Table 7 : Significance of difference between age groups for SPEED OF TRANSITION (F2)

To summarize, the results indicate the following :

1) Transition duration was longest when the low vowel /a/ was involved and short when high vowels /i/ & /u/ were involved.

2) Within the consonants there appeared to be no preferences.

3) Transition duration appeared to increase from 4.6 years for all the consonants in all the vowel environment and from 5.6 to 7 years for /k/ & /p/ in /a/ & /u/ environments.

4) TF2 of consonants preceeding the high vowel /i/ was the highest followed by /a/ & /u/. Among the consonants the dental /t/ had the highest TF2.

5) TF2 of consonants preceeding /a/ & /u/ decreased from 4 years to 5.6 years (initial positons).

6) While the ETF2 was greater for the low vowel /a/ in the initial position it was so for the high vowels /i/ & /u/ in the medial position.

7) The ETF2 was greater for the labial and dental consonants in the initial and the medial positions respectively.

8) STF2 was higher for the bilabial consonant /p/ & lowest for the back high vowel /u/ & the velar consonant /k/.

9) STF2 of the consonants preceeding the high vowels /i/ and /u/ and the bilabial & dental consonants /t/ & /p/ decreased from the age of 4 to 5.6 years.

DISCUSSION:

It was not possible to derive any conclusions about the general development trends from the widely varying results. The results failed to indicate any definite pattern of co-articulatory development.

Only the transition duration of the second formant showed a specific pattern where transition duration increased from first age group (4 to 4.6 years) to the second age group (4.6 to 5 years) and decreased for the next two age groups (5 to 5.6 and 5. 6 to 6 years) and increased for the fifth (6 to 6.6 years) and sixth (6.6 to 7 years) age group for all the vowels and consonants.

In order to see if any change existed between the youngest age group (4 to 4.6 years) and the oldest age group (6.6 to 7 years), the percentage times the values increases at 7 years was calculated (Table 8).

	TD		TF		STF2		ETF2	
	I	M	I	M	I	M	I	M
VOWELS	100	33	33	67	67	67	67	67
CONSONANTS	100	67	100	33	100	67	33	67

Table 8 -1 percentage times the value of a parameter increased from age 4 to 7 years for vowels and consonants.

Though there was no linear development observed as reported by sereno and Liberman (1987), Repp (l986) and Sereno et al(l987), the table indicates that the Transition duration, extent and speed of transition increased in the age of 7 years compared to that of 4.6 years. However the terminal frequency in the initial position decreased at the age of 7 years. This indicates that the developmental changes occured during speech acquisition when the childern modify the segmental pattern as they grow in order to achive adult like fluent speech pattern.

The increase or decrease in these paramters can be attributed to the change in the aerodynamics due to physiological maturation which in turn changes the acoustical properties of the speech sounds. As childern grow, thier vocal tracts also grow in size and volume. This increase in the volume would reduce the resonance frequency and hence older childern show reduced terminal frequency for vowels.

Highest terminal frequency (F2) for the high front vowel /i/ that was observed in this study is in consonance with the results of the other studies (Fant 1962, Pet erson & Barney 1952, Sereno et al 1987,Repp 1986). Though the formant frequency pattern observed in this study follow the same as that of adults the F2 were higher than adult men and women for all vowels (Fant 1962, Pet erson and Barney 1952) which is due to the growth of cavity volume.

Increase in the transition duration perhaps indicates that the younger childern produce speech segment by segment. Hence there is not much of transition as well as overlapping of acoustic features between segments or phonems whereas in older childern the increased transition indicates overlapping as well as an attempt to articulate the stop consonants better.

A high terminal Frequency (F2) is expected for /i/ as it is a front high vowel and the volume of the front cavity is less. The same is true for the consonant /t̲/ also. Longest transition duration and the extent of transition of /a/ vowel may be due to the mass, thickness of the tounge involved in the production of /a/.This in turn reduces the movement of the tounge dorsum.Due to this it takes longer time to achive the vowel target after articulation of the consonant preceding and may also be due to the lesser contact period for the velar stops (Parush et al 1982).

As the volume of the cavity increases,the tongue moves to a greater extent to achive the target and hence there is increased extent of transition. This also indicates that the childern learn to transit better to the neighbouring sounds as they grow older. Also /a/ being a low vowel, the distance the articulator travels will be longer from consonant to /a/ than from consonant to /i/ or /u/. Shortest transition duration and extent of tranition for high back vowel /u/ may be due to the less displacement and maximum velocity of the tounge (Parush et al 1982 , Sereno et al 1987).

As the speed of transition is directly propositional to the extent and the duration of the transition the increase in the speed of transition in older childern indicates that they are capable of making fast articulatory movements.

Increase in the terminal frequency for plosives perhaps is due to the acquisition of fine motor control which is required for building up of more intra oral pressure by tight closure of the articulators.

Decrease in the speed of transition of alveolar /t/ and velar /k/ may be because of the child's acquition of palatal and velar consonants following that of the dentoalveolar and labial consonant especially in syllable initial position (Locke 1983 and

Recansens 1987). Because of this late acquisition finer aspects like speed of articulators especially for velar and alveolar may be reduced and are yet to be developed precisely. Difference between initial and medial position for vowels and consonants though not very significant, could be attributed to the stress and effort applied in the beginning of the word repetition task.

These results and predicted explanation clerly indicate, that complex goal directed speech - muscle activity are required which are not the consequence of innate mechanisms. Hence, childern's utterances are more variable than adult utterences, suggesting different age levels for the acquisition of individual motor processes for speech.

CHAPTER 5 : SUMMARY AND CONCLUSIONS

Coarticulation may be defined as a speech production process in which the coarticulatory characteristics, features or properties of one sound are modified by another sound. Evidences for the presence, different types & extent of coarticulation have come from physiological, acoustical and perceptual study. The extent or magnitude of coarticulation is highlighted by the physiolagical and acoustical studies.

The present study was aimed to shed some light onto this aspect of coarticulation and also to trace its development. Six Kannada speaking normal childern one each in the age range of 4 to 4.6, 4.6 to 5, 5 to 5.6, 5.6 to 6, 6 to 6.6 & 6.6 to 7 years participated in the study. The material chosen for the study were divided into two sets of stimuli. In the first set,the final syllable remained constant (ta) which was preceded by varying CV combinations where c = /p/, /k/, /t/ & v = /a/, /i/, /u/ the second set, the initial syllable remained constant (pa) followed by CV combinations where C was /p/, /t/ & /k/ & v = /a/, /i/ & /u/. There were nine words in the first set & eight words in the second set. These 17 words were randomized to make five sets and thus a total of 85 words formed the child's sample.

The childern were tested individually. The repetitions of the childern were recorded onto a spool at a high speed (7 1/2' /min) by using the internal tape recorder of the sound spectograph VII 700. Bar type expanded (upto 4KHz) wide band spectograms were obtained for all the words. A total of 510 spectograms were obtained and were analyzed for the following four parameters.

1) Transition duration of F2 : It is the time duration between the onset of the second format for the vowel to the steady state of the same.

2) Terminal frequency of F2 : It is the frequency of the F2 at the onset of the vowel following the stops.

3) Extent of transition (H2) : It is the frequency difference between the terminal frequency of F2 & the onset of the steady state vowel.

4) Speed of transition (Hz/m.SEC) : Speed of transition of F2 is the rate at which
the F2 moves. It is the ratio between the extent of transition and transition duration.

The data was tabulated and averaged across subjects for each consonant and vowel in the initial and medial positions. The data was subjected to repeated measures ANOVA with Fisher's LSD.

The results indicated no specific developmental pattern for any of the parameter and the results were highly variable. However, when the measurments obtained at the age of 7 years were compared with that of 4.6 years, it was noticed that the T.D, S.T and extent of transition were longer and the terminal frequency of F2 was reduced in the older age group. These findings may be because of the acquisition of fine motor control in articulating plosives, and changes acquired in the oral cavity, articulators due to physiological maturation.

Further research in coarticulation may be carried out to study the coarticulatory effects in childern & their developmental patterns in depth . This will enable the speech & language pathologists to understand the effects of coarticulation on defective sounds as well as to use coarticulatory principles in remediation of the same.

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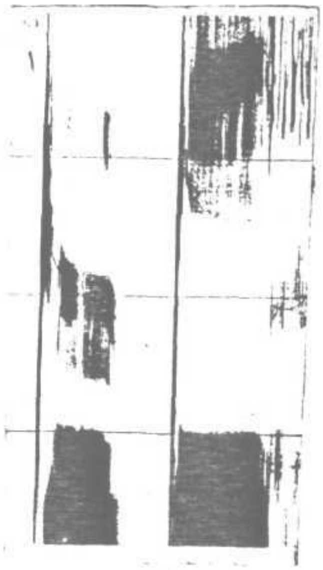
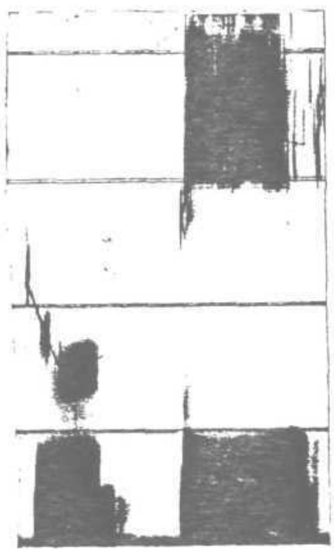


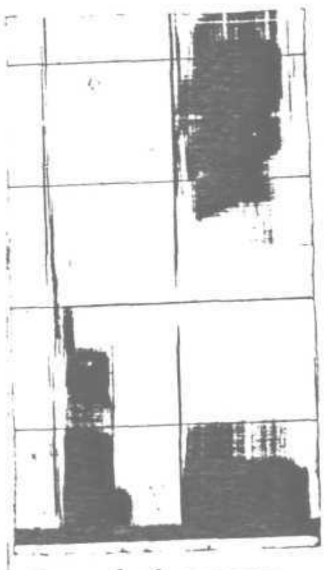
4 - 4.6 years

4.6 - 5 years

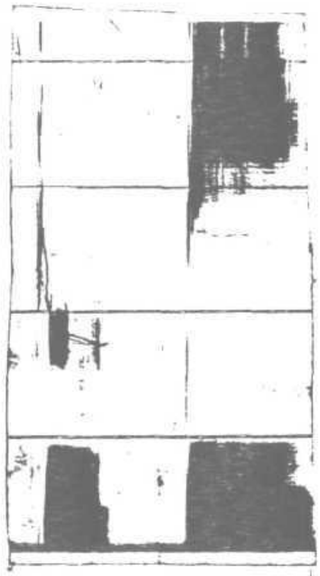


5 - 5.6 years

5.6 - 6 years

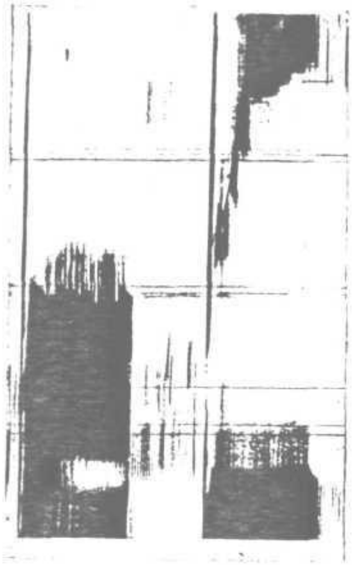


6 - 6.6 years



6.6 - 7 years

APPENDIX I : Word (tuti)



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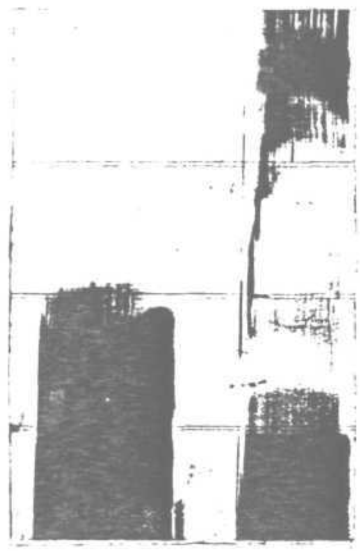

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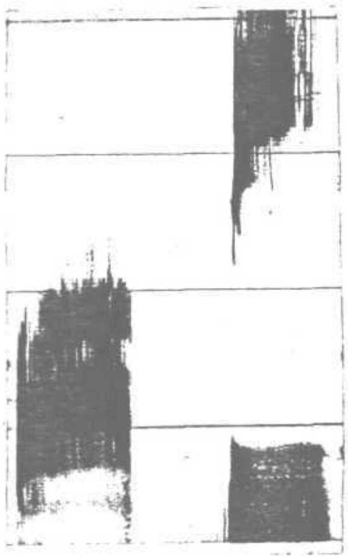
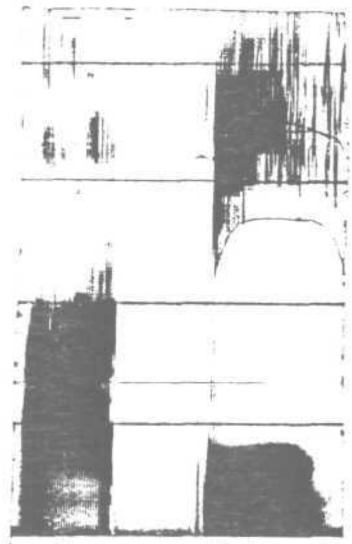
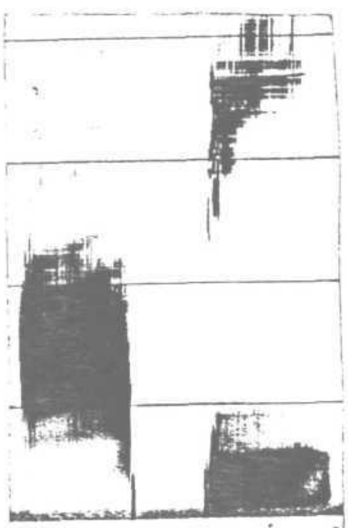


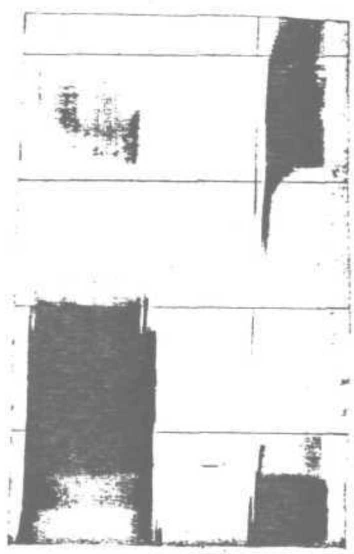
5 - 5.6 years



5.6 - 6 years



6 - 6.6 years



6.6 - 7 years

APPENDIX II : Word (pa:pi)