PRECEDING VOWEL DURATION AS A CUE FOR VOICING

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Dissertation submitted as part fulfilment for the second year

M.Sc. (Speech and Hearing) to the University of Mysore

All India Institute of Speech and Hearing
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1992

To my MOM & DAD

for the

love

understanding

laughter

and

freedom

they have given me

CERTIFICATE

This is to certify that the Dissertation entitled: **'PRECEDING VOWEL DURATION AS A CUE FOR VOICING"** *is a bonafide work, done in part fulfilment for the Second Year M.Sc. (Speech and Hearing) of the student with* **Reg.No.M902l.**

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1992

CERTIFICATE

This is to certify that the Dissertation entitled: 'PRECEDING VOWEL DURATION AS A CUE FOR VOICING' *has been prepared under my supervision and guidance.*

MYSORE
1992

Mr.C.S. VENKATESH
GUIDE

DECLARATION

This dissertation entitled: **"PRECEDING VOWEL DURATION AS A CUE FOR VOICING"** *is the result of my own study under the guidance of* **Mr.C.S.VENTAKESH,** *Lecturer, Department of Speech Sciences, All India Institute of Speech and Hearing, Mysore and has not been suhmitted earlier at any other University for any other Diploma or Degree.*

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INTRODUCTION

Speech perception is the process where by a living organism receives and interprets information about the surrounding world (Julesz and Hirsch, 1972). The human auditory mechanism analyses sound according to the changes in frequency and intensity across time. These sounds also change in their mode of transmission as they travel from the outer (mechanical) to the inner ear and finally to the areas of hearing through the auditory nerve (electro chemical).

Attempts to explain how linguistic value is determined from a speech signal has resulted in various theories of speech perception. These theories can broadly be classified into:

a) Active and passive theories.

b) Theories of variance and invariance.

Active theories necessiate the presence of a mediational process in speech perception. Analysis by synthesis theory, put forth by Halle and Stevens (1959), theorises that the listener has an auditory model of his production which he uses for analysis of the incoming auditory stimuli. Correct generative rules are identified and this allows for invariance to be maintained through computation of error. Normalisation is therefore explained by this theory.

Liberman (1957) put forth the motor theory of speech perception, which speculates that the articulatory knowledge forms the basis for speech perception, ie., speech is perceived by running the production process backwards. Liberman and Matingley (1985) revised the motor theory of speech perception. They claim that phonetic transformation is perceived by a "module" which is biologically distinct. The module has lawful relationships between the gestures and the acoustic patterns in which they are variously overlapped. The nodule causes perception of phonetic structure without translation from preliminary auditory impressions.

Of these theories the analysis-by-synthesis theory is considered as a theory of invariance and the other active theories are considered as theories of variance.

To test these theories, various physical and psychophysical methods like analysis-by-synthesis (Halle and Stevens, 1959), articulatory studies (Fant, 1960) and synthesis-by-rule (Flanagan et al, 1970) have been adapted, which has thrown more light in the area of speech perception.

Research in the area of speech perception has been focussed on perception in: 1) normal adults 2) clinical population and (3) normal children. In adult speech perception the chief interest has been to understand how the listener perceives a continuous sound stream in terms of discrete phonetic units. This led to a search for invariant acoustic cues in the speech signal that would uniquely characterize a particular phonetic dimension. Professional concern regarding speech and language problems which require special education and therapy has resulted in the study of perception in the clinical population.

Interest in child perception has increased in the past decade and several studies have been conducted in this regard. On one hand, some acoustic - phonetic dimensions appear to be determined by biologically given predispositions that are operable shortly after birth. On the other hand, perception by adults of these same acoustic - phonetic dimensions reflects to a high degree their specific linguistic experience. Clearly a great deal of modification of perceptual abilities takes places between infancy and adult hood, as the individual learns his language.

Several investigators have attempted to study this development of speech perception and production in children. Many of them have focussed on various features of stop consonants.

Preston, Yeni-Komshian and Stark (1967); Preston and Port (1968, 1969); Zlatin (1972) and Kent (1976) provide evidence to support that perception and production of acoustic features changes during the first 6 years in a systematic manner. Zlatin and Koenigsknecht (1975) found a perceptual development of VOT between 2 years of age and adulthood. Flege and Efting (1986) studied production and perception of /t/-/d/ contrast in native English and Spanish adults and children. They found that boundaries of native English and native Spanish adults occurred at significantly longer VOT values than those of children who speak the same language. Also native English speakers showed significantly longer VOT values than age matched native Spanish speakers.

Krause (1982, a) studied the use of vowel duration cue in 3-and 6-year old children and in adults. Significant developmental differences were found in the perceptual judgement of voicing. Wardrip - Fruin and Peach (1984) found that 3 year olds were most sensitive to duration (vowel) and 6 year olds were most sensitive to spectral cues (final consonant transition) but adults were able to use both durational and spectral cues in making judgements of final consonant voicing. Lehman and Sharf (1989) studied children in the age range of 4.4-10.11 years and adults. Their results supported the findings of Krause (1982,a). They further said that children's perception was adult like at 5 years of age.

The literature is equivocal regarding cues to perception of stop consonants. However the cues are known to differ depending on the language studied (Burnham, Earnshaw and Clarke, 1991). An understanding of how cues differ for different languages is therefore necessary. The studies conducted so far have been restricted to English, Spanish, French and to discrete age groups. Studying the development of perception throughout early childhood would be more fruitful as it reveals the details of the developmental changes, if any.

The aims of this study was to:

1) Investigate the role of PVD as a cue to voicing of the following stop consonants in 3-6 years old Kannada Speaking children, and
2) Investigate the developmental trend, if any, in the perception of voiced-voiceless stop-consonants with preceding vowel duration as a cue.

REVIEW OF LITERATURE

Speech perception has been an area of interest for the past two decades and extensive research has been conducted in this area. Of the speech sounds the stop consonants have been the most frequently studied. Stop consonants are considered to be special because of their:

1) Non-linearity: As the articulators are rarely in one position for a long time, the acoustic characteristics keep changing from moment to moment; and

2) Redundancy: A large number of acoustic cues are available to cue their place, manner and voicing. If one cue is absent another cue takes over.

Stop consonants are produced by occluding the oral cavity by an articulator for some time. Air is held behind the articulator for some time and is then released. The salient -features of stop consonants are:

1) A period of occlusion (silence/voiced).
2) A transitory explosion (usually less than 20msec produced by shock excitation of the vocal tract upon release of occlusion).
3) A very brief (0-10msec) period of friction as articulators separate and air is blown through a narrow constriction as in the homorganic fricative.

4) A brief period of aspiration (2-20rasecs) within which may be detected noise excited formant transitions reflecting shifts in vocal tract resonances as the main body of the tongue moves towards the position appropriate for the following vowel.

5) Voiced forraant transitions, reflecting the final stages of articulatory movement into the vowel during the first few cycles of laryngeal vibration.

Lisker (1977) in his study has listed 16 parameters that cue voicing of stop consonants - viz:

1) Presence/absence of low frequency buzz during the closure interval.
2) Duration of closure.
3) F1 offset frequency before closure..
4) F1 offset transition duration.
5) F1 onset transition duration.
6) F1 onset frequency following closure.
7) Preceding Vowel duration.
8) Fl cut-back following closure.
9) Fl cut-back before closure.
10) VOT delay after closure.
11) VOT cut-back before closure.
12) Fo contour before closure.
13) F contour after closure.
14) Amplitude of /i/ relative to vowel.
15) Decay time of glottal signal preceding closure.
16) Intensity of burst closure.

A large number of studies (Raphael, 1972; Mermelsten, 1978; Ohde, 1978; Hogan and Rozyspal, 1980; Hillenbrand et al 1984; Dsha Rani, 1989) have been carried out to determine the importance of these cues in voicing.

While First formant transition has been studied by Mermelstein (1978), Walsh and Parker (1983), Hillenbrand et al (1984), Summers (1988), Usha Rani (1989), Fisher and Ohde (1990), Vinay Rakesh (1990), closure duration as a cue to the perception of voicing in stops has been well documented (Lisker, 1959, 1978; Lisker and Price, 1979; Price and Lisker, 1979; Stathopoulous and Weismer 1983; Davis and Summers, 1989; Usha Rani, 1989; Vinay Rakesh 1990).

Voice onset time is yet another parameter which has been studied extensively by several investigators (Ohde, 1978; Keating, 1979; Lahiri, 1980; Ahmed and Gupta, 1980; Keating, Mikos and Ganong, 1981; Nagamma Reddy, 1985; Usha Rani 1989; Vinay Rakesh 1990; Sreedevi, 1990). A few cues are said to be major cues while others are referred to as minor cues.

Of late, interest has shifted to importance of these cues in child perception, this has resulted in a few developmental studies. One of the continuing questions posing those interested in verbal language acquisition is whether the childs perception of the speech signal is the same as, or different from adult perception of the same signal. Whether the child first distinguishes only the coarser contrasts between the sounds which reachs his ear is a continuing question. As the present study is concerned with preceding vowel duration the review will be restricted to preceding vowel duration as a cue for voicing in stop consonants and it will be dealt in two subsections:

1) Studies on preceding vowel duration as a cue to voicing in normal adults.

2) Studies on preceding vowel duration as a cue for voicing in children.

1) STUDIES ON PVD AS A CUE TO VOICING IN NORMAL ADULTS:

Preceding vowel duration (Henceforth PVD) has been reported to cue the voicing of stop consonants. Longer PVD cues voiced stops and shorter PVD cues voiceless stops, as in Fig-1.

Vowel duration difference is often considered to be of primary perceptual importance to final stop cognate oppositions. Experimental evidence supporting this conclusion consists primarily of a series of synthetic speech studies by Raphael and his colleagues (Raphael, 1972; Raphael et al 1975; 1980). Raphael (1972) used pattern playback to synthesize syllables [CVC(C)] ending in voiced and voiceless stop fricatives. In general final consonants were heard as voiceless when preceded by vowels of shorter duration and as voiced when preceded by vowels of longer duration. He concluded that preceding vowel duration was both a necessary and sufficient cue to syllable final voicing. Similar findings were reported in two subsequent synthesis studies by Raphael et al (1975, 1980).

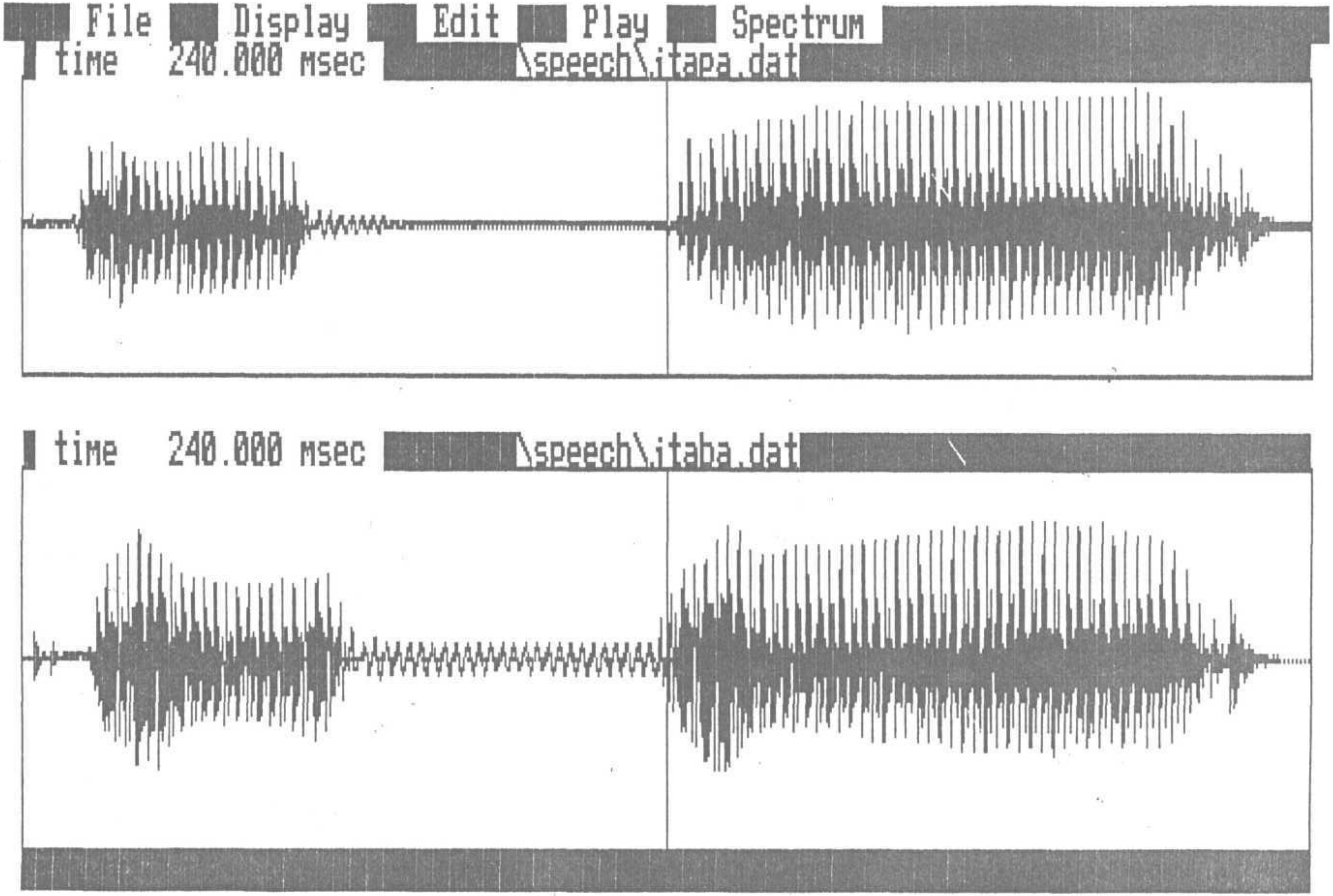


Fig1 :- WAVEFORM DEPICTING PRECEDING VOWEL DURATION FOR VOICED AND VOICELESS STOPS.

These conclusions based on synthesis studies have not been supported by more recent work involving edited natural speech samples. Fruin and Bischoff (1976) found that there was no clear relation between length of preceding vowel and perception of the final consonant, when CVC's recorded as stressed citation were used.

Hogan and Rozyspal (1980) edited natural speech samples and demonstrated that while short vowel durations might result in fewer voiced post vocalic consonants being correctly identified. Categorical changes in voicing perception did not necessarily result. They also found that vowels with intrinsically shorter durations such as /i/ and / / showed little change in voiced-voiceless distinction regardless of vowel duration.

Wardrip - Fruin (1982, a) presented 521 tokens derived from 52 monosyllables to adults. The subjects were asked to judge whether the syllables ended in voiced or voiceless stops. They concluded that syllable duration was a more significant cue to voicing feature than vowel duration. Also, preceding vowel could be reduced in duration by one third without eliciting voiceless response and it may be necessary for desambiguating final voiced stops.

It was shown that perception of voicing in Dutch in two - obstruct sequences (C1C2) was affected by voice-onset time, voice termination time, duration of the preceding vowel resonance and constriction duration of the second consonant (C2) in the sequence (Van Den Berg, 1986, 1987). Van den Berg (1988) obtained the same results using natural speech C1C2 sequences.

Davis and Van Summers (1989) examined the influence of post vocalic voicing on vocalic and consonantal durations in VCV sequences as compared to VCV sequences. Their findings suggested that neither vowel duration nor closure duration are reliable perceptual cues for consonantal voicing when the preceding vowel is stressed. Further, they suggested that . vowel length is a more reliable cue for intervocalic voicing than closure duration. However, vowel duration in itself not an entirely reliable cue.

Usha Rani (1989) used the words /agga/ and /abba/ to create stimuli with different preceding vowel durations. She reported that on truncation of the preceding vowel duration, no change in the percept was observed for the Kannada and Hindi language groups, at least upto the truncation of 50 msecs. Vinay Rakesh (1990) using the same stimuli reported of similar findings in Malayalam and Telugu.

Crowther and Mann (1990) carried out experiments to test the hypothesis by Chen (1970) that preceding vocalic duration is a universal cue to final consonant voicing in CVC monosyllables. They compared native speakers of Mandarin, Chinese, English and Japanese. Their experimentation revealed that native speakers of English showed the strongest implementation and sensitivity to vocalic duration as a cue to consonant voicing. Mandarin Chinese speakers showed significantly weaker effects and the Japanese fell in between. These findings qualify theories about vocalic duration contrast as a universal cue. While there may be a universal tendency to lengthen the vocalic portion before voiced stops, the magnitude of the contrast seems to be determined by language specific considerations.

Fisher and Ohde (1990) reported of increase in voicing ratings across all continua, for synthetic CVC, when vowel duration was increased. However, there was not necessarily a change in the voicing category. Further, vowel duration was found to be a less effective cue for continua terminating in low as compared to high offset frequencies.

2) STUDIES ON PRECEDING VOWEL DURATION AS A CUE TO VOICING IN NORMAL CHILDREN:

Review of literature indicates that young infants can discriminate speech sounds across phonetic boundaries regardless of specific relevant experience and that there is a modification in this ability during ontogeny such that adults often have difficulty in discriminating phonetic contrasts which are not used contrastively in their native language. If this is the case it becomes important that one knows what happens between infancy and adulthood.

Developmental studies in children, have risen from a need to understand these modification processes which occur during the years the child is acquiring phonology. A dirth of developmental studies exist because of major problems involved in maintaining attention during testing, finding appropriate response modes and also in obtaining reliable responses. The few that have been conducted have done so using VOT, closure duration and preceding vowel duration.

It is known that the acoustic features change during the first six years in a systematic way (Kent, 1976). Evidence of this emerges from the studies by Preston, Yeni - Komshian and and Stark (1967); Preston and Port (1968, 1969) Zlatin (1972).

Koenigsknecht (1968) found that perception of spectral acoustic cues improved significantly between the three years old children, 6 year old children and adult groups. Garnica (1973) and Zlatin and Koenigsknecht (1975) report that 2-3 year old children were not consistent in identifying voicing differences in stop consonants.

Zlatin and Koenigsknecht (1976) studied development of voicing contrast, using VOT, in ten two-year old children, ten six-year old children and twenty adults. Both production and perception was studied in these subjects. Results revealed that two and a half to three year old children had wider phoneme boundaries than older children and adults. By the end of the sixth year, children showed discrete perceptual categories with relatively narrow phoneme boundaries. Further, a developmental pattern of change, primarily for voiceless stops, in the form of increased correspondence between perceptual identification categories and production VOT values was noted.

Williams (1977) performed a post hoc acoustic analysis of naturally produced Spanish stops that had been identified as voiced or voiceless by native speakers of Spanish. She speculated that Spanish listeners gave greater weight age to the presence of an audible release burst and lack of low frequency energy immediately following it as a cue for voicelessness.

In a study by Krause (1982, a) on the development of use of durational cue in 3-year olds, 6-year olds and adults, the duration of vowels was varied to construct three stimulus continua (BIP-BIB, POT-POD, BACK-BAG). Significant developmental differences were found in the perceptual judgement of voicing. These were reflected in both the locus of category boundary and the slope of identification function.

Wardrip-Fruin and Peach (1984) found that 3-year olds were most sensitive to duration (vowels) and 6-year olds were most sensitive to spectral cues (final consonant transition) but adults were able to use both duration and spectral cues in making judgements of final consonant voicing.

Flege and Efting (1986) studied the perception and production of the contrast between /t/ - /d/ by subjects differing in native language and in age. In the perception task, boundaries of both native English and Spanish adults occurred at significantly longer VOT values than those of children who spoke the same language.

Lehman and Sharf (1989) conducted a study on 30 children in the age range of 4.4-10.11 years and 10 adults in the age range of 19.7-36.10 years. They studied production and perception in these groups. Perceptual data was collected using a synthesized speech continuum that varied the vowel duration. Their results indicated that perception of category boundary and category separation in children was adult like at 5 years of age. Perceptual consistency was not adult like until 10 years of age. Further, perception was consistently more advanced than production. This study supported the results of the study by Krause (1982, a).

Burnham, Earnshaw and Clark (1991) tested English language environment infants, two-and six-year old children and adults for their identification of sounds of a native (voiced-voiceless bilabial stop) and a non-native (pre-voiced-voiced bilabial stop) speech continuum. Categorical perception of the two contrasts diverged with age, increasing for native contrast and decreasing for the non-native contrasts between two to six years. This difference in developmental course for the perception of native and non-native contrasts indicates an effect of specific linguistic experience on categorical perception.

Thus, this review indicates that some investigators support the view that PVD is a cue for voicing and some do not. Also several of the studies indicate that the language and the subject is very important and linguistic experience plays a role in the perception.

However, most of the studies done have been restricted to non-Indian languages and the studies are conducted on discrete age groups. A continuous tracking of speech perceptual abilities in children would be more fruitful in the understanding of development of speech perception in children. In this context, the present study intends to track the development of speech perception in Kannada speaking children of 3-6 years for the cue PVD.

METHODOLOGY

The methodology will be dealt under the following sub-sections:

I Development of synthetic stimuli.

II Perceptual evaluation.

I DEVELOPMENT OF SYNTHETIC STIMULI:

Three plosives - voiced unaspirated velar plosive /g/, voiced unaspirated dental plosive /d/ and voiced unaspirated bilabial plosive /b/, as embedded in the medial position of four meaningful bisyllabic Kannada words (/b/ in 2 words), were selected as shown in Table-1. These words mode a minimal pair with the voiceless cognate /k/, /t/, /p/ respectively. These words, each written on a card formed the material.

Phoneme	Word
/d/	kade
/g/	baga
/b/	taba
/b/	aba

Table-1: Words selected for this study (key phoneme is emphasised)

Subject

A seven-year old Kannada speaking male was selected as the subject. His speech was normal as judged by a speech pathologist and had no hearing problem as reported.

Method

The subject was seated comfortably in a sound treated room and was provided with the stimulus cards and familiarized with the words. He was then visually presented with the stimulus cards one at a time and instructed to utter the words into a dynamic cardiode microphone (AKG D-222) kept at a distance of 10cm from the mouth. The microphone was connected to a digital tape recorder (DAT, TCD-T3, Sony) and the words thus uttered were audio-recorded in metallic cassettes. The speech material was transferred to a computer PC-AT (386) and digitized using a 12 bit ADC card, developed by VSS, Bangalore, at a sampling rate of 20KHz. These digitized words served as the material for synthesis.

The wave forms of the words were displayed on the screen of the computer to measure the vowel duration preceding the plosive. Vowel duration was measured as the duration between the onset and offset of regular complex wave form (Fig-2).

The wave form editor "DSW" was used and the steady part of the vowel was identified as that part with steady intensity in the waveform. The steady portion of the waveform was cut in steps of 2 waves until there was no steady state (Fig-3).

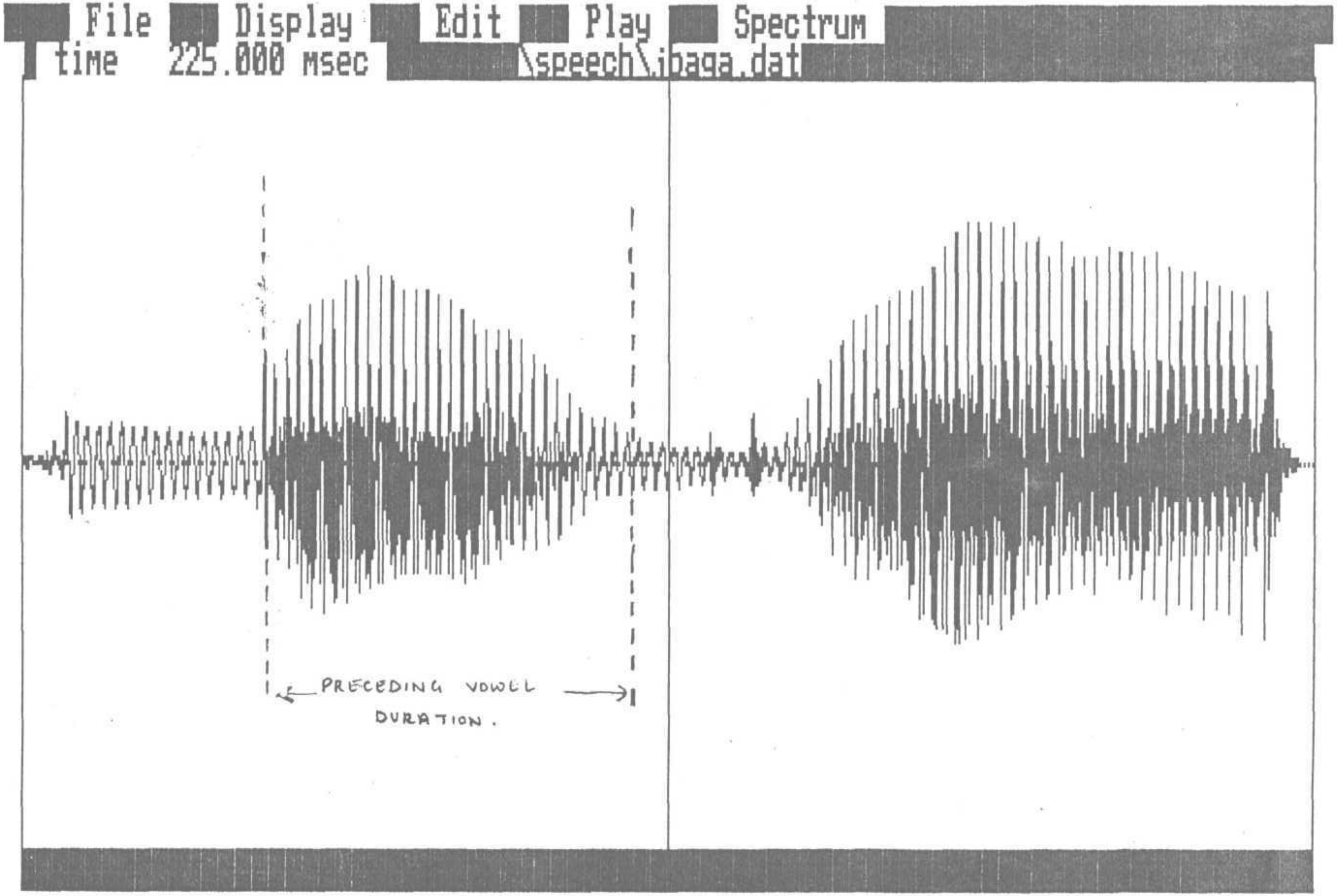


FIG.2 :- WAVEFORM OF STIMULI INDICATING MEASUREMENT OF PRECEDING VOWEL DURATION.

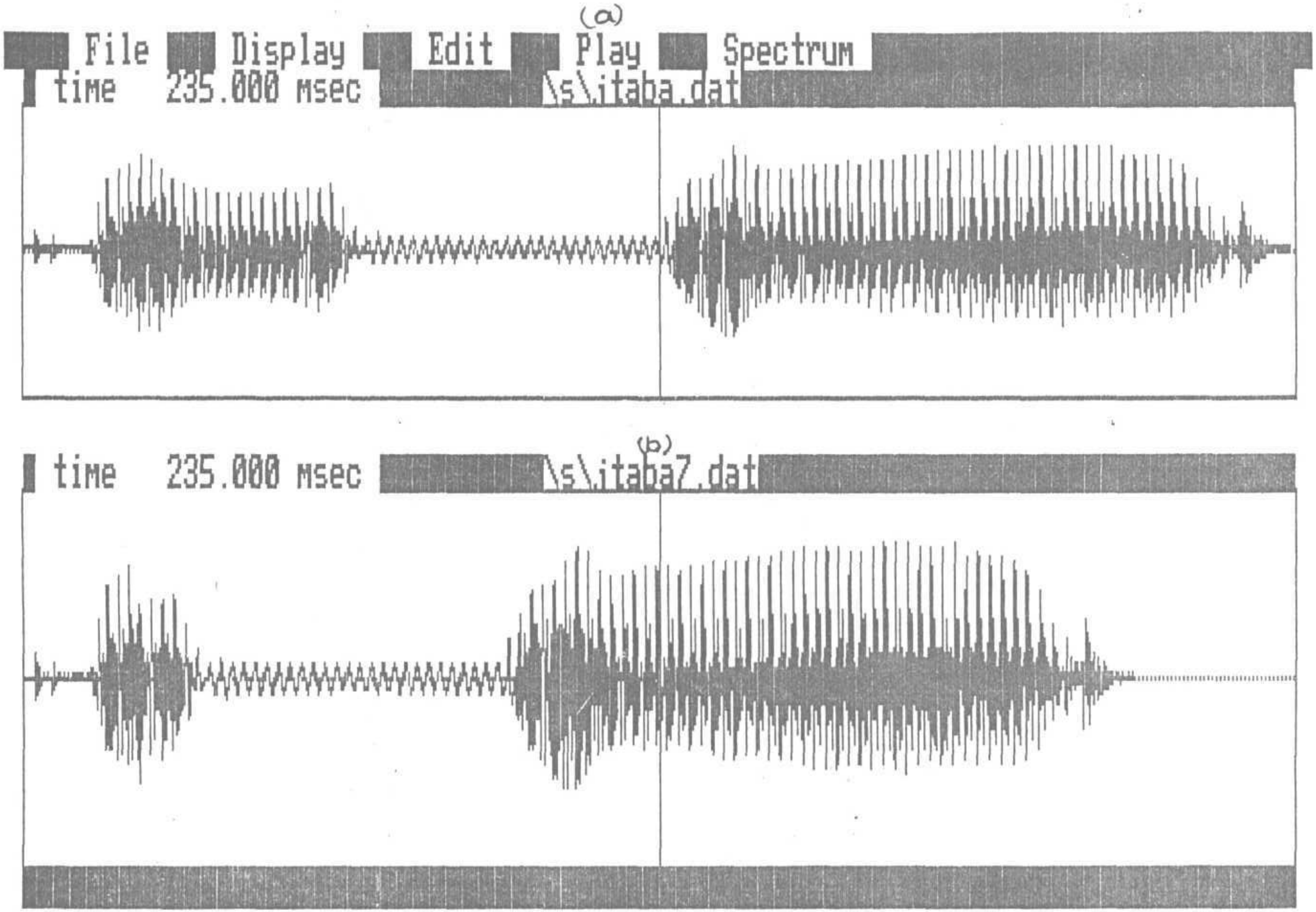


FIG.2 :- WAVEFORM OF /taba/ :- (a) ORIGINAL WAVEFORM
(b) WAVEFORM AFTER TRUNCATION

Totally 32 synthetic words were prepared, as depicted in Table-2.

Phoneme	Word	Total PVD (in msec)	PVD cut (in msec)	No. of tokens
d	kade	37.0	32.8	5
g	baga	70.0	66.4	9
b	taba	66.45	50.4	8
b	Vaba	109.6	81.0	10

Table-2: Details of synthetic stimuli.

Token of each phoneme set were randomised and iterated twice and then audio recorded in a metallic cassette with an interstiraulus interval of 5 seconds. Thus, totally 64 tokens (32x2 iterations) were considered for perceptual evaluation.

II PERCEPTUAL EVALUATION:

Subjects

Thirty normal Kannada speaking subjects (ten each in the age ranges of 3-4 years, 4-5 years and 5-6 years) served as subjects. Each age group had 5 male and 5 female subjects. All the subjects had normal speech as per the opinion of a speech pathologist and none of them reportedly had any hearing loss. Table-3 provides subject details.

Age Range	Mean Age (In years) No. Males	No. Females
3-4 years	3.9	3.9
4-5 years	4.6	4.7
5-6 years	5.5	5.7

Table-3: Mean age of subjects

Procedure:

The perceptual experiment was carried out in a quiet room at the All India Institute of Speech and Hearing, Mysore and each child was tested individually. The children were seated comfortably, facing the loudspeaker, at distance of 3-4 feet from the loudspeaker. The recorded stimuli were presented through the loudspeaker at a comfortable level.

Children in the age range of 4-6 years were provided with an alternate forced choice response and were instructed to verbally repeat the stiumli presented. However, children in the age range of 3-4 years were conditioned for each set of stimuli /k-g/, /t-d/, /p-b/, using toys. Totally 8 toys were used (2 toys for each set) and the toys were given the names depicting the word of the minimal pairs. For Example: One of the toy was named as /taba/ and the other as /tapa/ as in the following picture.

taba

tapa.

The children were to point to the toy which was associated with the word heard. The response of the child was recorded by the experimenter on a forced choice printed response sheet.

Analysis

The data thus obtained was tabulated and percent response for the stimulus was calculated by the following formula:

$$\frac{\text{Obtained number of responses for the stimuli}}{\text{Expected number of response for the stimuli}} \times 100$$

For eg: If the expected number of response for a stimuli is ten and obtained number of response is six then the percentage response would be (6/10) x 200 = 60%.

The percent response for voiced and voiceless plosives were tabulated for each of the test stimuli on the basis of which the identification and discrimination functions for each plosive were plotted. The percent response and the identification and discrimination functions were used to delineate the results.

RESULTS AND DISCUSSION

As no significant difference was found to exist between the two trials (Mann-Whitney test), percent response of both trials are combined and discussed.

/t-d/ percept: Table-4 shows the result for /t/-/d/ percepts and Figure-4 depicts the percent response for /t/ - /d/, in all the age ranges.

It could be observed that there was no clear crossover from /d/ to /t/ as the preceding vowel duration was reduced. However there was an increase in the percent identification of the voiceless percept /t/ from 3 years to 6 years (Fig-5). While at the age of 3 to 4 years a low percent of children identified /t/ percept, the children identifying /t/ increased at 5-6 years of age.

Crossoveer was noted in the 5-6 years old males at 18.8msec. As the vowel duration was decreased there was an increase in percent of voiced percept.

Vowel duration (msec)	3 - 4 years				4 - 5 years				5 - 6 years			
	Male		Female		Male		Female		Male		Female	
	d	t	d	t	d	t	d	t	d	t	d	t
4.8	80	20	80	20	60	40	20	80	40	60	50	50
12.85	70	30	50	50	60	40	10	90	30	70	50	50
20.9	80	20	70	30	60	40	0	100	40	60	60	40
28.95	80	20	60	40	50	50	10	90	50	50	50	50
37.0	100	0	80	20	60	40	10	90	50	50	40	60

Table-4: Percent response for /t/-/d/ contrast (Kate Vs

FIG-4a: PERCENT RESPONSE AS A FUNCTION OF PVD, FOR /t/-/d/ CONTRAST IN 3-4 YEARS

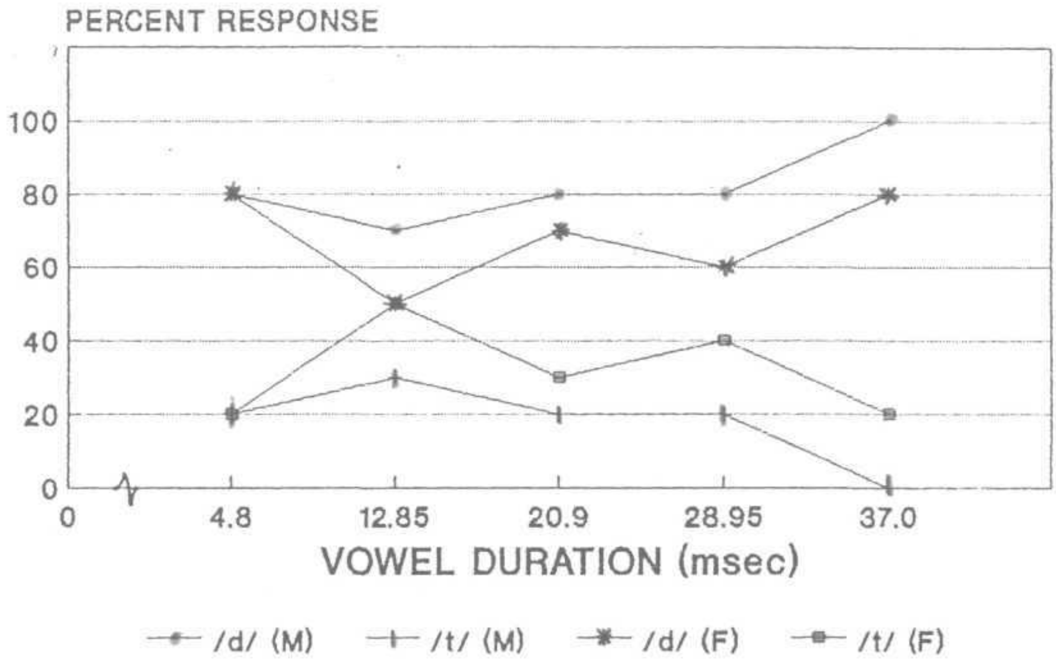


FIG-4b: PERCENT RESPONSE AS A FUNCTION OF PVD, FOR /t/-/d/ CONTRAST IN 4-5 YEARS

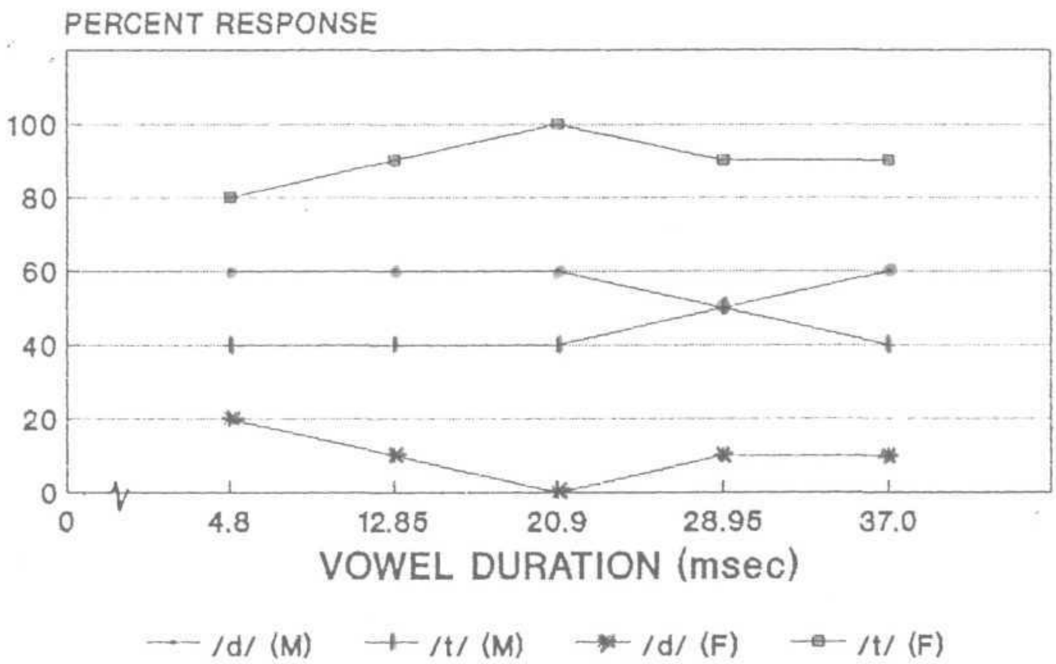


FIG-4c: PERCENT RESPONSE AS A FUNCTION OF PVD, FOR /t/-/d/ CONTRAST IN 5-6 YEARS

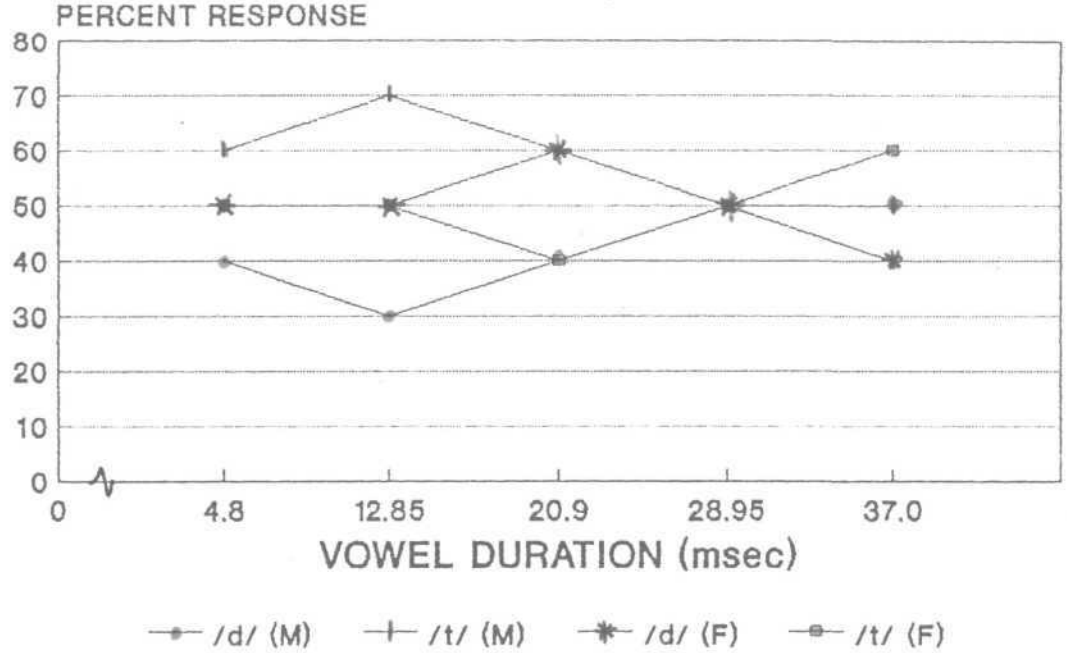


FIG-4d: PERCENT RESPONSE AS A FUNCTION OF PVD, FOR /t/-/d/ CONTRAST IN 5-6 YEAR MALES

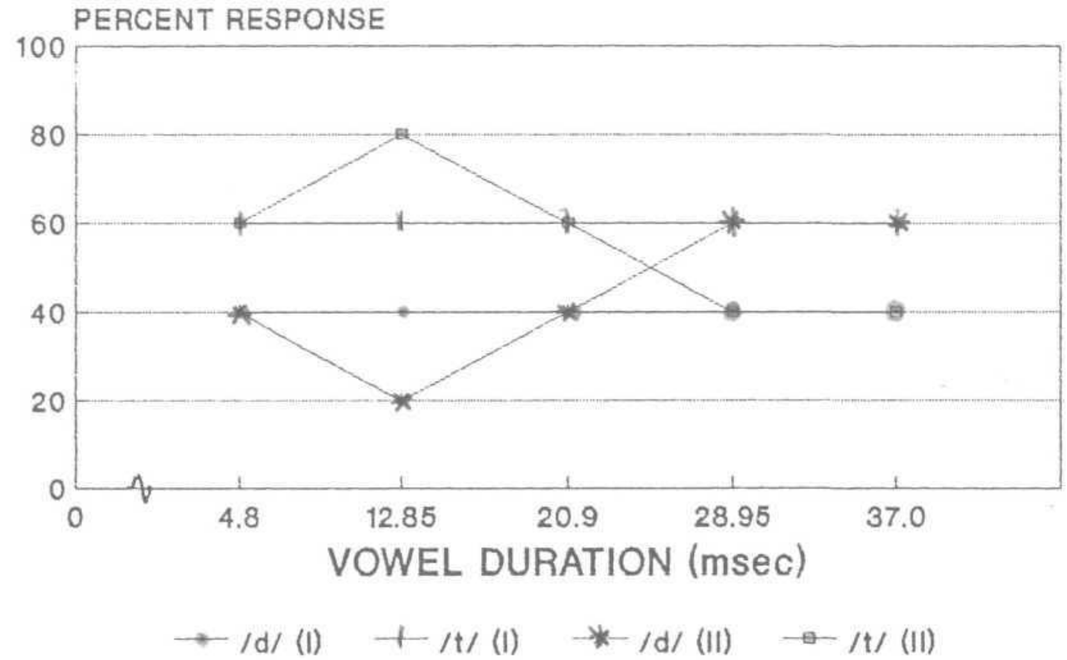


FIG-5a: PERSON IDENTIFICATION OF /d/ AT 37.0msec OF PVD

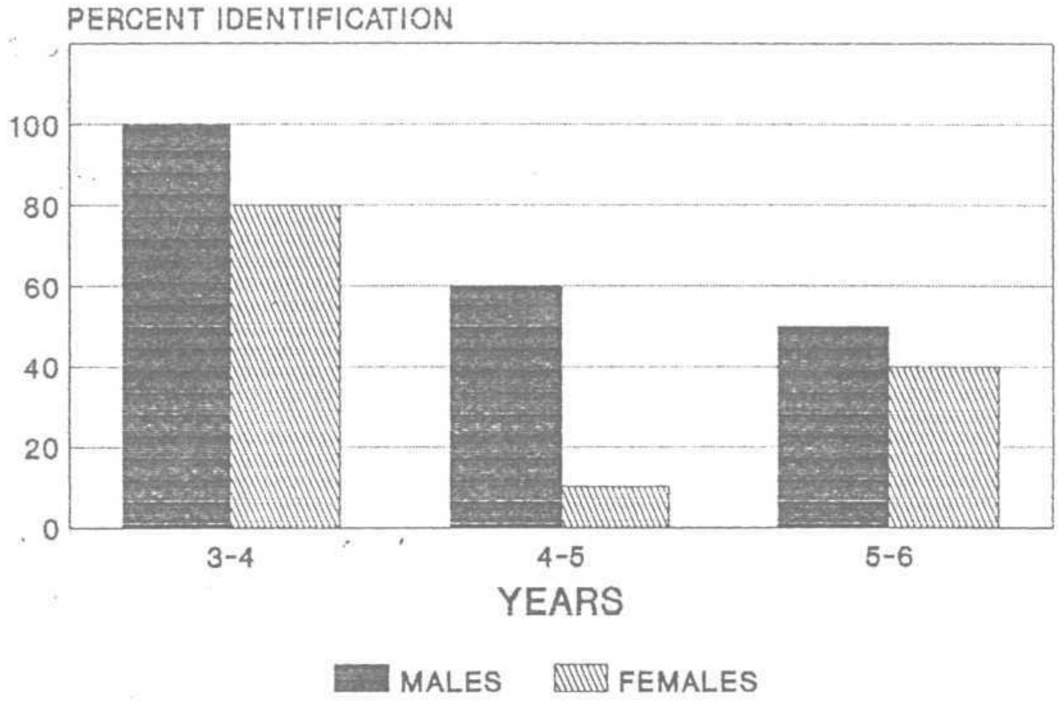
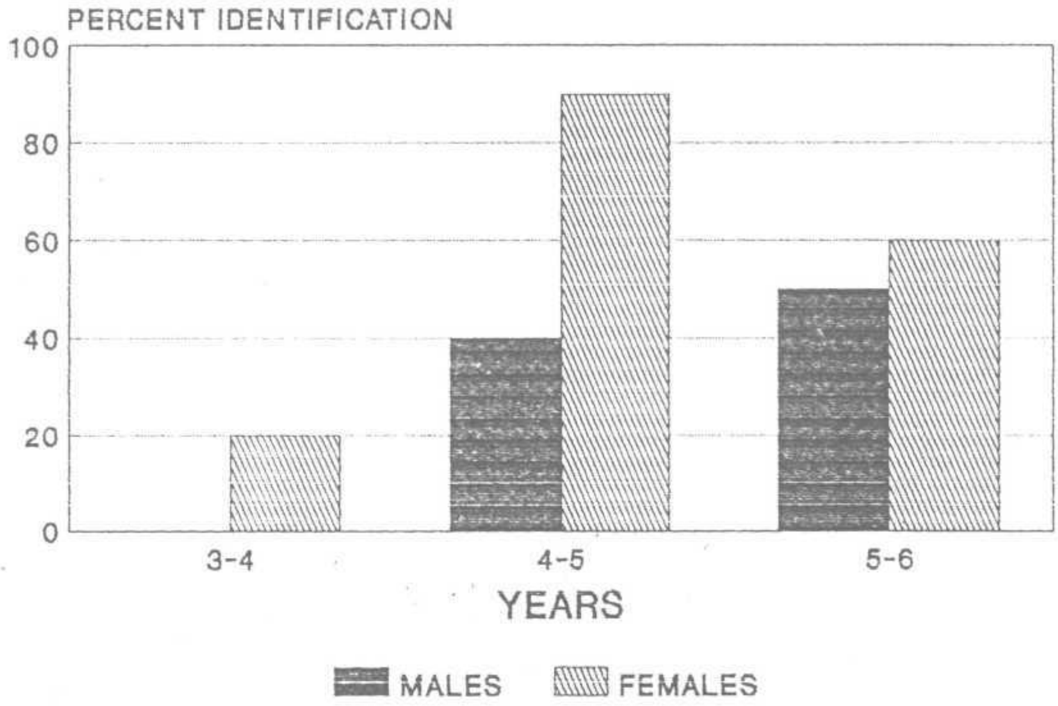


FIG-5b: PERSON IDENTIFICATION OF /t/ AT 37.0msec OF PVD



/k-g/ percept: Table-5 shows the results for /k/-/g/ percepts, and Figure-6 depicts the percent response for /k/-/g/ in all the age ranges.

No clear crossover of percept from /g/ to /k/ was observed as the preceding vowel duration was reduced. Children from 4 years to 6 years perceived a voiced stop consonant for the entire continuum of preceding vowel duration (3.6msecs to 70.0 msecs).

Vowel duration (msec)	3 - 4 years				4 - 5 years				5 6 years			
	Male		Female		Male		Female		Male		Female	
	g	k	g	k	g	k	g	k	g	k	g	k
3.6	80	20	40	60	100	0	100	0	100	0	100	0
11.9	70	30	30	70	100	0	100	0	100	0	100	0
20.2	90	10	40	60	100	0	100	0	100	0	100	0
28.5	60	40	40	60	100	0	100	0	100	0	100	0
36.8	90	10	50	50	100	0	100	0	100	0	100	0
45.1	80	20	50	50	100	0	100	0	100	0	100	0
53.4	90	10	50	50	100	0	100	0	100	0	100	0
61.7	100	0	50	50	100	0	100	0	100	0	100	0
70.0	90	10	40	60	100	0	100	0	100	0	100	0

Table-5: Percent response for /k/ - /g/ contrast (Baka-Baga)

/p-b/ percept: There were two sets of synthetic stimuli for /p/-/b/ percepts, one contrasting / aba/ -/ apa/ and the other contrasting /tapa/ - /taba/. Table-6 shows the results for /p/-/b/ percepts for / aba/ - / apa/ Figure-7 depicts the percent response for /p/ - /b/ in all the age ranges.

FIG-6a: PERCENT RESPONSE AS A FUNCTION OF PVD, FOR /k/-/g/ CONTRAST IN 3-4 YEARS

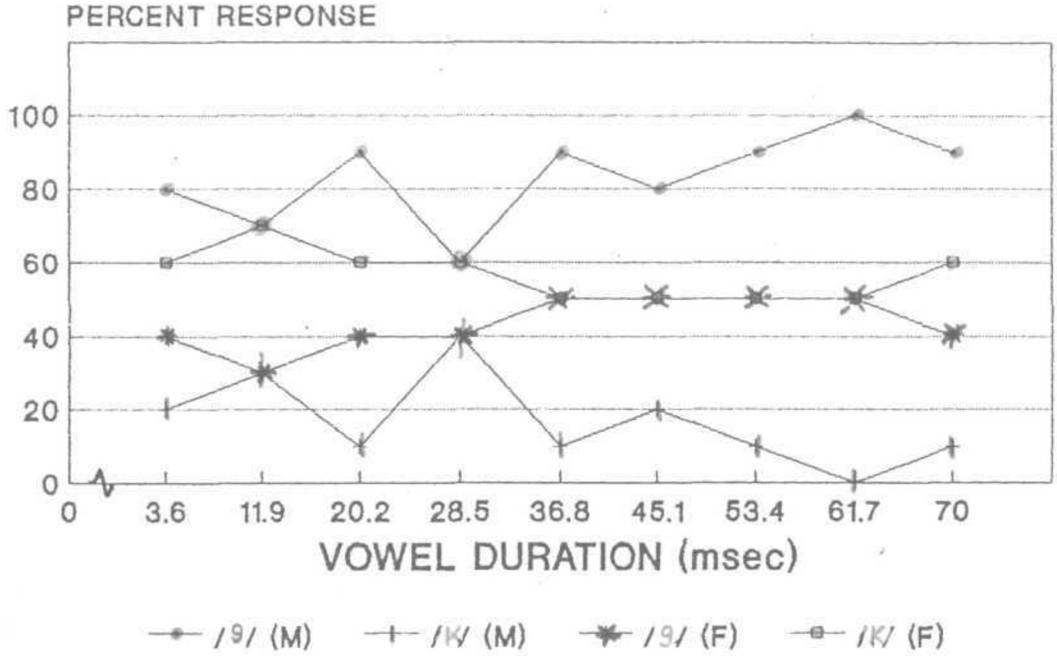


FIG-6b: PERCENT RESPONSE AS A FUNCTION OF PVD, FOR /k/-/g/ CONTRAST IN 4-5 YEARS

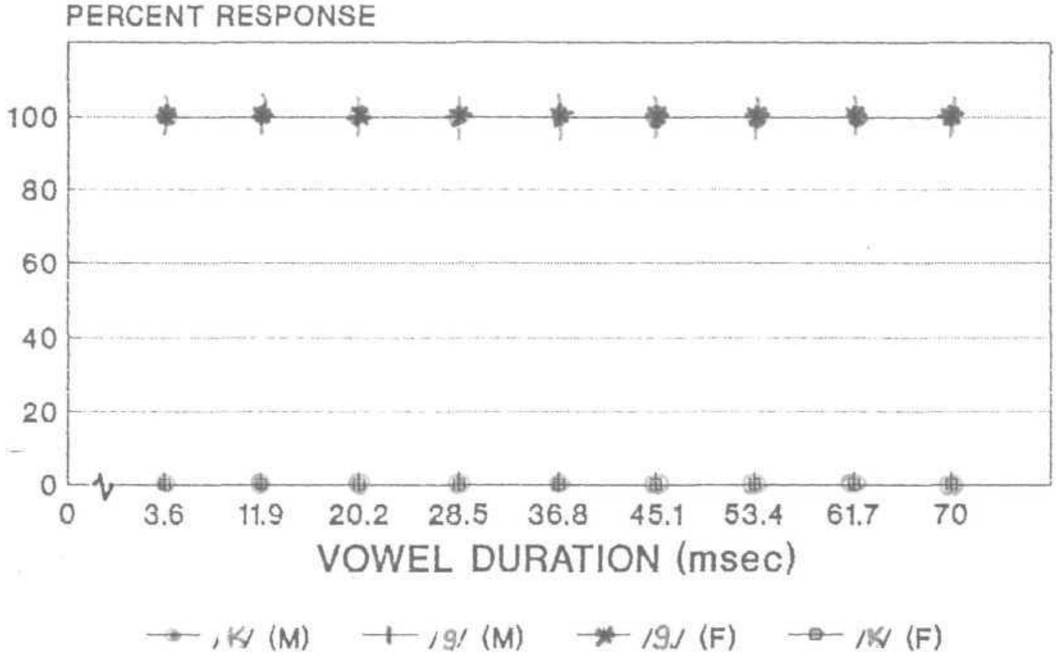


FIG-6c: PERCENT RESPONSE AS A FUNCTION OF PVD, FOR /k/-/g/ CONTRAST IN 5-6 YEARS

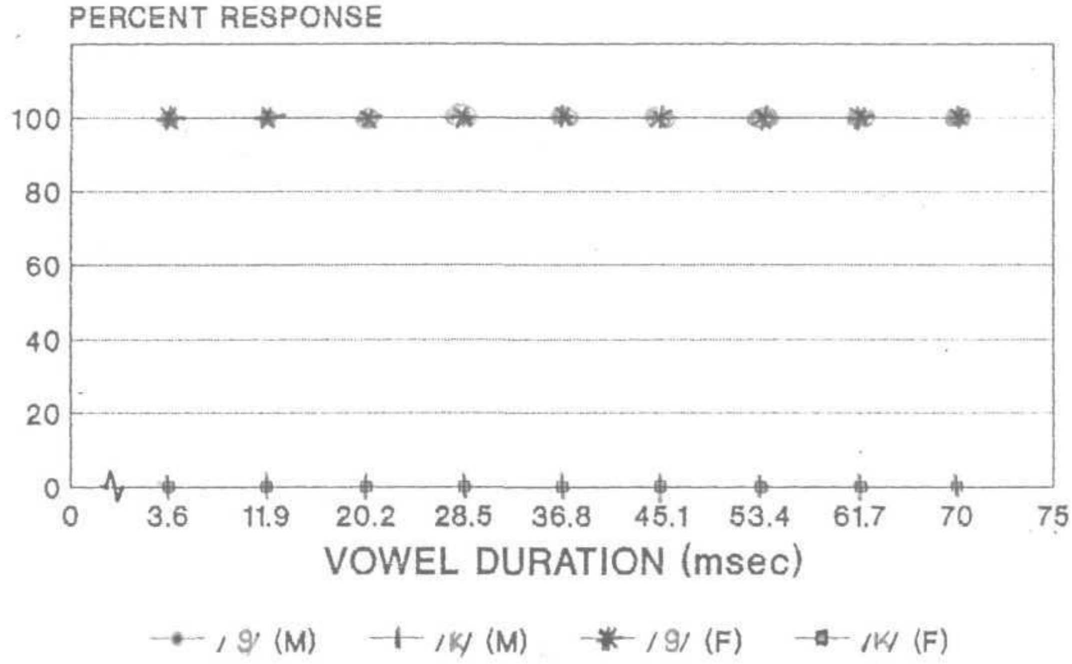


FIG-7a: PERCENT RESPONSE AS A FUNCTION OF PVD, FOR /p/-/b/ CONTRAST IN 3-4 YEARS (/ʃapa/-/ʃaba/)

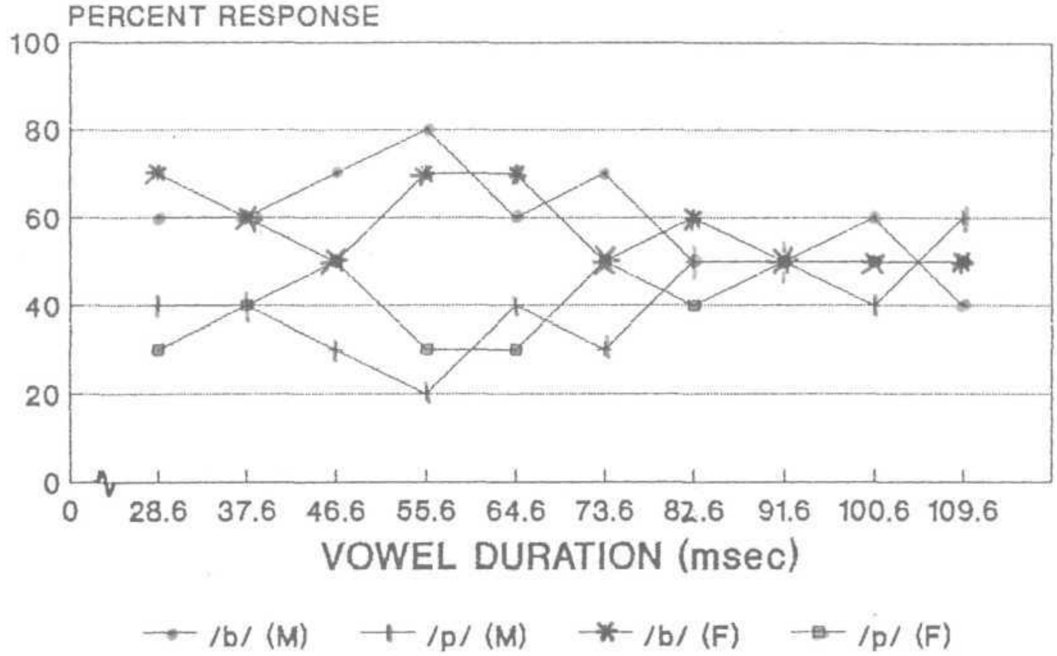


FIG-7b: PERCENT RESPONSE AS A FUNCTION OF PVD, FOR /p/-/b/ CONTRAST IN 4-5 YEARS (/ʃapa/-/ʃaba/)

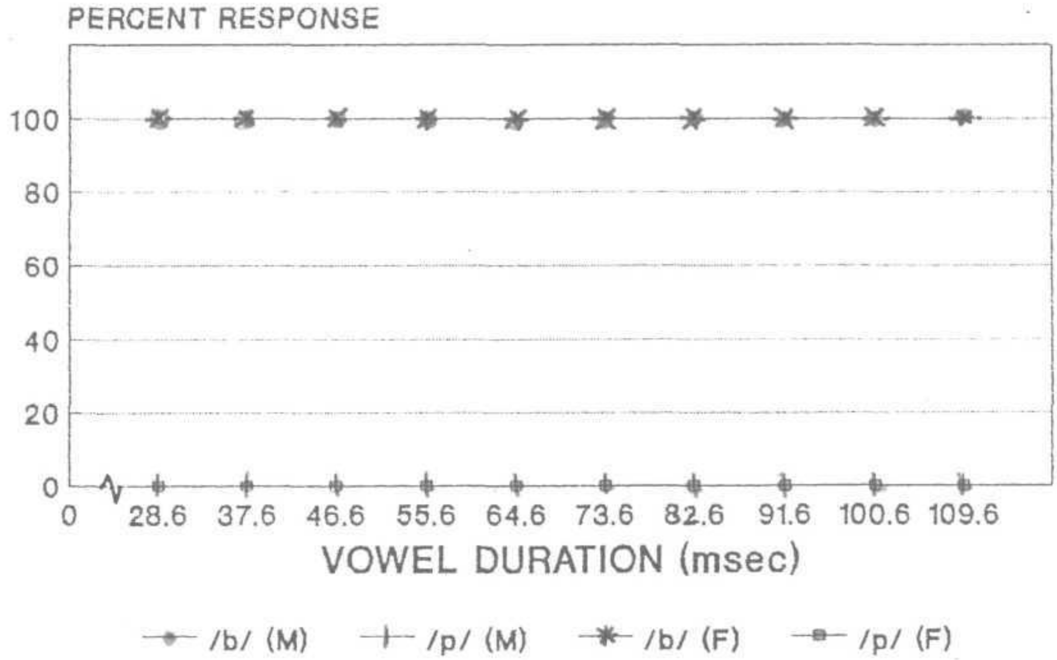
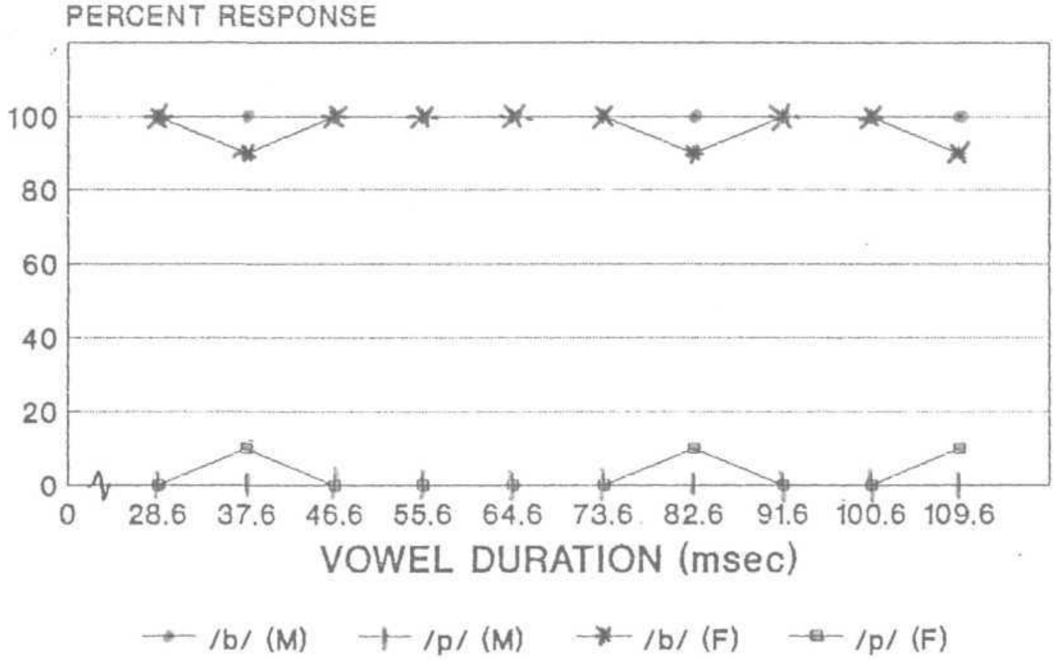


FIG-7c: PERCENT RESPONSE AS A FUNCTION OF PVD, FOR /p/-/b/ CONTRAST IN 5-6 YEARS (/ʃapa/-/ʃaba/)



No clear crossover of percept from /b/ to /p/ was observed as the preceding vowel duration was reduced. Children from 4-6 years perceived a voiced percept for the entire continuum of preceding vowel duration (28.6 msec - 109.6 msecs).

Vowel duration (msec)	3 - 4 years				4 - 5 years				5 - 6 years			
	Male		Female		Male		Female		Male		Female	
	b	P	b	P	b	P	b	p	b	p	b	p
28.6	60	40	70	30	100	0	100	0	100	0	100	0
37.6	60	40	60	40	100	0	100	0	100	0	90	10
46.6	70	30	50	50	100	0	100	0	100	0	100	0
55.6	80	20	70	30	100	0	100	0	100	0	100	0
64.6	60	40	70	30	100	0	100	0	100	0	100	0
73.6	70	30	50	50	100	0	100	0	100	0	100	0
82.6	50	50	60	40	100	0	100	0	100	0	90	10
91.6	50	50	50	50	100	0	100	0	100	0	100	0
100.6	60	40	50	50	100	0	100	0	100	0	100	0
109.6	40	60	50	50	100	0	100	0	100	0	90	10

Table-6: Percent response for /p/ - /b/ contrast (aba Vs. apa)

In the synthetic stimuli contrasting /taba/ - /tapa/ also, no clear crossover from /b/ to /p/ was noticed as the preceding vowel duration was reduced (Table-7, Fig-8). However, it was observed that the ability to discriminate between voiced and voiceless percepts decreased as a function of age.

FIG-8a: PERCENT RESPONSE AS A FUNCTION OF PVD, FOR /p/-/b/ CONTRAST IN 3-4 YEARS (/tapa/-/taba/)

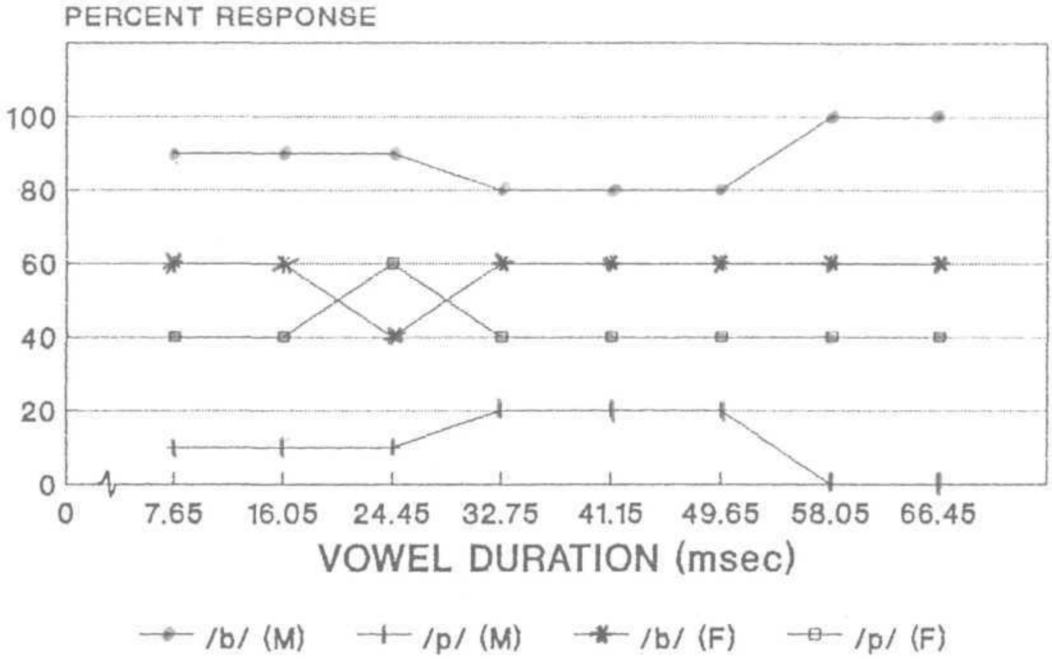


FIG-8b: PERCENT RESPONSE AS A FUNCTION OF PVD, FOR /p/-/b/ CONTRAST IN 4-5 YEARS (/tapa/-/taba/)

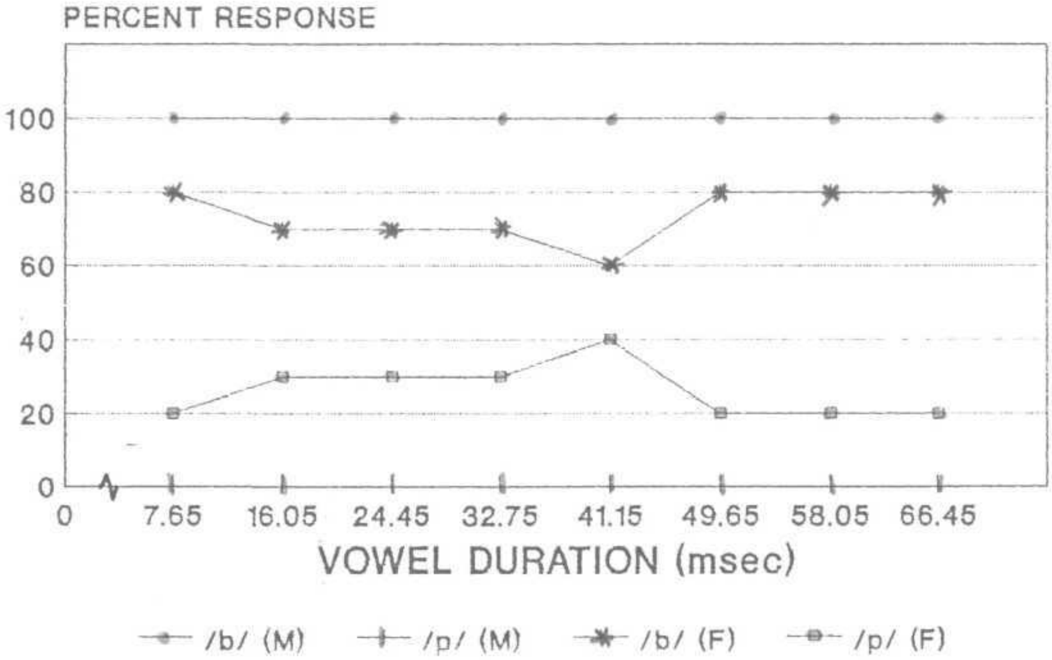
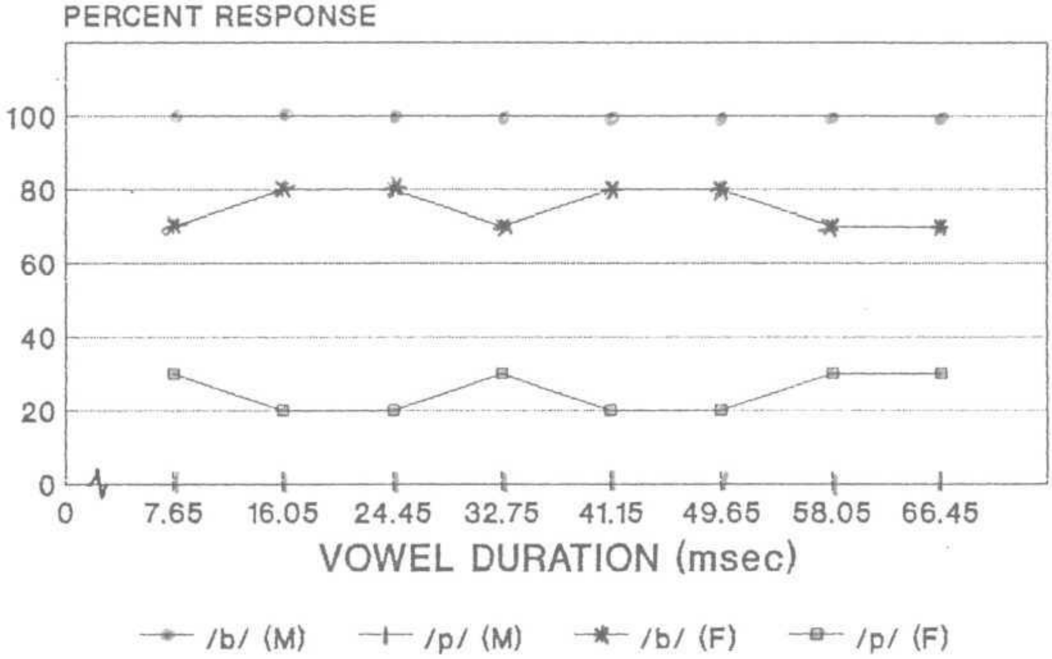


FIG-8c: PERCENT RESPONSE AS A FUNCTION OF PVD, FOR /p/-/b/ CONTRAST IN 5-6 YEARS (/tapa/-/taba/)



Vowel duration (msec)	3 - 4 years				4 - 5 years				5 - 6 years			
	Male		Female		Male		Female		Male		Female	
	b	P	b	p	b	P	b	P	b	p	b	p
7.65	90	10	60	40	100	0	80	20	100	0	70	30
16.05	90	10	60	40	100	0	70	30	100	0	80	20
24.45	90	10	40	60	100	0	70	30	100	0	80	20
32.75	80	20	60	40	100	0	70	30	100	0	70	30
41.15	80	20	60	40	100	0	60	40	100	0	80	20
49.65	80	20	60	40	100	0	80	20	100	0	80	20
58.05	100	0	60	40	100	0	80	20	100	0	70	30
66.45	100	0	60	40	100	0	80	20	100	0	70	30

Table-7: Percent response for /p/ - /b/ contrast (Taba Vs Tapa)

DISCUSSION

The results reveal several interesting findings. First of all, there was no change in the perception from voiced to voiceless with decrease in the preceding vowel duration. **Thus preceding vowel duration was not a cue for voicing in Kannada speaking children.** This agrees with the findings of Fruin and Bischoff (1976); Hogan and Rozyspal (1980), Van den Berg (1988), Usha Rani (1989) and Vinay Rakesh (1990) in that PVD is not a cue for voicing.

These findings, however, do not support those of Krause (1982, a) and Lehman and Scharf (1989) who indicated the cuing nature of PYD for voicing in children.

Fischer and Ohde (1990) found that there was an increase in voicing ratings across all continua when the vowel duration was increased without a change in the voicing category. However, the results of the present study did not reveal any such findings.

While several of these studies have been conducted in American English and a few on Dutch, the present study is in Kannada. The difference in the languages and their structure may be a cause for the difference in results.

Second, no consistent developmental trend in PVD cuing voicing was noticed. However, children from three years to six years showed an increase in percent identification of the voiceless percept /t/. These results are not in consonance with the findings of Krause (1982, a) and Lehman and Scharf (1989), who reported a clear developmental trend.

Third, there is some concurrence between the perceptual data and production data. When the perceptual data is compared with the production data, in production vowels are longer preceding voiced stop consonants and are shorter preceding voiceless stop consonants in 3-6 years old children and in adults (Table-8). However, 3-4, and 5-6 year old children show inconsistency in their production. At times the vowels preceding voiceless stops are found to be longer in duration (Savithri, 1992).

Age Range	Vowel Preceding voiced consonant (msec)	Vowel Preceding voiceless consonant (msec)	VD/VL Ratio	Ratio in English
3-4yrs	64.96	53.45	1:1.21	-
4-5yrs	103.02	98.96	1:1.04	1:2.75
5-6yrs	78.71	85.63	1:0.95	-
Adults	87.41	70.3	1:1.24	1:1.64

Table-8: Production data for preceding vowel and vowel duration ratio in Kannada children and adults (Savithri,1992) and in American - English Children and adults (Lehman and Scharf, 1989).

Also, vowel duration ratios are found to decrease from 3-6 years and increase in adult hood for Kannada native speakers. The ratio of vowel duration preceding voiced and voiceless plosives are reported to be very short when compared to English both in children and adults (Table-8). Also there is a large amount of overlap between the vowel durations before voiced and voiceless stop consonants (Fig-9a). Comparatively, the production range of American English for 5 years old children and for adults do not overlap (Fig-9b). This indicates the possibility of PVD not being a cue for voicing in Kannada.

Satya (1992) has found that closure duration is a cue to voicing in Kannada speaking children.

In the production data, also, the closure duration ratios for voiced voiceless are greater than the PVD ratios, this might perhaps reflect the interdependency of production and perception (Table-9).

FIG-9a: RANGE OF VOWEL DURATION ACROSS AGE IN KANNADA

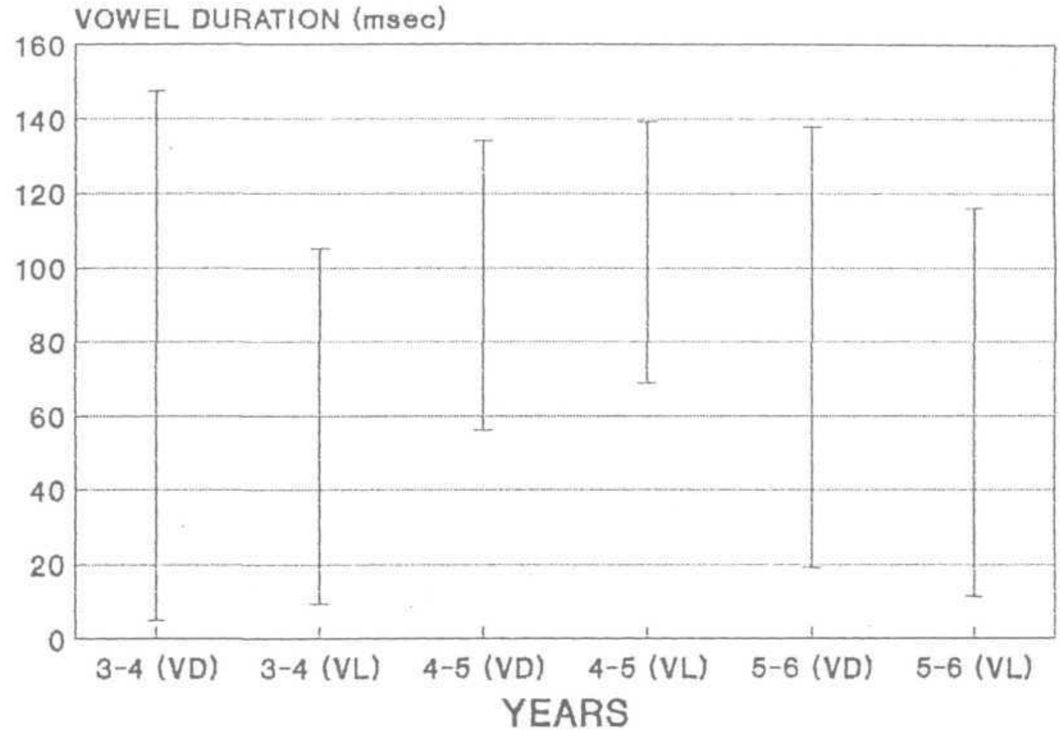
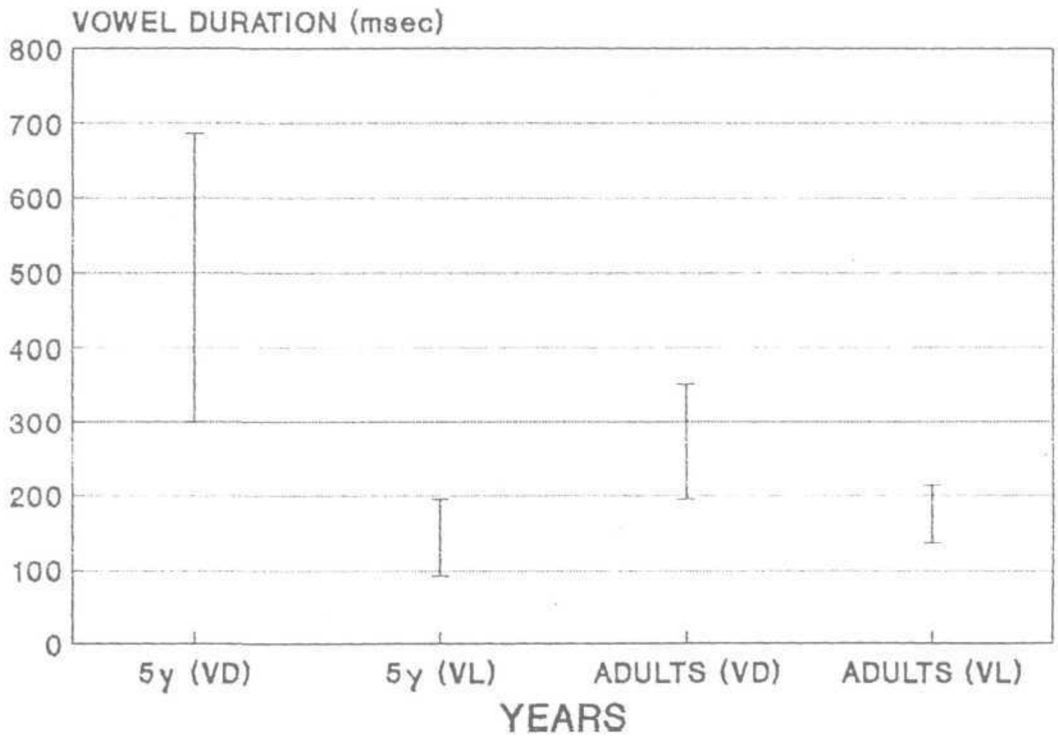


FIG-9b: RANGE OF VOWEL DURATION ACROSS AGE IN AMERICAN-ENGLISH



Age Range	PVD VD/VL	CD VL/VD
3 -4 years	1.21	1.38
4 -5 years	1.04	1.25
5 -6 years	0.92	1.37

Table-9: PVD ratio and closure duration (CD) ratio for voiced-voiceless cognates in Kannada speaking children (Savithri, 1992).

Thus, between PVD and closure duration, in Kannada, closure duration appears to be major cue for voicing, relegating PVD to the background. Also, in English, PVD is reported to be a voicing cue for final consonants. In languages like English, where final consonants exist, it becomes necessary that PVD be a voicing cue. However, in languages like Kannada where no final consonants occur, the lengthening or shortening of PVD may not be necessary to cue voicing of the following consonants. Studies involving manipulation of multiple parameters along with PVD may throw light on the nature of speech perception in children.

SUMMARY AND CONCLUSION

Speech perception in children is an area of focus in the past 2 decades. The presence of developmental trends in childrens perception has triggered several studies in this area using various cues to perception. Variation in adult perceptions across different languages has necessitated the study of speech perception in children from different linguistic backgrounds.

The present study was aimed, at determining the cuing strength of preceding vowel duration in the perception of voicing of the following stop consonants, in Kannada speaking children (3-6 years), and to investigate the developmental trend, if any, in the perception of voicing of stop consonants with preceding vowel duration as a cue.

Three plosives - voiced unaspirated velar plosive /g/, voiced unaspirated dental plosive /d/ and voiced unaspirated bilabial plosive /b/, as embedded in the medial position of four meaningful bisyllabic Kannada words, (baga, kade, taba, V aba) were selected.

These words as uttered by a seven-year old normal Kannada speaking male, were recorded and digitized by a 12 bit ADC at 20KHz sampling rate. These digitized words were edited using the wave form editor "DSW". The words were displayed on the screen of the computer and the steady state portions of the vowel were truncated in steps of two waves until there was no steady state.

In total there were 32 stimuli. These were randomized and iterated twice and then audio recorded in a metallic cassette. These synthetic stimuli were audio presented to 30 Kannada speaking children (5 males and 5. females each in the age range of 3-6 years with one year interval). The children were tested individually. Children in the age range of 3-4 years were conditioned to the toys representing the word pairs (Eg.baga-baka). On hearing the synthetic stimuli the child was to point to the appropriate toy and the examiner wrote the responses immediately on a printed forced-choice format. In 4-5 and 5-6 year old children, verbal alternate forced choice responses were obtained.

The percent response for each stimuli was calculated on the basis of which the identification and discrimination functions were plotted for each stimuli.

The results indicated the following:

1) Preceding vowel duration is not a cue for voicing in Kannada in children (3-6 years).
2) No consistent developmental trend is present for preceding vowel duration.
3) The perceptual data concurred with the production data.

In English PVD is a strong cue for voicing of stop consonants in final position. Several reasons could be attributed as to why PVD is not a voicing cue in Kannada. One of the reasons is that in production data (Kannada), the ratio of the PYD voiced and voiceless stop consonants is not high and significant (Savithri, 1992). However, the ratio of closure duration for voiced and voiceless stop consonants is high. Thus, in Kannada the perceptual trend may follow the production trend. Also, the results of the study by Satya (1992) indicate that closure duration is a cue for voicing in Kannada which again is in concurrence with the production data.

Another reason is that in Kannada, stop consonants do not occur in the final position. In the initial position PVD does not need to cue the voicing. In the medial position PVD is one among the several cues and it might be a secondary cue. It is possible that, in the absence of other cues PYD may cue voicing, or it may trade with other cues. It is suggested that the trading relation of PVD with other cues be investigated. Also, the importance of several cues should be delineated by manipulating multiple cues at a time.

The present study has contributed to the area of child perception. First of all, it indicates that the developmental trend reported in other studies might be only for the major or sufficient cues. Second, the cues seem to operate differently in different languages. Third, speech perception seems to be related to the abilities of speech production. Fourth, inspite of the generalisations made individual differences seem to be present in the development of speech perception. It is not known whether these individual differences are inherent or they are because of the experimental set up. It is doubtful whether one could generalize and if one could, care should be taken to see that at least majority of the responses are similar.

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