CLOSURE DURATION AS A CUE TO STOP CONSONANT VOICING A DEVELOPMENTAL STUDY IN 3-6 YEAR OLD KANNADA SPEAKING CHILDREN

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1992

Mother of mine

Mine of Gold

Mine of Mine

Mother Sweet Mother of Mine

For your Love, Support and Wisdom

CERTIFICATE

This is to certify that the Dissertation entitled " ***CLOSURE DURATION AS*** **A CUE** ***TO STOP CONSONANT VOICING - A DEVELOPMENTAL STUDY IN 3-6 YEAR OLD KANNADA SPEAKING CHILDREN"*** *is the bonafide work in partial fulfilment for Second year* M.Sc. [Speech *and Hearing] of the student with Register Number M. 9014.*

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CERTIFICATE

This is to certify that the dissertation entitled CLOSURE DURATION AS A CUE TO STOP CONSONANT VOICING - A DEVELOPMENTAL STUDY IN 3-6 YEAR OLD KANNADA SPEAKING CHILDREN" has been prepared under my supervision and guidance.

May 1992

Dr.S.R.Savithri
GUIDE

DECLARATION

The dissertation entitled ***CLOSURE DURATION AS A CUE TO STOP CONSONANT VOICING - A DEVELOPMENTAL STUDY IN 3-6 YEAR OLD KANNADA SPEAKING CHILDREN"*** *is the result of my own study undertaken under the guidance of Dr. S. R . Savithri, 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 1992

REGISTER NO.M.9014

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My pen falls mute to chant your praise
and I adore you in silence"

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"Where we love is home - home that our feet may leave but not our hearts"

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Our mistakes are one of the few things we can truly call our own and if we cannot learn from them who can?

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INTRODUCTION

"Anyone who has tried to work in this area will attest to the ingenuity, skill and patience required in conducting rigorous experiments with immature responders (children)..."

-Yeni-Komshian and Ferguson(1980)

Speech is a fascinating human attribute that can be analyzed, synthesized and recognized; it can also be compressed, stored and enhanced by digital signal processing techniques. Speech seems almost a by-product of evolution since no organ concerned in generating speech is uniquely dedicated to this task.

Speech may be defined as a form of oral communication in which transformation of information takes place by means of speech waves which are in the form of acoustic energy (Fant, 1960). The processing of speech signals with in the existing constraints of natural language has interested and excited scientists for many years. The ear seems to be custom built for the purpose of detecting and analysing sounds. The speech signals which are long spurts of a complex and constantly changing stream of sounds radiate from the speaker's lips, travel in air, impinge upon the ear drum of the listener and reach the higher cortical structures through middle and inner ears and the auditory pathway. The speech signal is analyzed at lower centres [below the thalamus level] to some extent and processing of specific speech parameters and other complex acoustic features of natural stimuli begins only at the level of medial geniculate body [MGB] which is located in the thalamus (Kiedel, Kallert, Korth & Humes, 1983). The linguistic components are added only at the higher centres of the cortex to the already analyzed signal to reconstruct the percept intended by the speaker. When the listener has reconstructed this signal (i.e. decoded and interpreted) speech perception is said to have occured.

Speech sounds are varied and have numerous acoustic cues. It seems that the auditory system depends on some of the acoustic cues of the speech sounds to identify and thus to perceive it. From the speech production studies it is known that speech sounds have different acoustic cues like the formants, their bandwidths and levels, Fundamental frequency(Fo), energy, duration of closure, preceding vowel duration,(PVD), burst energy and voice onset time(VOT).

In most of the speech perception studies, speech sounds are reconstructed from their known spectral and temporal parameters and presented to the listener's for judgement. Various parameters of the acoustic signal can be altered individually or in combination to evaluate the effect of their cues on listener's perception. The parameters that characterise the speech sounds are considered to cue the perception of those sounds. The different techniques used in the perceptual studies are Analysis by synthesis [Halle & Stevens, 1959], articulatory studies [Fant,1960] and synthesis by rule [Flanagan et.al 1970] . These techniques have been used to assess the role of temporal parameters like VOT [Lisker 1978, Lahiri 1980, Keating, Mikos Ganong 1981, Winitz et.al 1975], closure duration [Lisker 1977, Gupta, Agrawal & Ahmed 1973, Savithri 1989, Usharani 1989, Vinay Rakesh 1990, Van den Berg 1988, Fisher-Jorgensen 1979] transition duration [Summerfield & Haggard 1977, Dorman & Raphael 1980] and spectral parameters like F1 onset frequency, F2 onset frequency [Lisker 1978, Alwan 1989] etc. within and across languages.

The major areas of interest in speech perception have been speech perception in adults, speech perception in children and speech perception in the clinical population. Until fairly recently the study of speech sounds perceived and produced by children was a rather limited field of research. Interest in child phonology came from several sources such as general interest in child development, professional concern with language or speech problem requiring special education or therapy, or linguistic speculations about the relation between phonological development in the child and sound change in language. Unlike adult subjects, children are harder subjects and this area presents with methodological problems.

A related problem is the nature of phonemic perception in children i.e. does the child respond differently to a given phonetic contrast when the contrast is tested by use of known words and nonsense words [Graham & House 1967, Tikofsky & McInish 1968]. The relation between perception and production is another topic of concern. Crosslinguistic research is one way of investigating the effects of exposure to a given phonological system on the perception and production of phones from another phonological system [Williams 1980]. Another avenue of research in this area is the systematic comparison of children's production to their perception of the same phonetic contrasts [Zlatin & Koenigsknecht 1976, Broen et.al 1983, Lehman & Sharf 1989]. Such an approach is useful for investigating the phonology of normally developing children and language delayed children.

While studies of Broen et.al(1983) Hoffman et.al (1984), Krause (1982b), Meynuk & Anderson(1969), Ohde & Sharf (1983, 1984), Zlatin & Koenigsknecht 1975, 1976) support that there is a relation between perception and production, Straight (1981) considers that it is not necessary to assume a common basis for perception and production.

There are only a few studies on perceptual development in children. Zlatin & Koenigsknecht (1975) made the first attempt to investigate the perceptual development of the voicing contrast in 2 year old children, 6 year old children, and adults. Thirty eight VOT variants ranging from -150 to +150 msecs were given to ten 2 year old children and ten six year old children and 20 adults. The results indicated that the 2 year old children shifted their identification from /g/ to /k/ at a significantly later mean lag time than both 6 year old children and adults. Also, comparing this with the production data of the same subjects, Zlatin et.al stated that a correspondence between perceptual identification categories and production VOT values existed. Moslin(1976) found that voicing contrast is achieved by 1.3 to 2.8 years. In contrast, Bailey & Haggard (1980) found low correlation between production and perceptual VOT category boundary for 20 to 50 months old children. Among Indian languages, Shanthi et.al(1991) in a study on the effect of reducing closure duration(CD) on the perception of place and manner in 4-11 year old Kannada speaking children reported an incosistent developmental trend. However, one of the unresolved issues in the current explanations of phonological development is the relationship of the child's perception of phonemic contrast to his or her production of those contrasts.

Some experiments have studied only small number of children and have utilized informal testing procedures in which the exact nature of the stimuli are not specified. Others [Zlatin & Koenigsknecht 1975] examined only children who have acquired the contrast that is being tested and at discrete age groups i.e. 3 years, 6 years and adults.

Although these sources of data are useful, there is a pressing need for both cross sectional and longitudinal studies with groups of children of sufficient size to allow atleast preliminary generalisation about development of speech perception. It is also of equal importance that the study utilize stimulus materials that allow for the precise specification of the acoustic phonetic dimension that children "do" and "do not" differentiate at various stages of development and also in different language environments.

In this context the present study was planned. It aimed at evaluating the effect of reducing the closure duration on the perception of voicing in stop consonants in 3 year to 6 year old Kannada speaking children. Specifically the study aimed at determining -

(i) the developmental trend in the perception of closure duration as a cue to voicing of stop consonants (p,t,t,& k) in 3 to 6 year old Kannada speaking children,

(ii) the effect of linguistic syllabic boundaries i.e. whether bisyllabic and trisyllabic boundaries influence the perception of voicing of stop consonants in medial position in 3-6 year old Kannada speaking children,

(iii) the changes across the place of articulation in closure duration needed for change in perception for 3 to 6 year old Kannada speaking children, and

(iv) the concurrence of perception data with production data on closure duration for stop consonants.

REVIEW OF LITERATURE

Stop consonants are produced by occluding the oral cavity by an articulator. Air is held behind the articulation for sometime and then is released. The stops represent the nonlinearity of the speech production system. They also demonstrate the redundancy of acoustic cues available to distinguish speech sounds. The nature of stop perception provides the best example for listener's use of the acoustic overlapping of phonemes in speech systems. Also, they have consistently produced evidence for phonetic level processing. They appear to be the most highly encoded speech sounds [Day & Vigorito 1973].

The salient features of stop consonants are:

(1) A period of occlusion (silence/voiced)

(2) A transient explosion (usually less than 20 msec) produced by shock excitation of the vocal tract upon release of occlusion,

(3) A very brief (0-10msecs) period of frication as articulators separate and air is blown through a narrow constriction as in the homorganic fricative,

(4) A very brief period of aspiration (2-20msec) 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 formant transitions, reflecting the final stages of articulatory movement into the vowel during the first few cycles of laryngeal vibration (FIGURE-1)

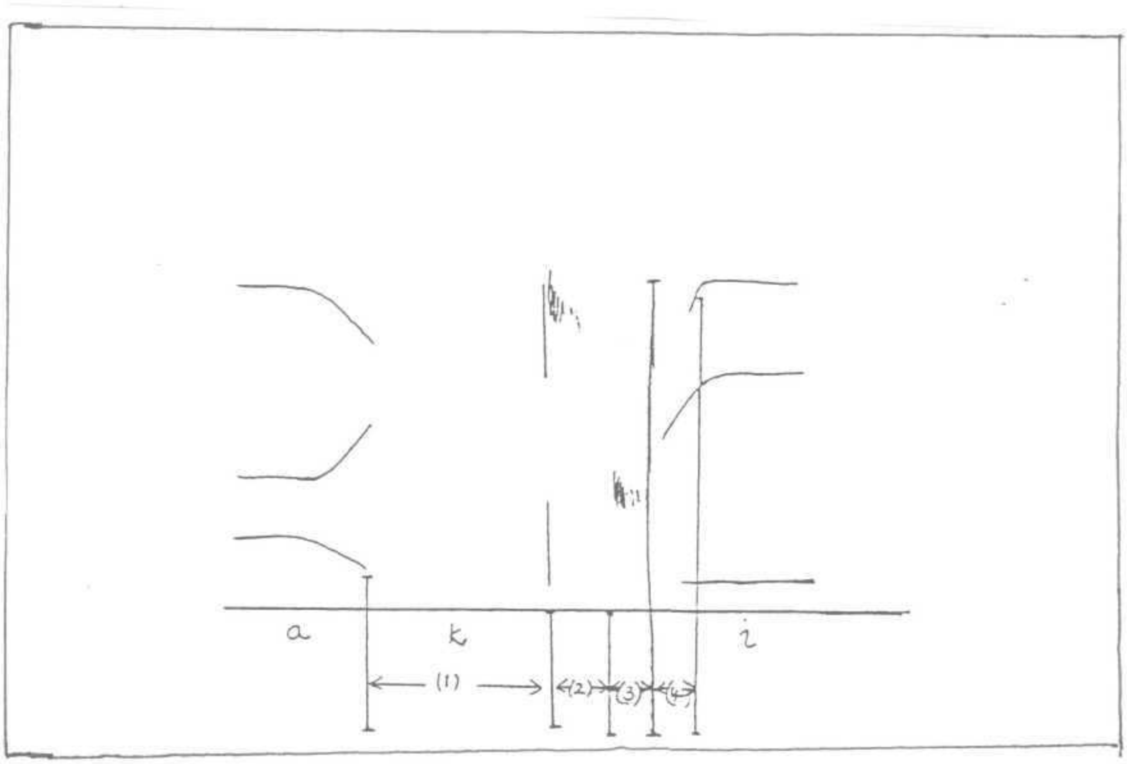


FIGURE-1 Spectrogram depicting the salient features of /k/

(1) period of occlusion

(2) period of frication

(3) period of aspiration

(4) voiced formant transition into the following vowel

Several experiments have been conducted to investigate the perceptual cues of stop consonants in normal adults and children and in handicapped population. The various parameters studied can be listed under the spectral and temporal characteristics.

The spectral parameters include:

(a) burst amplitude

(b) burst frequency

(c) Fo change in the succeeding vowel

(d) Frequency of formants 1,2,& 3

(e) Bandwidth of formants 1,2, & 3.

(f) Direction of second and third formant (F2 & F3) transitions.

(g) Voicing during closure

The temporal parameters include :

(a) preceding vowel duration (VD/PVD)

(b) closure duration (CD)

(c) voice onset time (VOT)

(d) voice offset time

(e) stop consonant duration

(f) off glide duration of the first formant F1

(g) off glide duration of the second formant F2

(h) burst duration (BD)

Voicing cues in stop consonants have been extensively studied and the various cues are:

(a) presence or absence of low frequency voice bar

(b) presence or absence of noise indicating aspiration

(c) change in first formant onset time

(d) preceding vowel duration

(e) closure duration

Of these, closure duration is the interval of stop closure indicating the time for which the articulators are held in position for a stop consonant. FIGURE-2 depicts the closure duration for voiced and voiceless stop consonants.

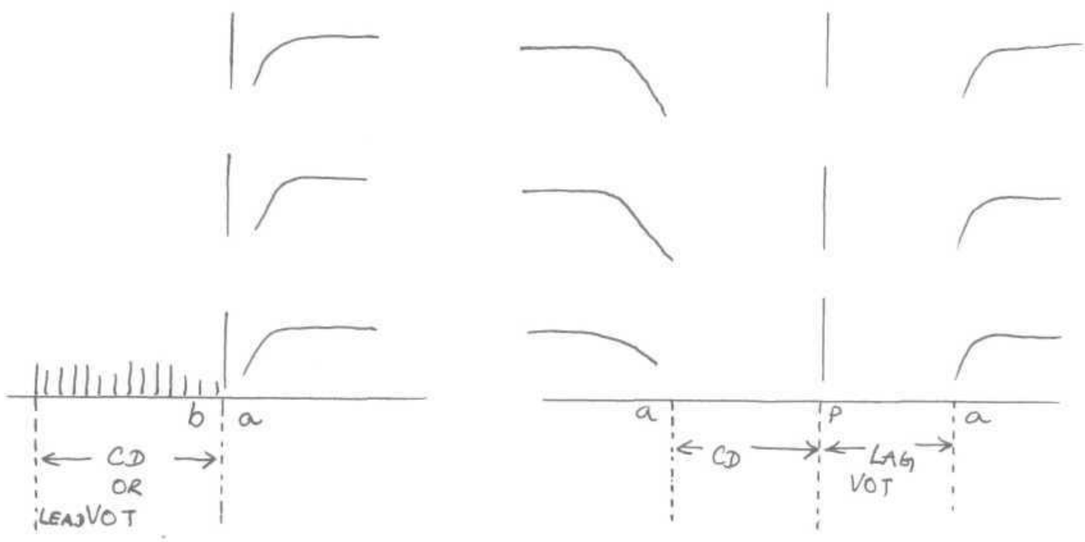


FIGURE-2 Spectrogram depicting CD and VOT for /b/ & /p/.

Voice Onset Time (VOT) is defined as the temporal interval between the beginning of stop release burst and onset of periodicity [Flege & Eefting 1986]. For a voiced stop consonant, closure duration (CD) is synonymous to Lead VOT.

As the present study is on closure duration as a cue for voicing of stop consonants, this review is restricted to the studies on the role of closure duration as a cue to the perception of stops which is dealt under the following subheadings.

(1) C.D as a cue for voicing of stop consonants in adults.

(2) C.D as a cue for of stop consonants in children.

Also as lead VOT is equivalent to closure duration, studies on lead VOT will also be dealt with.

1] CLOSURE DURATION AS A CUE FOR VOICING OF STOP CONSONANTS IN ADULTS:

CD has found to cue voicing, place of articulation and manner of articulation. Also, it has been reported to trade with spectral cues. While Lisker(1978), Price & Lisker(1979) Lisker & Price(1979), Port(1980), Raphael (1981), Price & Simon (1984), Usharani (1989), Cazals & Palis (1991), Vinay Rakesh (1990) studied CD as a cue to voicing, Fischer - Jorgensen (1979), & Repp(1984) studied the effect of varying CD on the perception of place of articulation. CD as a cue to stop manner has been reported by Dorman et.al (1979), Bailey & Summerfield(1980), Fitch et.al(1980) & Datta(1989). Port (1979) considers CD to trade with spectral cues for the perception of place of articulation. Also lead VOT has been studied by Keating et.al(1981).

a) Closure duration as a voicing cue:

Lisker in 1978 studied the perception of synthetic stop consonants and concluded that there are significant differences among subjects to the extent in which their labelling of silent CD as /p, t, k/ or /b,d, g/ are duration controlled. At short durations subjects perceived voiced stops and at longer CD subjects perceived VL stops. Also, the response patterns differed in crossover values and clearness of category separation when different tokens of same words serve as stimulus sources. When the two places of articulation, labial and velar are considered, the nature of closure interval - silent Vs buzz filled seems a more reliable predictor of labelling behaviour than does duration. The perception of labially produced closures as alveolar flaps when the duration are very short depends at least partially on the failure of alveolar flap articulation to produce place cues clearly distinguishable from those of bilabial stop articulation.

In contrast, Lisker & Price's (1979) study showed that there is a context in which the manipulation of closure duration has a rather different phonetic outcome, where in fact a longer duration is reported as /d/ and a shorter as /t/. The word pair /center-sender/, where the medial consonants are described for many varieties of American English as a nasalized flap in one case and as a sequence of nasal plus stop in the other is such a context. Shortening the oral voiced closure of sender yields center when the closure is reduced to 40 msec or less.

Port(1980) studied V/C cue ratio as a post-vocalic voicing cue. Synthetic stimuli of the words /dibber/ and /dipper/, created with five durations of dib (140 - 260 msec) and nine medial stop closure durations (20-140 msec) were identified by 16 listeners. The boundary along the stop duration continuum was different for each /dib/ duration, but when plotted as the ratio of the stop closure to the preceding vowel, all curves were superimposed. In a matching experiment with /digger-dicker/, the same effect was found except that the V/C cue ratio boundary was different for the velar as was expected from production results. These findings, similar to the v:c - vc syllable type contrasts in other geminate languages imply that the voicing effect on preceding vowels cannot be handled insightfully with a postsegmental temporal implementation rule that modifies the vowel since production and perception data agree that the phonologically relevant parameter is an abstract ratio between these two intervals appropriate for a particular context.

Raphael (1981) questioned the efficacy of individual acoustic cues to word final stop cognate perception in naturally uttered syllables isolated from their original context and whether the context in which such syllables occur contain acoustic information i.e. perceptually relevant to stop cognate opposition. Naturally produced tokens of the word /peg/ were excised from two different contexts and acoustically analyzed. One representative token from each context was then edited in several ways in order to ascertain the cue values of a number of variables. The stimuli were tested in isolation, in their original context and in contexts from which the word /peck/ had been deleted. They were given to two groups of subjects of 5 members each, one experienced in perceptual studies and other naive listeners. The results of the experiment indicated that the number of variables can be a sufficient cue to cognate opposition and that the efficacy of a particular cue depends in a large measure both on context from which it was extracted and context in which it was heard. They also found the CD was generally a sufficient cue for voicing while the VD is an idiosyncratically sufficient cue for voicing. The implication of the study was on discovering and describing a general articulatory strategy underlying both production and perception of cognate opposition.

Price & Simon (1984) explored silence durations from 35-125 msec in four steps and established that on decreasing silence duration, normal hearing young adults perceived voiced cognates. Cazals & Palis (1991) investigated the perception of voicing of an intervocalic plosive for a natural speech sample "aka" as a function of occlusive silence duration. 20 normal hearing subjects participated in this study. The CD was cut in 20 msec step from 0-200 msec. For all normal subjects the perceptive change occured over a range of about 60 msec to 120 msec showing CD is an important cue to voicing.

Usharani (1989) aimed to determine the effect of closure duration on the perception of medial geminate unaspirated bilabial and velar stop consonants across the language groups

Kannada & Hindi. Four meaningful Kannada words with the geminate bilabial and velar stop consonants (akka, agga, appa & abba) synthesized by analysis by synthesis and synthesis by rule method were the stimuli. Ten native Kannada speakers and five native Hindi speakers served as subjects. CD of the stop consonant /kk, gg, pp and bb/ was varied in these test words by truncating the CD in 10msec steps. It was found that when CD was reduced, percept changed from cluster to non cluster and voiceless to voiced. Vinay Rakesh (1990) using the same stimuli as Usha Rani reported similar findings with Telugu and Malayalam speakers.

(b) CD as a cue for place of articulation:

Price & Lisker (1979) studied the acoustic invariance question in an observed asymmetry in the effect of closure manipulation on naturally produced tokens of /rapid & rabid/. Shortening the /p/ closure has relatively little effect and lengthening the silence in /b/ closure produce a decisive shift in labeling from voiced to voiceless.

Fischer-Jorgensen (1979) used synthetic CV syllables /p,t,k/ & /b,d,g/ produced by synthesis by rule in Danish. A forced choice percept of the syllables was given. The results indicated that CD increased from /g/ to /b/ percepts implying CD cues the place of articulation of stop consonants.

Repp (1984) studied the perception of stop consonants in a consonant neutral (s-1) context in English. Truncated natural

/p/, /ṭ/ & /k/ release bursts at two intensities were preceded by variable silent closure intervals. Ten subjects listened to the stimuli and identified in writing as beginning with /sl, spl. stl or skl/. The bursts though spectrally distinct, conveyed little specific place information but contributed to the perception of stop manner by reducing the amount of silence required to perceive a stop (relative to a burstless stimulus). Burst amplitude was a cue for both stop manner and place, higher amplitudes favoured /ṭ/, lower amplitudes favoured /p/ responses. The silent closure interval, a major stop manner cue, emerged as the primary place cue in this situation. Short intervals led to /ṭ/, long ones to /p/ responses. All these perceptual effects probably reflect listener's tacit knowledge of systematic acoustic differences in natural speech.

(c) CD as a cue to Manner of Articulation:

Dorman, Raphael & Liberman (1979a) on using synthetic speech stimuli /Spe/ & /Ske/ found that when CD was less than 20 msec listeners reported no stop consonant and thus only /Se/ responses. If the duration was more than 40 msec then stop was heard. The same investigators in (1979b) studying the duration of silence between s & 1 in /slit/ found that intervals less than 6 msec were perceived as /slit/ and at longer intervals of 450msec, /split/ was perceived.

Fitch, Halves & Erickson & Liberman (1980) used synthetic /slit/ & /Split/ produced by synthesis by rule in English. The silence interval was varied from 8-160msec in 8msec steps. Using a forced choiced identification of /slit/ & /split/, it was found that silent duration was effective in contrasting "slit" from "split". As the silent durations increased, judgements shifted from /slit/ to /split/. The smallest shift was 8msec and the highest was 40msec.

Datta (1989) using natural speech /Stri/ and /Sri/ in Bengali found that when silence between /S/ & /tri/ was removed listeners perceived /Sri/. Also, when silence of about 30msec was introduced between /S/ & /ri/ it was perceived as /skri/.

(d) CD Trading and Spectral Cues:

Port (1979) examined the formant trajectories of /rabid/ & /rapid/ and suggested that while CD were quite distinct, the formant trajectories were not. Some evidence was also found that in bilabial stops, the CD was not normally shorter than 30msec. Thus, it seems that when C.D was long enough, so that either lip or tongue tip could have produced the stop, the spectral information dominated and 16 listeners heard bilabial stop. But when CD was shorter than a possible labial stop duration, cues become unambigous and was apparently not contradicted by the spectral information. He also opined that if CD is a major cue to the number of stops between vowels it might also serve as a distinctive cue to a particular place of articulation.

2] CLOSURE DURATION AS CUE FOR STOP CONSONANTS IN CHILDREN.

Studies on child perception have been evolved with the intention of searching an answer for the basic questions - Viz. (1) Is the child perception similar to adult perception or different? (2) Does the child perceive the adult speech in the same way as he perceives the children's speech? (3) Is there a developmental trend in the perception? (4) Does this development trend in perception correlate with that in production?

Studies have continued as these questions remain unanswered. Two views are prevalent in the area of child perception. While one view is that the child's production and perception are related, the other view is that they are independent.

Zlatin and Koenigsknecht (1976), Chaney (1978), Strange and Broen(1981), Krause (1982b), Broen, Strange, Doyle, Heller(1983)and Menyuk & Anderson(1969), Hoffman, Daniloff, Alphonso, and Shucker(1984), Hoffman, Daniloff, Bergon & Shuckers(1985), Ohde & Sharf (1983, 1984) all support that there is a relation between perception and production. However, Straight (1981) considers it unnecessary to assume a common basis for perception and production and instead proposed that the two systems can use information from both systems in making various judgements.

In support of these two views, studies which involve only production or perception in children and studies which involve both production and perception in children have been conducted. VOT studies are the major ones discussed followed by those involving language differences and development of CD perception.

(a) CD/VOT as a voicing cue:

Winterkorn, Macneilage & Preston (1967) used five selected VOT stimuli with 3 year old children and found that they were able to differentiate between apical stops when VOT differed by at least 25msec. In this study, inference regarding the perception of VOT differences between Voiced and Voiceless apical stops were based on the children's ability to imitate synthetic CV syllables.

Yeni-komshian, Preston, Cullen (1967) studied the perception of VOT difference between Voiced and Voiceless apical stops based on the children's ability to imitate synthetic CV syllables. The authors presented a greater number of stimuli, and found that majority of their 5 & 6 year old children did not demonstrate the ability to distinguish between apical cognates in the manner consistent with the above study. In fact only 4/12 subjects evidenced phoneme boundaries between voicing categories at about +35 msec on the same stimuli. Other children gave a singular response to all VOT variations [for Eg. /da/] or produced sounds which were not always consistent with the stop consonants /t/ & /d/ [for eg. /h/] closure.

Perceptual ability in children has also been assessed with combined identification and discrimination. Wolf (1973) found that VOT continuum discrimination functions for eight Kindergarten and eight second grade children were consistent with their identification functions, with good discrimination of cross category stimuli, and chance discrimination of within category stimuli. Phoneme boundary width for Kindergarten subjects were 27.72 msecs and second grade was 23.77 msec. Difference limen (msec) was 6.63 msec for Kindergarten children and 4.50 msec for second grade.

Simon(1974) found results in support of a relation between perception and production of speech in subjects aged 6 to 14 years of age. He also found significantly larger difference limens as a function of age. The phoneme boundary width was between 15 and 20msecs and difference limen for 4-6 year old was less sharp than 14 year olds. He expected that the younger children should have less sharp boudaries since these children have only recently acquired some confidence in manipulating the adult phonological system and are still not very sure of themselves in extreme situations of forced choices.

Kewley - Port & Preston (1974) found that in the acquisition of productive control over VOT, children appear to progress through three developmental stages. During the first stage, children do not distinguish between Voiced and Voiceless stops, producing both with short lag range. In the Second stage, children begin to differentiate between the two stop categories but employ VOT values that are more variable and exhibit more overlap than the comparable adult VOT values. In the final stage, the amount of overlap between the VOT values for the two stop categories decrease, assuming a more bimodal distribution. Gilbert (1977) reported the same results as Kewley - Port & Preston (1974).

Zlatin & Koenigsknecht (1975) designed a study to investigate the perceptual development of the voicing contrast in 2 year old children, 6 year old children and adults. An underlying hypothesis of this research was that there is a progressive change in the ability of children to make linguistically relevant discriminations between homorganic stops on the basis of variations in VOT.

Meaningful monosyllabic speech stimuli were generated for four VOT continua on the Haskins laboratories computer controlled parallel resonance synthesiser. The VOT continua for identification of voiced and voiceless labial, apical, and Velar stop consonants included bees/peas, bear/pear, dime/time and goat/coat which were picturable. Thirty eight VOT variants ranging from -150 to +150 msec were synthesised for each of the four continua subjects included 20 adults, 10 two year old children and 10 six year old children. A total of 150 judgements (10 occurences of 15 stimuli) on each continuum was analyzed for each subject. For labial and apical continua values in 5msec steps ranged from 0 or simultaneous onset of the burst and voicing to +60 and in 10 msec steps from +60 to +80 msec voicing lag. The stimuli for velar continuum ranged from +25 through +135 in 5msec steps to +60 and in 10 msec steps thereafter.

Four identification function for the labial [bees/peas, bear/pear], apical [dime/time] and velar [goat/coat] stop cognates were plotted for each subjects. Four measurements were obtained from each of these functions - VOT 50% crossover, lower limit of phoneme boundary, upper limit of the phoneme boundary and phoneme boundary width. MANOVA was used to test age effects for each of these four criterion measurements. The results indicated that 2 year old children shifted their identification from /g/ to /k/ at a significantly later mean lag time than both 6 year old children and adults. Examination of the crossovers for individual subjects within each age group on the velar continuum indicated that 60% of 2 year old, 30% of 6 year old and 30% of adults had crossover values between +67 and +76 msec. The remaining individuals in the latter two age groups evidenced earlier crossover. By contrast, the remaining two year olds showed crossover values in excess of 76 msec. No significant differences were found between the 6 year old children and the adults on the velar continuum and all three groups evidenced similar mean crossover times for labial and apical cognates.

Results also indicated that there was a difference among the three age groups with respect to velar boundary limits. No age effect was shown in comparison of lower and upper phoneme boundary limits for labial and apical stimuli. On the velar continuum 2 year old children displayed later lower boundary limits than the 6 year old and later upper boundary limits than six year olds and adults. The 6 year olds and adults evidenced similar boundary terminations.

Zlatin & Koenigsknecht (1976) used the acoustic cue of VOT to study the development of voicing contrast in 10 two year old children, 10 six year old children and 20 adults. A comparison was made between perceptual identification of homorganic labial, apical and velar stop consonants and VOT distributions associated with the production of these sounds for these three groups of subjects. Thirty utterances of the words bees/peas, bear/ pear, dime/ time, goat/coat were elicited from each subject, VOT measured and individual production distribution for labial, apical and velar stops plotted. Significant age related differences were shown for mean VOT, Mean lead time for voiced stops, range of production and discreteness of voicing categories.

For voicing lead, significant difference were found for /b/ & /g/. Differences in the perceptual performance among the 3 age groups were most clearly evident in the analysis of phoneme boundary width. The 2 year old children evidenced significantly wider boundaries than the 6 year olds for velars and bilabial and on all stops when compared to adults. While 6 year olds had wider phoneme boundary only for velar continum than the adults. Significant age related differences in the perception were observed in VOT difference magnitude required for distinguishing prevocalic stop cognates which decrease oas a function of age of listeners. Inferences concerning perceptual development need not be based solely on a general observation. Rather specific measurement of perceptual behaviour such as upper limit and lower limit of phoneme boundary and phoneme boundary width can also be used to specify the nature of the phonological change. There is no information that would indicate definitely whether perceptual development is a continuous gradually changing process or on going i.e. discontinuous and requires a reorganisation of the

P.T.O.

discrimination capacities shown in infancy.

Place of articulation	2 years	6 years	Adults
50% CROSSOVER			
p/b	31.6	28.7	29.65
p/b	33	28.30	33.60
ḍ/ṭ	26.3	24.3	26.55
g/k	76.9	62.30	65.65
LOWER LIMIT			
p/b	25.5	24.2	25.45
P/b	25.3	25.6	29.45
ḍ/ṭ	20.4	21.8	23.80
g/k	65.6	55.80	61.95
UPPER LIMIT			
p/b	38.7	33.5	33.55
p/b	39.4	31.7	37.6
ḍ/ṭ	32.4	27.8	29.8
g/k	86.3	68.7	69.5
PHONEME BOUNDARY			
P/b	14.2	9.3	8.10
P/b	14.1	6.10	8.15
ḍ/ṭ	12	6	5.80
g/k	20	12.7	7.50

Table-1 : 50% crossover, lower limit, upper limite and phoneme boudary (Zlatin & Koenigsknecht,1976).

Thibodeau & Sussman (1979) found categorical perception paradigm examining the voicing feature of bilabial stop consonants /b/ & /p/. 12 subjects between the ages 6 to 9.5 years were selected with mean age of 7 years. The stimuli used were copies of the synthetic speech sounds from the series made by Lisker & Abramson(1967) and classified as /ba/ or /pa/ consisted of 450msec. Three formant patterns with VOTs ranging from -100 (voicing lead) to +100 (voicing lag) in 10msec steps. 50% crossover, phoneme boundary width were calculated and also the group discrimination function. On the VOT continuum last 25msec for lead and lag produced 94% to 100% correct voiced/voiceless responses. Looking at identification scores away from the end points stimulus values 100 ms lead to +10ms lag and from +50ms lag to 100msec lag produced accuracy scores ranging from a low of 95% score to 100% correct. The mean difference limen for normal group was 8.75 msec and phoneme boundary width of 25.83.

Bailey & Haggard(1980) proposed two measures as production analogs of category boundary and separation in perception. Production boundary is defined as that value which has an equiprobable choice of being produced as a member of either category. Production separation is defined as the difference between the means of two distribution with respect to their SD. Bailey & Haggard found low correlation between production and perceptual VOT category boundary for 20 to 50 months old children and low positive correlation between production separation and measures of consistancy and boundary slope in perception. Although these results do not support a relation between perception and production of the VOT contrast they do provide a means of comparing perception and production data for other acoustic parameters.

Moslin(1976) found that voicing contrast is achieved by 1.3 to 2.8 years. Higgs & Hodson(1978) studying 4 year old children found that they were significantly poorer than adults in their ability to identify voicing from naturally produced minimal pairs contrasting final voiced and voiceless consonant.

B) Closure duration trading with spectral cues:

Wardrip-Fruin & Peach(1984) found that 3 year old were most sensitive to durations (VD) and 6 year old 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.

c) Acquisition of VOT in several languages:

Williams(1980) did a cross linguistic study on Spanish and English children of 8-16 years on labelling of VOT series as a function of exposure to English and he found that there was a gradual shift from Spanish like patterns to English which occured faster in the younger age groups. The children who were learning English were predicted to show VOT as that of bilingual English i.e. between monolingual Enlgish and Spanish patterns.

Eilers(1983) showed that Spanish learners appear to use specific linguistic experience at an early age to master perceptually the less salient lead Vs short lag contrasts. Eiler, Kimbrough Oiler, Bineto, Garcia & Carman(1984) studied the production of VOT in a group of Spanish and English learning subjects at 1 year and 2 years of age. VOT of initial stop consonants from cannonical utterances was measured oscillographically. At 1 year no significant difference in VOT production was found between Spanish and English learners at any place of articulation. Mean VOT values for infants fell in the short lag range. But at 2 years, 4/7 children in the English group and 4/7 of children in Spanish group showed significant evidence of having acquired VOT distinction in stop consonants appropriate for their native language.

Flege & Eefting (1986) examined the production and perception of the contrast between /ṭ/ - /ḍ/ by subjects differing in native language and age. The stimuli was a reading list of phonetically comparable Spanish and English words which includes eight exemplars of three minimal or near minimal pairs initiated by /p,ṭ,k/ or /b,ḍ,g/ in the context of /a/. Parking/barking, target/darling, carver/garner was used in English, Data/bato, tato/dato and cato/gato was used in Spanish. The VOT continuum used in the identification experiment consisted of CV stimuli with VOT value ranging from -60msec to 90msec in 10msec increments. Acoustic analysis revealed that native speakers of English realised word initial /ṭ/ with significantly longer VOT values (85msec) than native speakers of Spanish (19msec). Native English and Spanish adults realised /ṭ/ with VOT values that were non significantly longer than those of 9 year old of the same native language background. Native English adults prevoiced /ḍ/ more often than English children, but Spanish adults and children realised /ḍ/ with lead VOT values in nearly every instance. In labelling task, the native English speakers showed steeper identification functions and category boundaries at significantly longer VOT values than age matured native Spanish subjects. The boundaries of both the native English and Spanish adults occured at significantly longer VOT than those of children who spoke the same language. Three possible explanations were offered for the effect of age on stop voicing judgements, the auditory processing of acoustic parameters associated with stop changes with age, listeners require an increasingly long VOT interval to perceive /ṭ/ as they get older because they produce /ṭ/ with somewhat longer VOT values, listeners "attune" their perception to optimally match the stops they hear.

Burham A Earnshaw & Clark(1991) investigated the effect of specific linguistic experiences on categorical perception which would be reflected by different developmental courses for the perception of native and non-native contrasts. English language environment infants, 2 & 6 year old children , adults were tested for their identification of sounds on a native Voiced /voiceless bilabial stop from -70msec to +70msec VOT in 10msec steps and a non-native prevoiced/voiced bilabial stop speech continuum. Categorical perception of the two contrast diverged as a function of age, increasing for the native contrast and decreasing for the non-native between 2 and 6 years.

(d) Perceptual developmental study on closure duration.

Shanthi, Iyer & Savithri (1991) studied the importance of closure duration as a cue to place and manner of articulation of the velar and dental plosives in Kannada. Samples of two plosives /g/ and /d/ were obtained from the words /a:ga/, /i:ga/ & /adu/ as uttered by Kannada speaking children in the age range of 5-8 years. The closure duration of plosives in each word was systematically reduced and 47 stimulus with varying closure duration were synthesized and recorded and these were presented to 4-11 year old normal children for perceptual evaluation. The subjects had to identify labels as a response in a forced choice paradigm. The results indicated that closure duration was a cue for the perception of place and manner of articulation in Kannada. Reduction in closure duration brought about a change in place of articulation first and with further reduction there was a change in manner of articulation. For all tokens of /g/ except the token of /i:ga/ with continuous voicing during closure and for all tokens of /d/, this trend was observed. For the token of /i:ga/ which had continuous voicing during closure, the percept did not change to place/manner across the age groups. An important finding was that a shift in category boundary from velar to either alveolar or retroflex place of articulation in 4-5 year old occured at a longer closure duration values than that of 10-11 years old. The observation that at reduced closure duration, retroflex is perceived was in concurrence with the production data. However, in tokens with cessation of voicing of i:ga, there was no change in place and manner across the age groups even at minimum closure durations. This could be attributed to the fact that this token was produced with a very short closure duration (25msecs). Secondly, the /d-r/ category was observed at very short closure duration. Third, other responses like /y/, /d/, /h/ were also obtained for /g/ & /t/ for /d/. The second formant of /i/ and second formant of /y/ & /l/ are close and hence a reduction in closure duration of /g/ in tokens of /i:ga/ would bring about proximity of /i/ and /a/ to give a percept of semi vowel /y/ or /l/. The results of this study partly support the notion of a relation between production and perception data. Also, a developmental trend though not consistent was noticed across age groups for both place and manner.

The review indicates that research has been carried out in developmental phonology from description of the acquisition of specific speech sounds to more discrete examination of the evolution of phonological contrast. However, the field of child perception is full of paradoxical results. This warrants more systematic study over age groups and in different languages. The present study is an attempt towards this. It aims at evaluating the effect of closure duration on the voicing of medial stop consonants in bisyllabic and trisyllabic words in 3-6 years old male and female Kannada speaking children.

METHODOLOGY

Material:

Four plosives - Voiceless velar /k/, voiceless retroflex, /ṭ/ voiceless dental /t/ and voiceless bilabial /p/ were selected for the study. Four meaningful picturable bisyllabic Kannada words (baka, tuṭi, titi & wope) and four meaningful picturable trisyllabic Kannada words (pakoda, Karaṭi, Itara & Talapu) with these plosives in the medial position were considered. These words formed a minimal pair with a change from voiceless plosive to voiced plosive. Table-2 shows the words.

Key Phoneme	Bisyllabic word selected	Trisyllabic word selected
k	Baka	Pako:da
ṭ	tuṭi	Karaṭi
t	titi	Itara
p	Wope	Talapu

TABLE-2 : Words selected for the study
Phoneme underlined is the phoneme of interest.

These eight words with voiceless plosives in the medial position were written, one each on a card and a seven year old normal Kannada speaking male child was selected as the subject. The child was visually presented with one card at a time and was instructed to utter the word into a microphone kept at a distance of 10cms from the mouth in a sound treated room in a natural manner. All these were digitally recorded on a computer with a 12bit ADC at a sampling frequency of 20KHz.

Using the waveform Editor DWSSLC, Closure duration was cut in 10msec steps from the burst end until the closure duration was almost removed (less than 10msec). TABLE-3 shows the original closure duration and the number of stimuli for each plosive.

Each word with its synthetic tokens was considered as a test and within each of the eight tests, the tokens were randomized and iterated twice. These tokens were recorded on digital cassettes with an interstimulus interval of one second.

Test Word	Original Closure (msec)	Number of synthetic stimulus
Baka	83.2	9
Pakoda	122.55	13
tuti	84.95	9
Karati	63.65	7
titi	112.7	12
Itara	105.30	11
Wope	77.1	8
Talapu	117.5	12
	TOTAL NUMBER OF STIMULI	81

Table-3: Test Stimuli (Key phoneme of interest is underlined).

Totally eight tests consisting of 81 synthetic stimuli formed the material.

The digitized wave form was displayed on the screen of the computer by using the program DWSSLC developed by VSS (voice & Speech systems). Closure duration was measured for each plosive from the wave form. Closure duration was defined as the duration between the offset of regular waveform for the preceding vowel and the onset of the burst for the plosive (Figure-3).

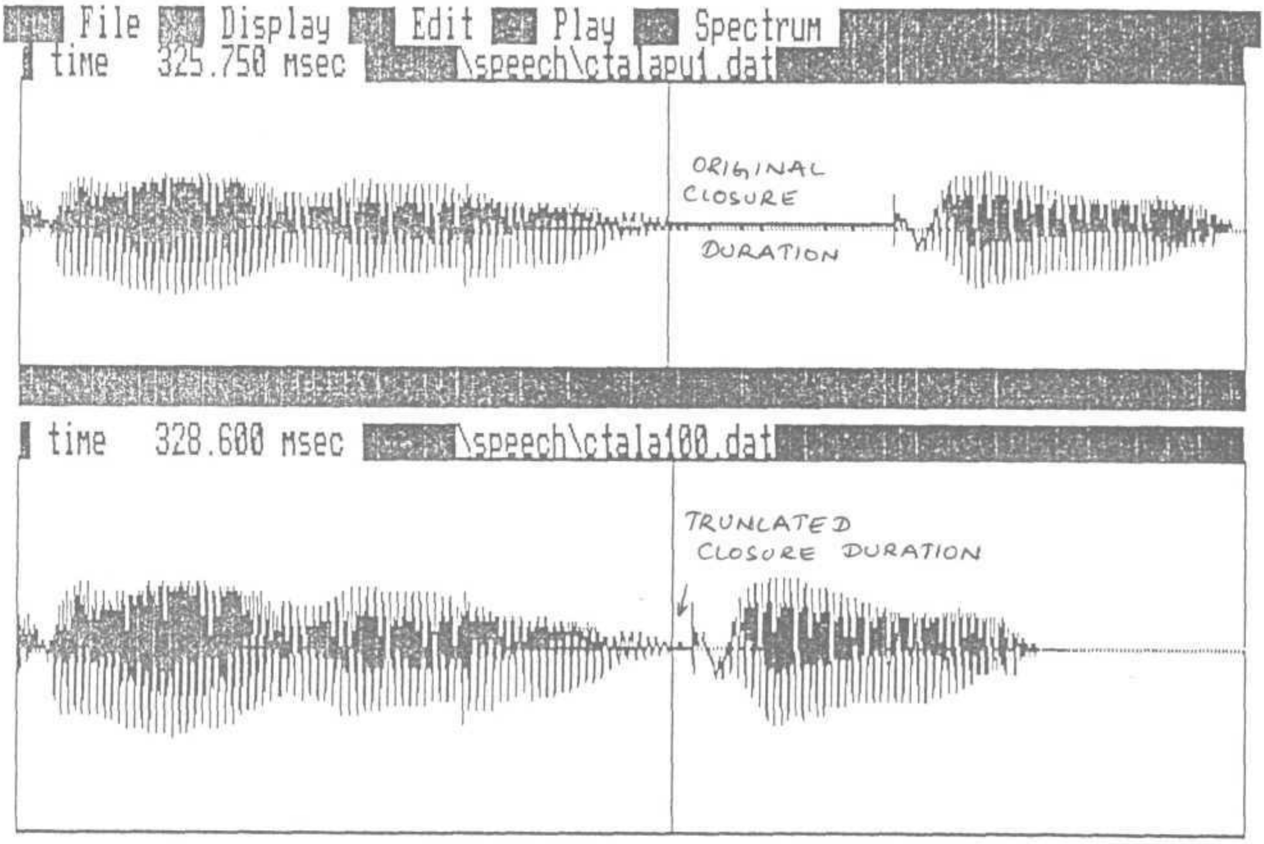


FIGURE-3: Wave form depicting VCV.(closure duration is labelled)

Subjects - Ten normal Kannada speaking children (5 males & 5 females) each in the age range of 3-4 years, 4-5 years and 5-6 years served as subjects. All of them had normal speech as evaluated by a speech pathologist and none of them reportedly had any hearing loss. The subject details are in Table-4.

Age in years	3-4 Avg age	4-5 Avg age	5-6 Avg age
Males	3.6 years	4.7 years	5.7 years
Females	3.4 years	4.5 years	5.8 years

Table-4: Details of the subjects.

PROCEDURE: Pictures representing these words (minimal pairs representing an alternate forced choice) were selected. Each child was tested individually and was initially conditioned to the pictures corresponding the test stimuli.

The subjects were tested in a quiet room and the stimulus was audio-presented through two loudspeakers, one on each side of the child. The two picture cards representing minimal pairs of a test were placed in front of the child. The child participated in four tests at one sitting.

A role play was adopted to make the task enjoyable for children. The taperecorder was covered with a life size doll of a monkey and the child was instructed that the monkey would speak to him and that he had to point to the picture appropriate to the word he listened to. The experimenter recorded the child's response on a response sheet (APPENDIX-I) immediately after the child's response.

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

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

For example if the total/expected number of response for a stimuli was 30 and obtained number of response was 20 then the percentage response was $\frac{20 \times 100}{30} = 66.66$

The percentage response for voiced and voiceless plosive were tabulated for each of the test stimuli on the basis of which the identification and discrimination functions for each plosive for each test stimuli were plotted.

Four measurements were obtained from the identification function (modified from Lisker & Abramson(1967) originally given for VOT and Doughty (1949)

(i) 50% crossover - It was that point on the graph which was the actual or interpolated point about the closure duration continuum for which 50% of the subject's response corresponded to the voicing category. For example in Figure-4 the 55% crossover will be 50 msec of closure duration i.e. the point "B" on the X-axis.

(ii) Lower limit of phoneme boundary width - was that point along the closure duration continuum where an individual identified voiced stop 75% of the time. For example in Figure-4 the lower limit will be 35 msec of closure duration i.e. the point "A" on the X-axis.

(iii) Upper limit of phoneme boundary width - was defined as the corresponding point for the identification of VL cognate 75% of the time For example in Figure-4 the upper limit will be 74 msec of closure duration i.e. the point "C" on the X-axis.

(iv) Phoneme boundary width (in msec)between voicing category was defined as the arc boundary crosspoint along the closure duration continuum and was determined by substraiting the lower limit from the upper limit.For example. In the Figure-4 the phoneme boundary width is 39msec i.e 74-35 (C-A)

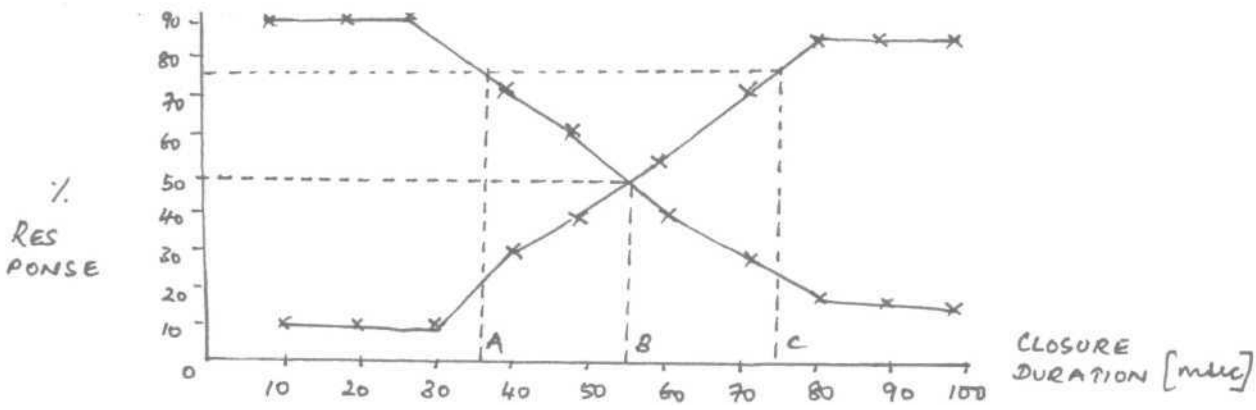


Figure-4: Curve showing lower limit, upper limit, 50% crossover and phoneme boundary width.

All these measurements were used to interpret the results and thus gain insight in the area of development of speech perception in children.

RESULTS AND DISCUSSION

The measurements of 50% crossover, lower limit of phoneme boundary, upper limit of phoneme boundary and phoneme boundary width were considered for interpreting the results and discussing the results.

RESULTS:

3 - 4 year age group:

/ṭ - ḍ/ Percept - The crossover value [50%] lower limit, upper limit and phoneme boundary width for /ṭ/ in the bisyllabic word /tuṭi/ and trisyllabic word /Karaṭi/ are in Table 5 and 6.

Sex	50% Crossover	Lower limit 75% voiced	Upper limit 75% voiceless	Phoneme Boundary Width
Male	-	-	-	-
Female	12.95	5.95	31.95	26
AVERAGE	9.95	-	22.95	-

Table-5: Various measures for /ṭ - ḍ/ percept in bisyllabic word (3-4 years)

Sex	50% Crossover	Lower limit 75% voiced	Upper limit 75% voiceless	Phoneme Boundary Width
Male	38.65	29.65	57.65	28
Female	28.65	24.65	50.65	26
AVERAGE	31.65	26.65	55.65	29

Table-6a: Various measures for /ṭ - ḍ/ percept in trisyllabic word (3-4 years)

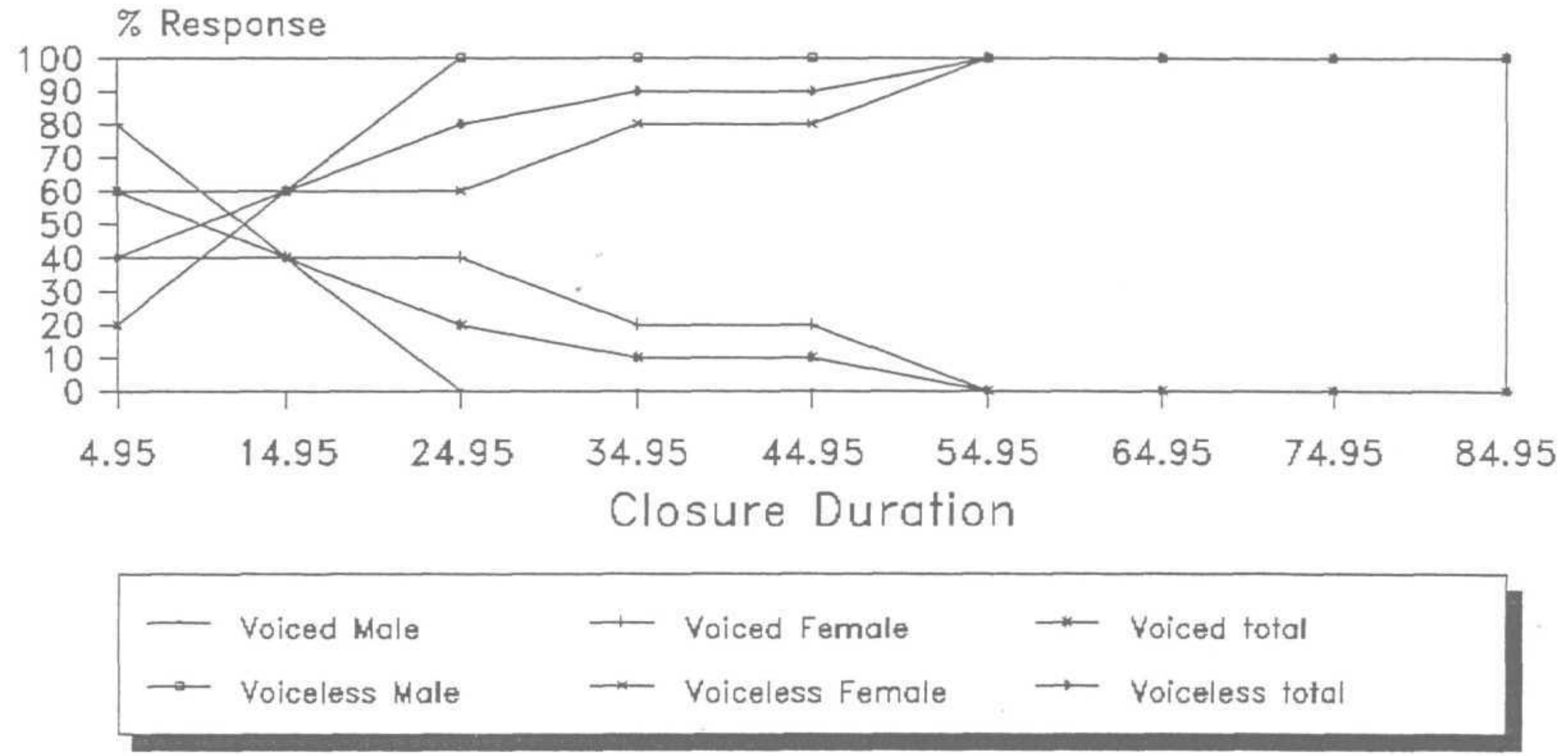


Fig-5: Identification & discrimination curve for /ṭ/ in bisyllabic word tuṭi in 3-4 years

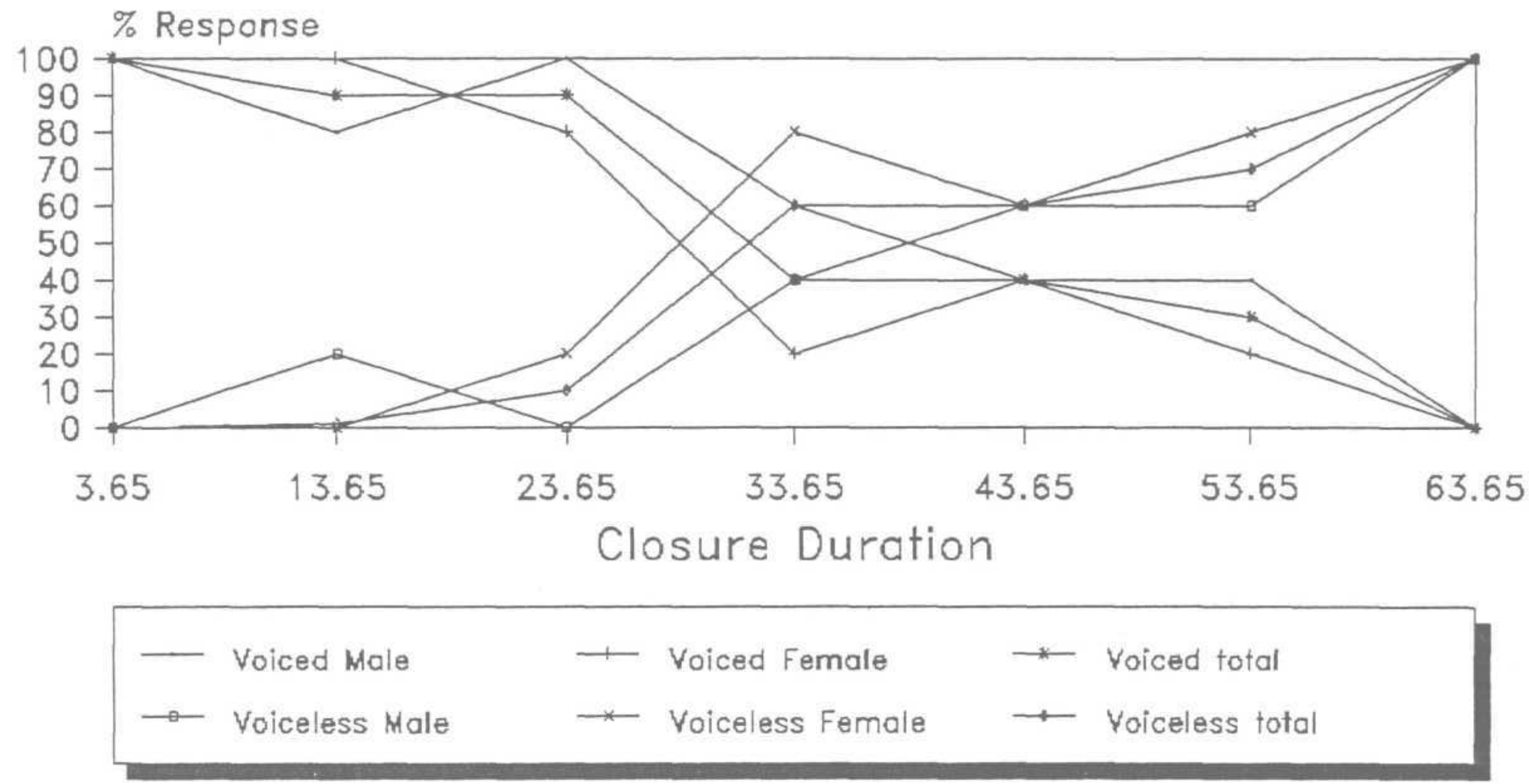


Fig-6. Identification & discrimination curve for /k/ in trisyllabic word karaṭi for 3 to 4 years.

From Table-5 it could be observed that while the females exhibited a change in the percept from voiceless / ṭ / to voiced / ḍ / as the closure duration was reduced, males did not show any change in the percept. The results indicate that below 12msec, voiced percept is identified and above 12 msec voiceless percept is identified. Figure- 5 and 6 shows the identification and discrimination function for /ṭ - ḍ/

From Table-6a it is evident that both males and females showed a shift in the percept from voiceless to voiced as the closure duration was reduced in a trisyllabic word. In females the crossover occured at a shorter duration than males and the lower and upper limits were higher in males than the females. Also, females exhibited shorter boundary widths than males.

/t - d/ Percept - Various measures for / t / in the bisyllabic word /titi/ and trisyllabic word /Itara/ are in Table-6b & 7.

Sex	50% Crossover	Lower limit 75% voiced	Upper limit 75% voiceless	Phoneme Boundary Width
Male	-	-	-	-
Female	47.7	38.7	60.7	22
AVERAGE	37.7	-	50.2	-

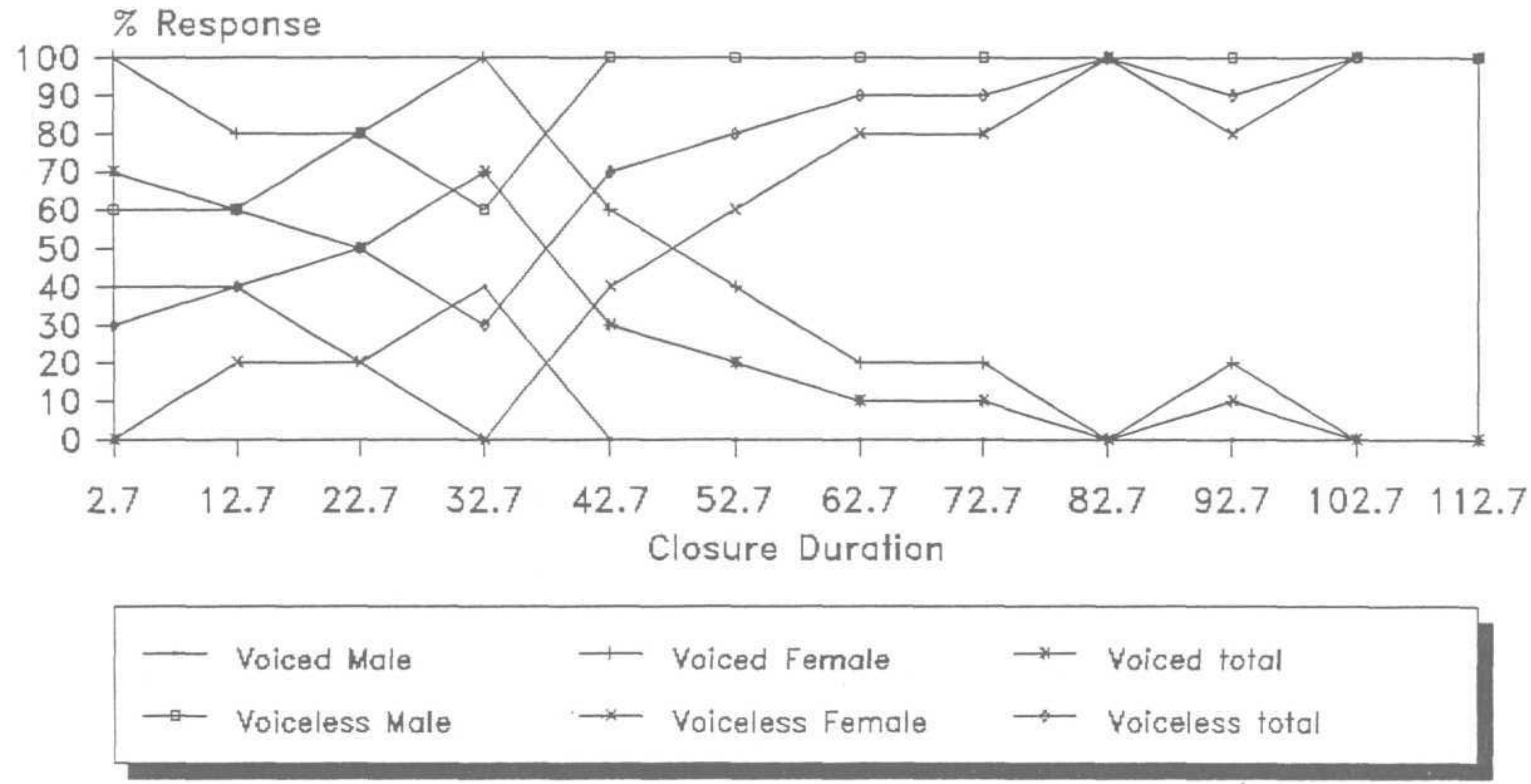
Table-6b: Various measures for /t - d/ percept in bisyllabic word (3-4 years)

Sex	50% Crossover	Lower limit 75% voiced	Upper limit 75% voiceless	Phoneme Boundary Width
Male	22.3	-	32.3	-
Female	20.3	-	38.5	-
AVERAGE	21.3	-	25.7	-

Table-7: Various measures for /t - d/ percept in trisyllabic word (3-4 years)

It was noticed that the male children did not show any change in the percepts from voiceless / t / to voiced / d / as the closure duration was reduced. However the females exhibited a change in percept from / t / to / d /. The results indicated that below 47 msec of closure duration voiced percept / d / is identified and above 47msec voiceless percept / t / is identified. Figure-7 and 8 shows identification and discrimination function for /t - d/.

From Table-7 it is evident that in trisyllabic word both males and females showed a shift in the percept from voiceless /t/ to voiced /d/ as the closure duration was reduced. For females the crossover occured at shorter duration than males. Though the percent identification of voiced /d/ increased with reduction in closure duration it did not reach 75%.



Fig—7. Identification & discrimination curve for /t/ in bisyllabic word tiɦ for 3 to 4 years.

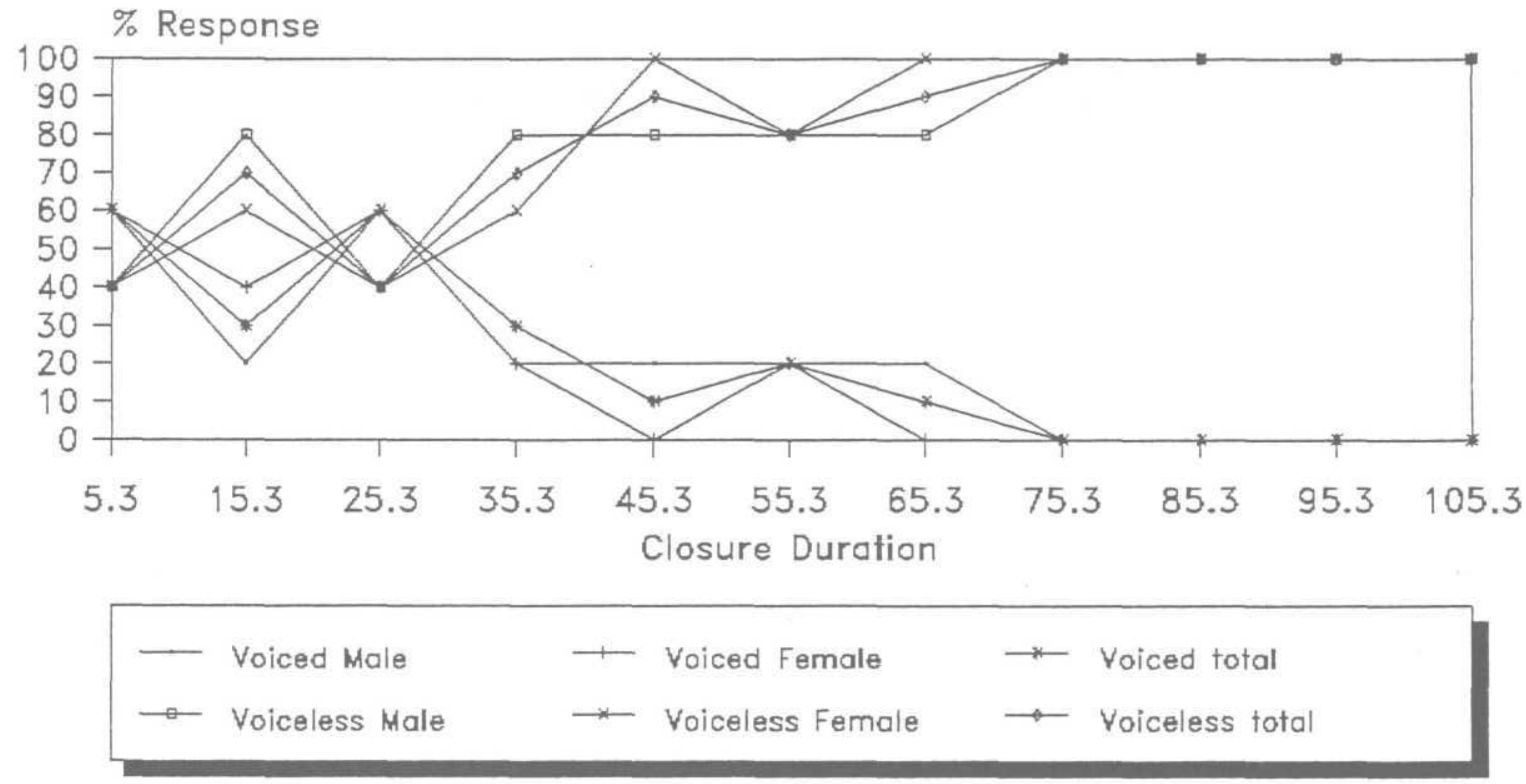


Fig-8. Identification & discrimination curve for /t/ in trisyllabic word Itara for 3 to 4 years.

/p - b/Percept - The 50% crossover value, lower limit, upper limit and phoneme boundary width for /p/ in the bisyllabic word /wope/ and trisyllabic word /Talapu/ are in Tables 8 & 9.

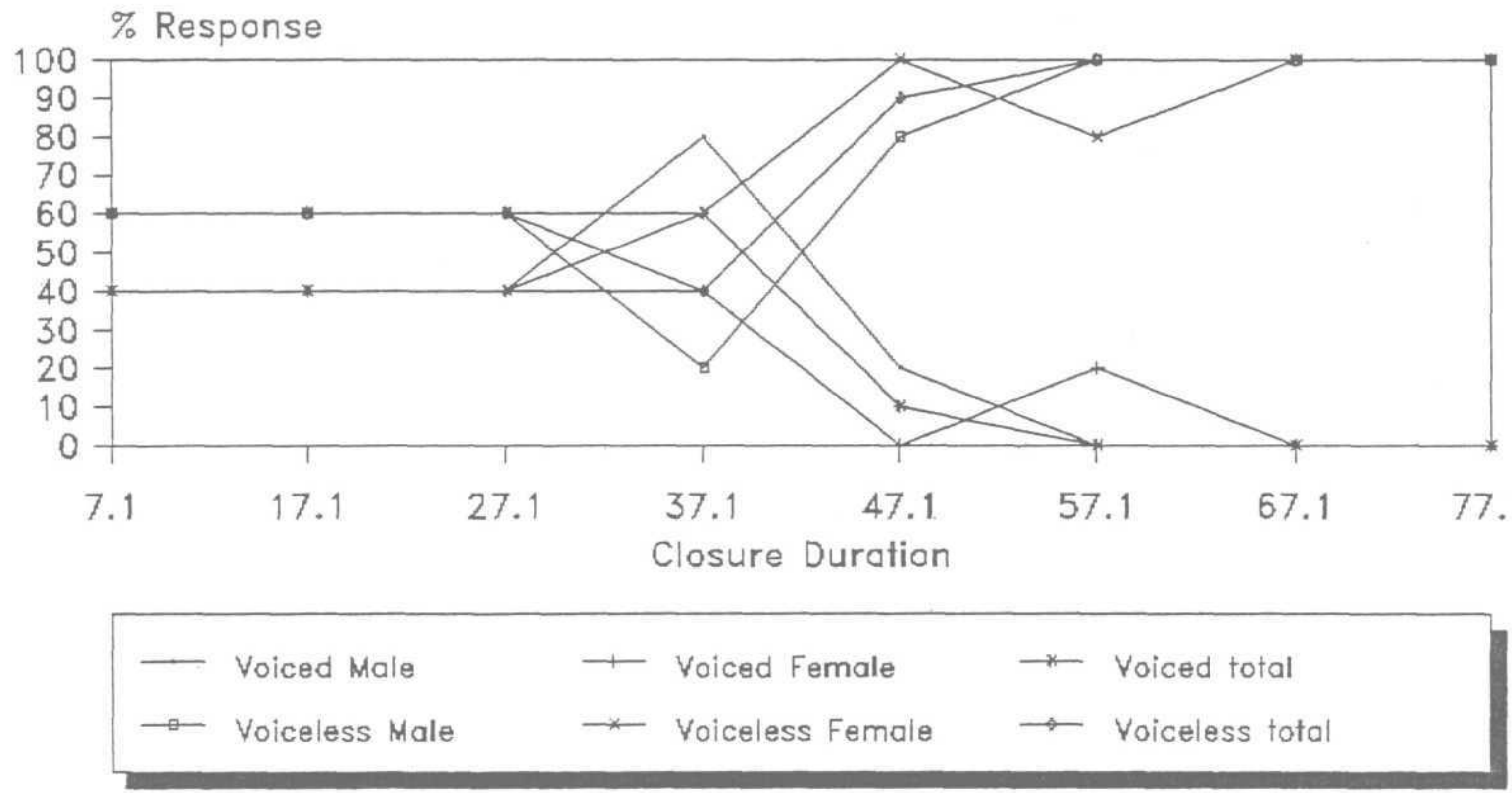
Sex	50% Crossover	Lower limit 75% voiced	Upper limit 75% voiceless	Phoneme Boundary Width
Male	29.6	-	46.1	-
Female	-	-	-	-
AVERAGE	32.1	-	44.1	-

Table-8: Various measures for /p - b/ percept in bisyllabic word (3-4 years)

Sex	50% Crossover	Lower limit 75% voiced	Upper limit 75% voiceless	Phoneme Boundary Width
Male	55	48.5	74.5	26
Female	72.5	63.5	84.5	21
AVERAGE	67.5	51.5	80.5	29

Table-9: Various measures for /p - b/ percept in trisyllabic word (3-4 years)

It was noticed that for the bisyllabic word, females did not show a change in percept of voiceless / p / to voiced / b / on reducing closure duration and males showed a shift in the percept from voiceless / p / to voiced / b / . The results indicate that below 29msec voiced percept was identified and above 29msec voiceless percept was identified. Figure-9 and 10 show the identification and discrimination curves for /p - b/.



Fig—9. Identification & Discrimination curve for /p/ in bisyllabic word wo*p*e for 3 to 4 years.

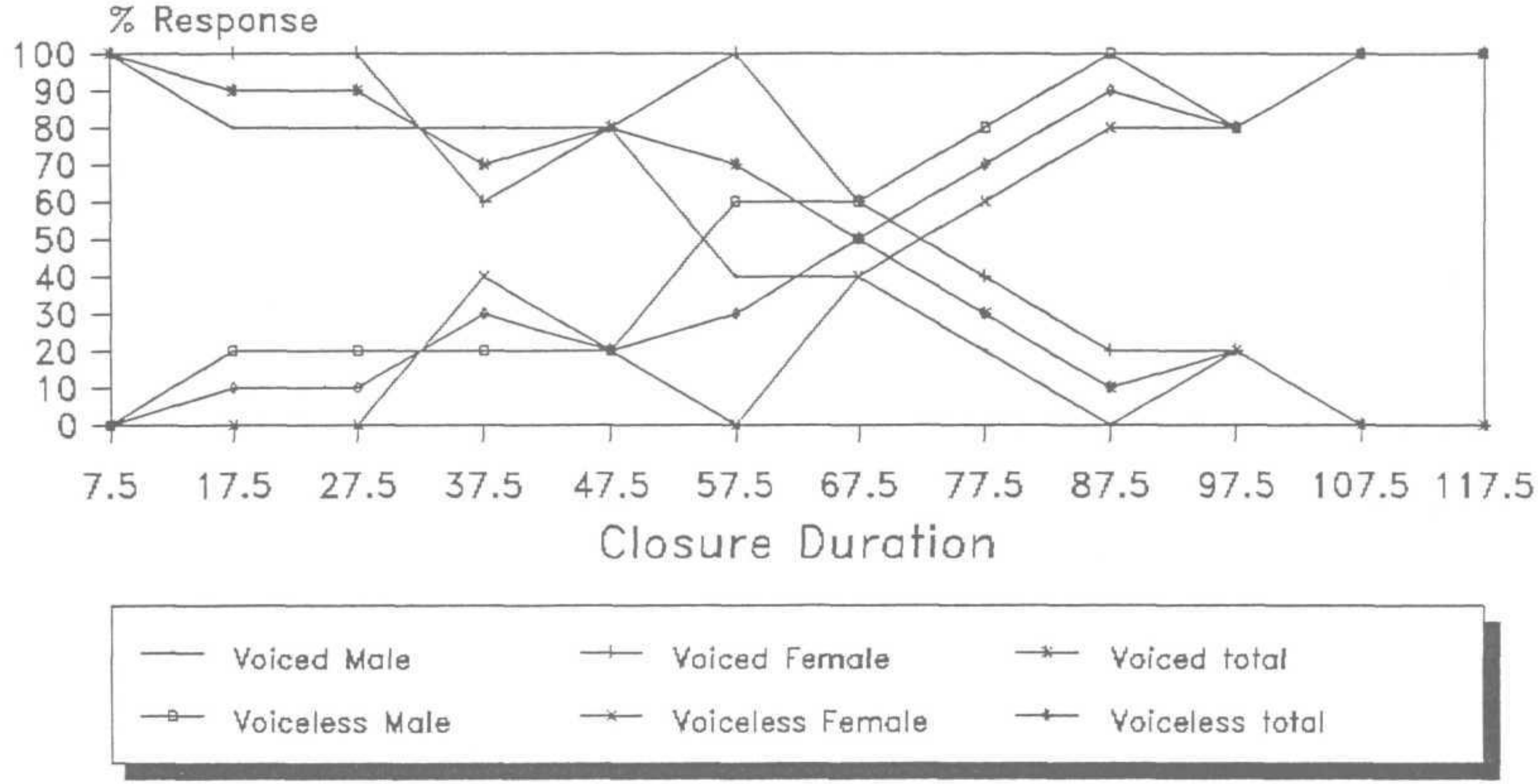


Fig-10. Identification & discrimination curve for /p/ in trisyllabic word talapu for 3 to 4 years.

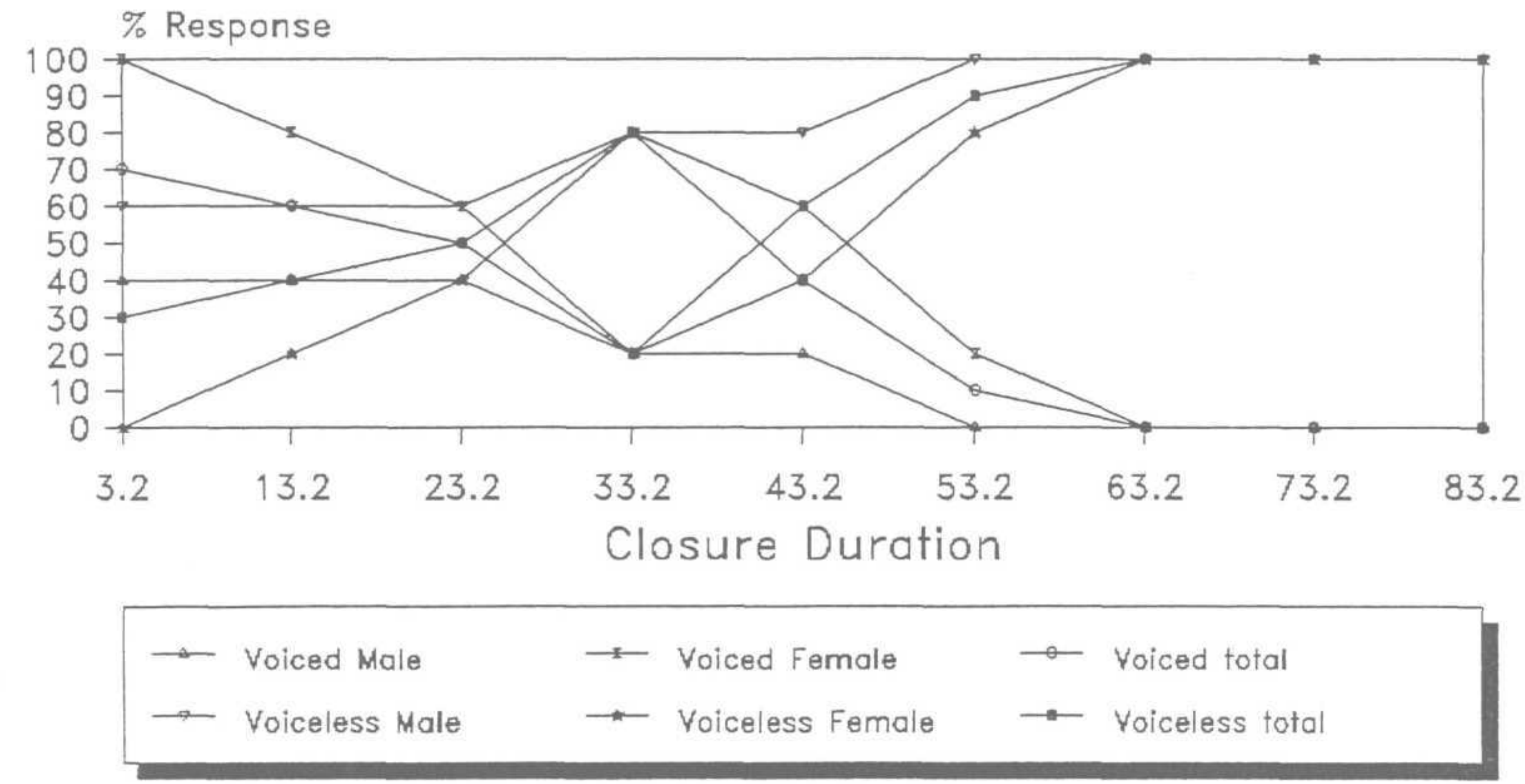
From Table-9 it could be observed that for /p - b/ that both male and female children identified voiced percept / b / as the closure duration was reduced. In males, the crossover occured at shorter closure duration than females. While the lower and upper limit was higher for females than males, the males had greater phonemic boundary width.

/k - g/ Percept - All the measures for /k/ in the bisyllabic word /baka/ and trisyllabic word /pakoda/ are in Table-10.

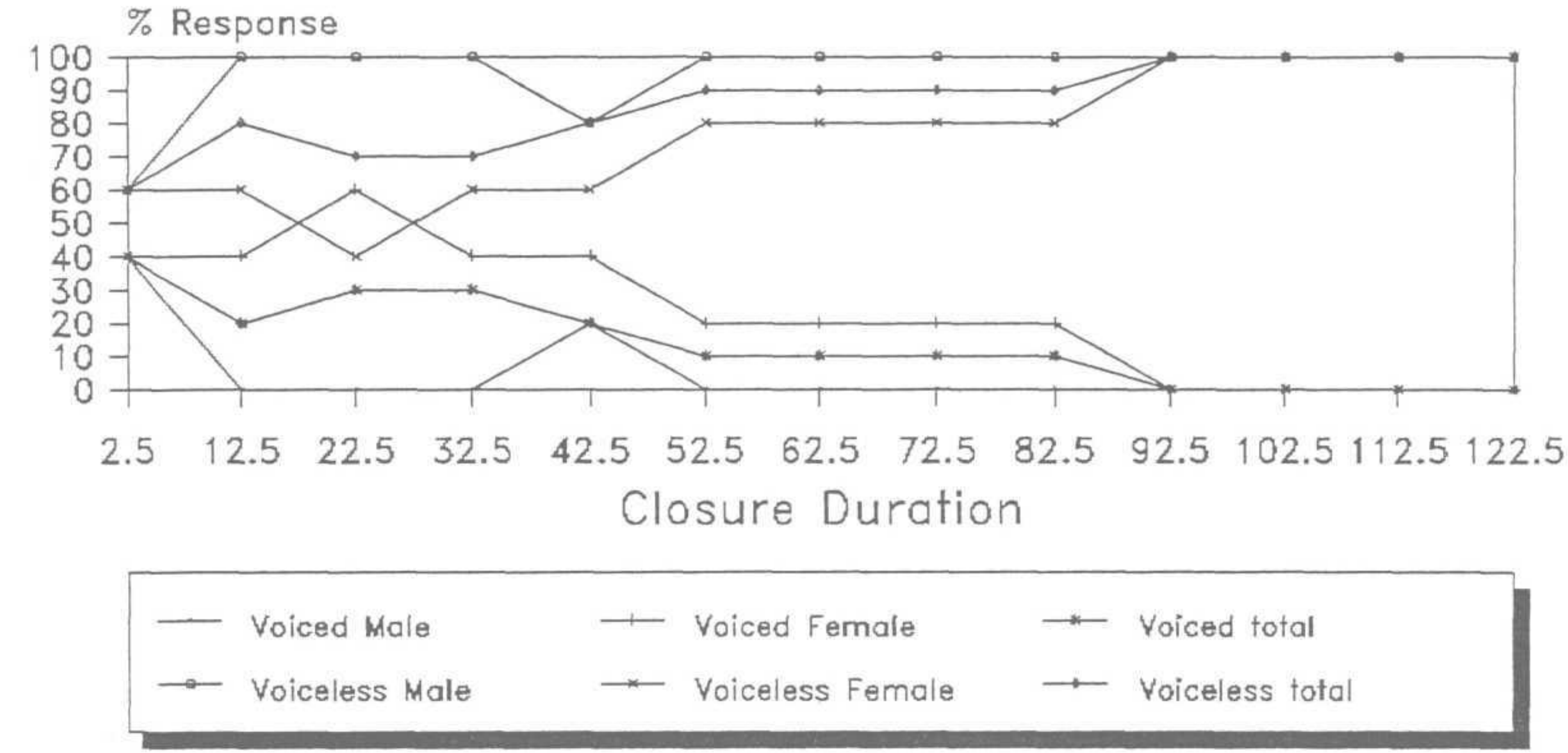
Sex	50% Crossover	Lower limit 75% voiced	Upper limit 75% voiceless	Phoneme Boundary Width
Male	—	—	—	—
Female	25.2	15.2	33.2	18
AVERAGE	23.2	-	48.7	-

Table-10: Various measures for /k/ percept in bisyllabic word (3-4 years)

While female children exhibited a change in the percept of voiceless /k/ to voiced /g/ on reducing closure duration, male children did not show any change in the percept. Below 25msec, voiced percept was identified and above 25msec voiceless percept was identified. Figure-11 and 12 show the identification and discrimination function for /k-g/. In trisyllabic word neither males nor females exhibited change in the percept from /k/ to /g/.



Fig—11. Identification & discrimination curve for /k/ in bisyllabic word baka for 3 to 4 years.



Fig—12. Identification & discrimination curve for /k/ in trisyllabic wd pakoda for 3 to 4 years.

4 - 5 year age group:

/ ṭ - ḍ / Percept - Tables-11 & 12 shows the 50% crossover value, lower limit, upper limit and phoneme boundary width for /ṭ - ḍ/ in the bisyallbic word / tuṭi/ and trisyllabic word / Karaṭi /.

Sex	50% Crossover	Lower limit 75% voiced	Upper limit 75% voiceless	Phoneme Boundary Width
Male	10.95	7.95	13.95	6
Female	10.95	7.95	13.95	6
AVERAGE	10.95	7.95	13.95	6

Table-11: Various measures for /ṭ/ percept in bisyllabic word (4-5 years)

Sex	50% Crossover	Lower limit 75% voiced	Upper limit 75% voiceless	Phoneme Boundary Width
Male	35.65	25.65	41.70	16.05
Female	38.65	25.65	50.5	24.85
AVERAGE	37.65	25.65	46.65	21

Table-12: Various measures for /ṭ/ percept in trisyllabic word (4-5 years)

Both male and female children of 4-5 years old showed a shift in percept from voiceless / ṭ / to voiced / ḍ / in bisyllabic and trisyllabic word as the closure duration was reduced. The results indicate that below 10 msecs, voiced percept is identified and above 10msec, voiceless percept is identified

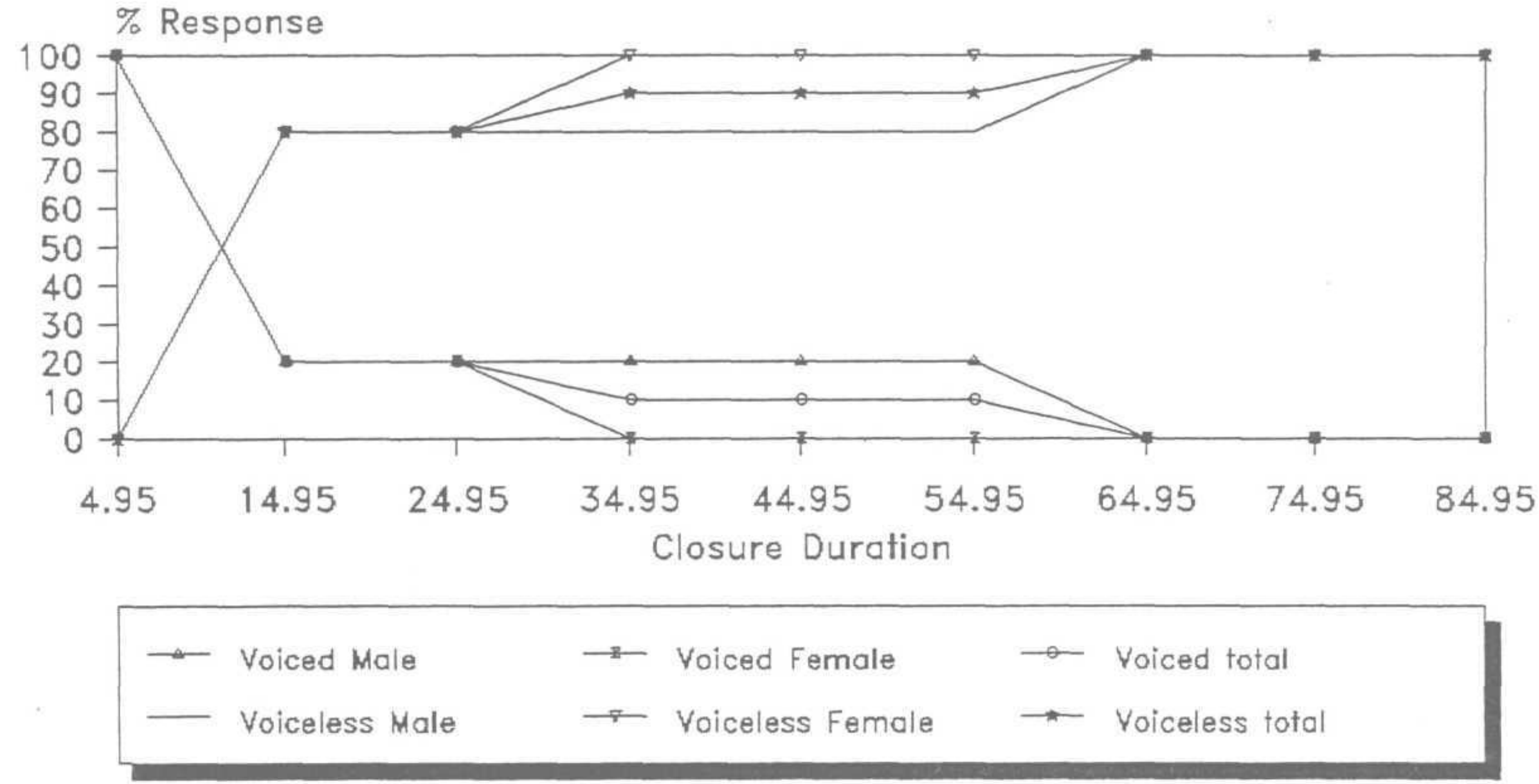
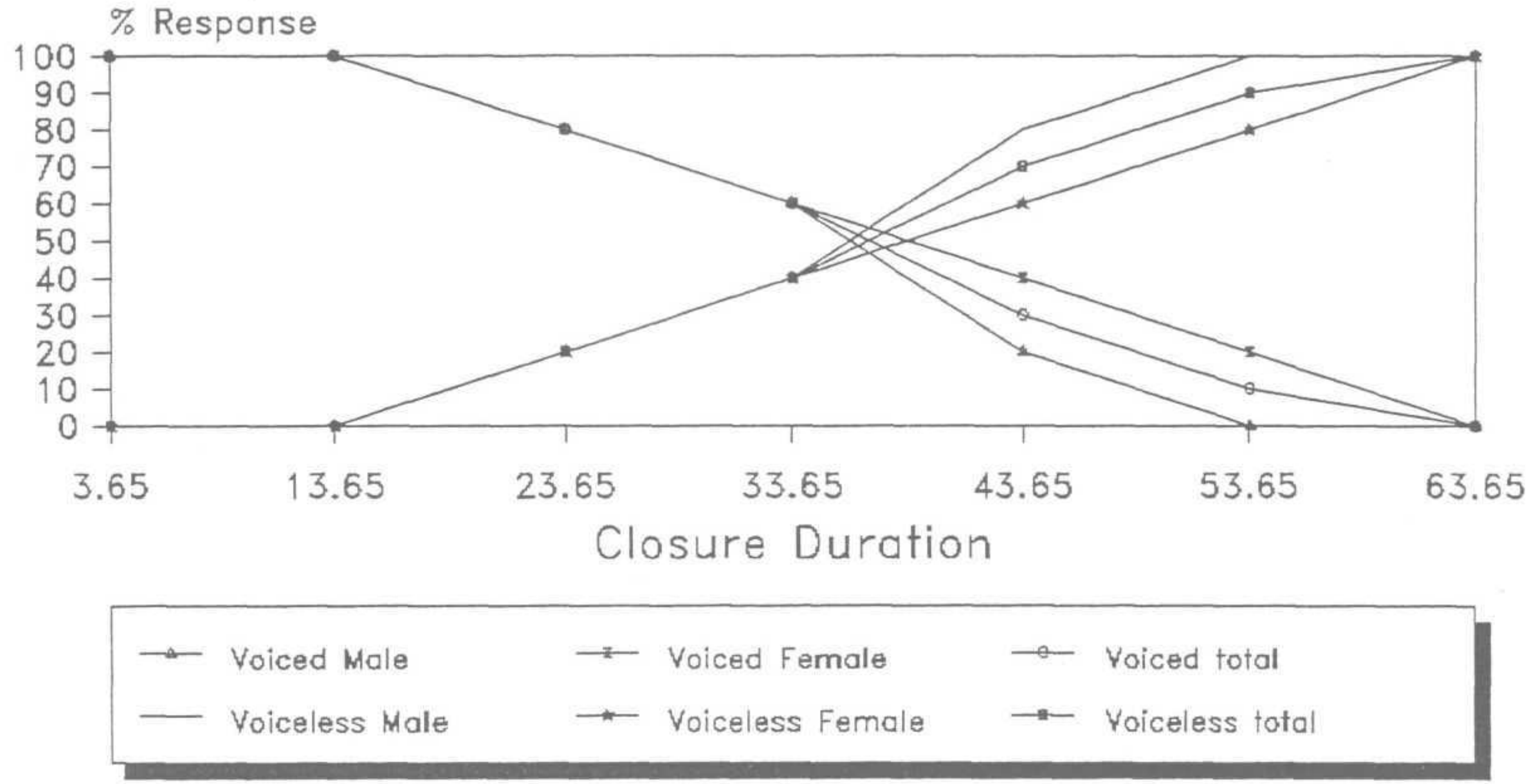


Fig-13. Identification & discrimination curve for /ṭ/ in Bisyllabic word tuʃi for 4 to 5 years.



Fig—14. Identification & discrimination curve for /t̪/ in trisyllabic word karaṭi for 4 to 5 years.

in bisyllabic word. The upper limit and the phonemic boundary width was shorter for males than for females in the trisyllabic word. The identification and discrimination function for /ṭ-ḍ / are in FigureS-13 and 14.

/t - d/ Percept - Tables 13 & 14 depicts the values for / t / in the bisyllabic and the trisyllabic word.

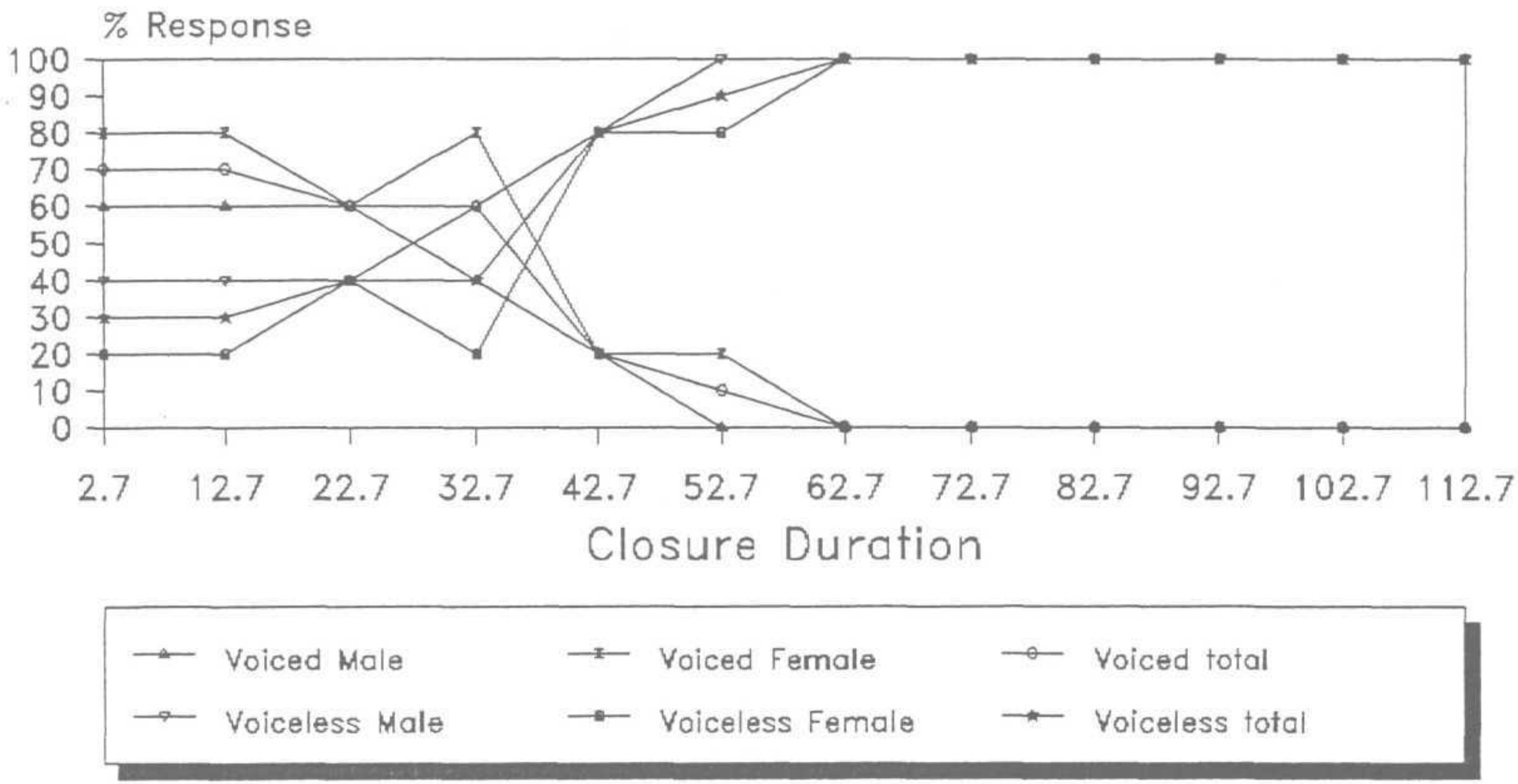
Sex	50% Crossover	Lower limit 75% voiced	Upper limit 75% voiceless	Phoneme Boundary Width
Male	27.2	-	37.7	-
Female	38.7	14.2	41.2	26.5
AVERAGE	32.95	-	39.45	-

Table-13: Various measures for /t/ percept in trisyllabic word (4-5 years)

Sex	50% Crossover	Lower limit 75% voiced	Upper limit 75% voiceless	Phoneme Boundary Width
Male	27.30	9.3	31.3	22
Female	10.3	5.3	28.8	23.5
AVERAGE	12.3	8.3	30.30	22

Table-14: Various measures for /t/ percept in trisyllabic word (4-5 years)

As the closure duration was reduced ,the percept changed from / t / to / d /. In the bisyllabic words, in males, the crossover value and the upper limit were shorter than females.



Fig—15. Identification & discrimination curve for /t/ in bisyllabic word /iti for 4 to 5 years.

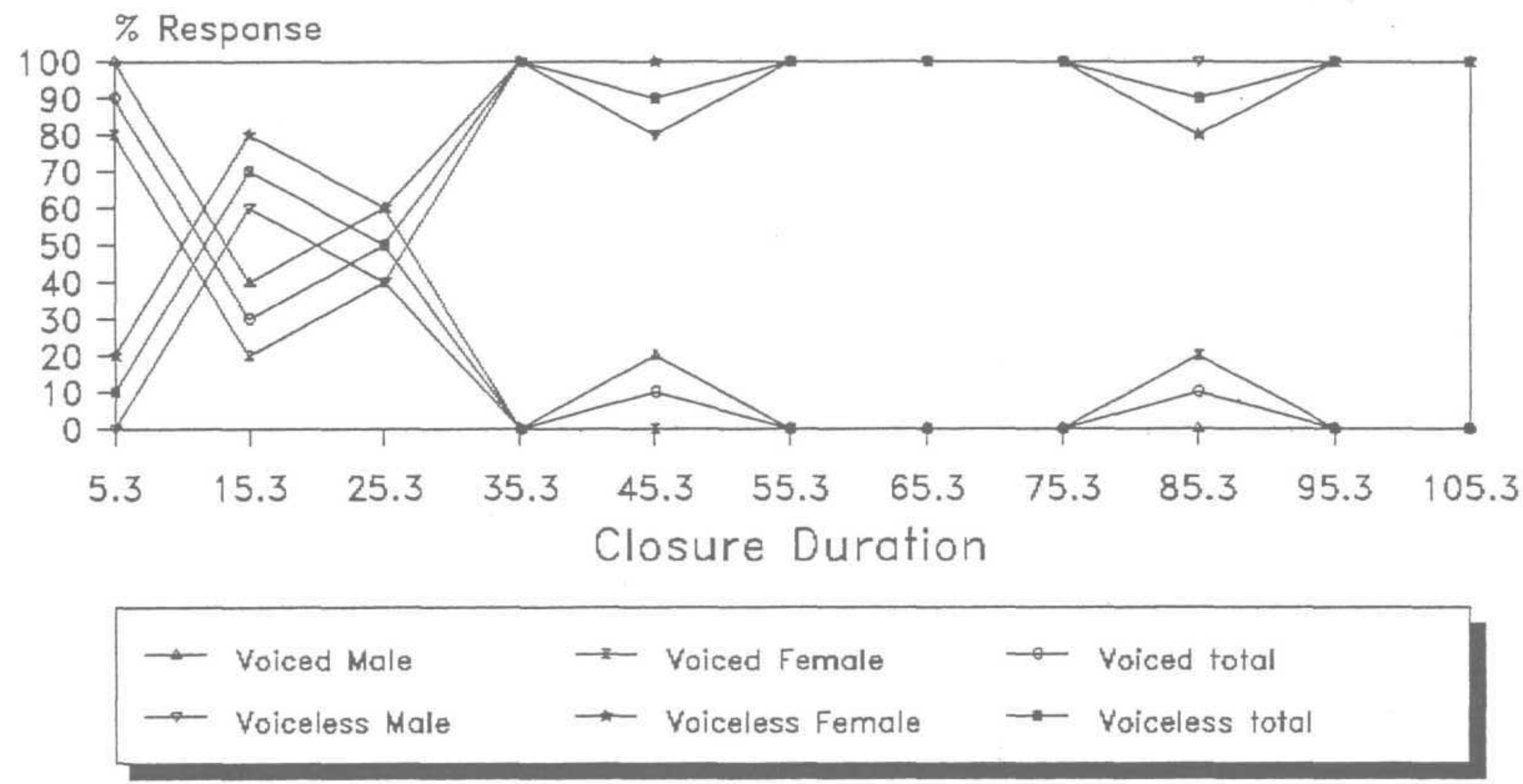


Fig-16. Identification & discrimination curve for /t/ in trisyllabic word Itara for 4 to 5 years.

However, in trisyllabic words females had short crossover value, lower limit and upper limit. Also, the phoneme boundary was shorter for males than for females. Figures 15 and 16 show the identification and discrimination function for /t - d/.

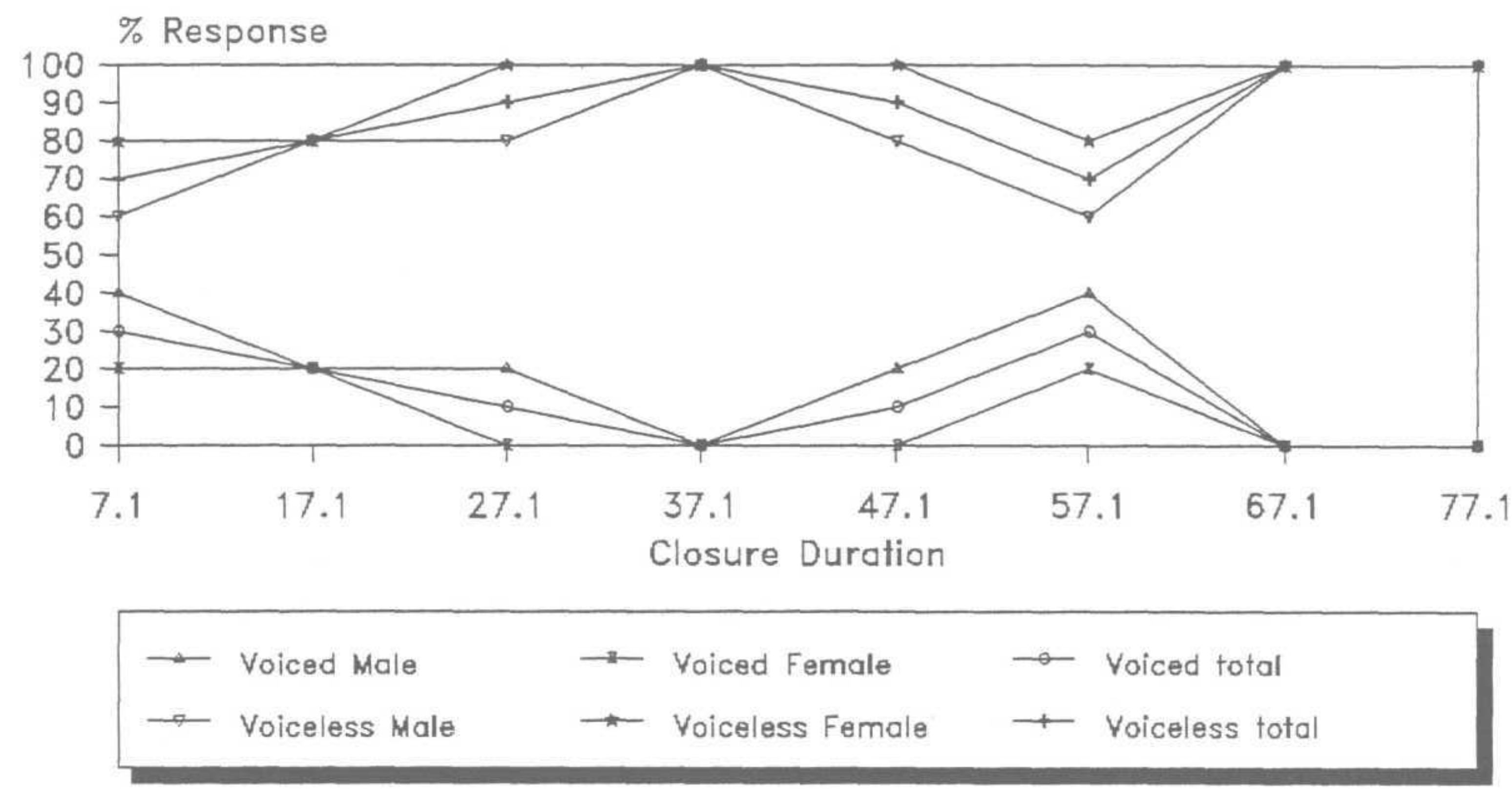
/p-b/ Percept:

Sex	50% Crossover	Lower limit 75% voiced	Upper limit 75% voiceless	Phoneme Boundary Width
Male	52.5	44.5	74.5	30
Female	76.5	71.5	82.5	11
AVERAGE	72.5	50.5	80.5	30

Table-15: Various measures for /p-b/ percept in trisyllabic word (4-5 years)

None of the subjects reported the voiced /b/ percept on reduction of closure duration in the bisyllabic word. However, in the trisyllabic word the percept changed from /p/ to /b/. In males the crossover value, lower limit and upper limit was shorter than in females. Also, the phoneme boundary width was wider in males. Figure 17 and 18 representes the identification and discrimination function for /p-b/

/k - g/ Percept - The 50% crossover value, lower limit, upper limit and phoneme boundary width for /k/ in bisyllabic word



Fig—17. Identification & discrimination curve for /p/ in bisyllabic word w*o*pe for 4 to 5 years.

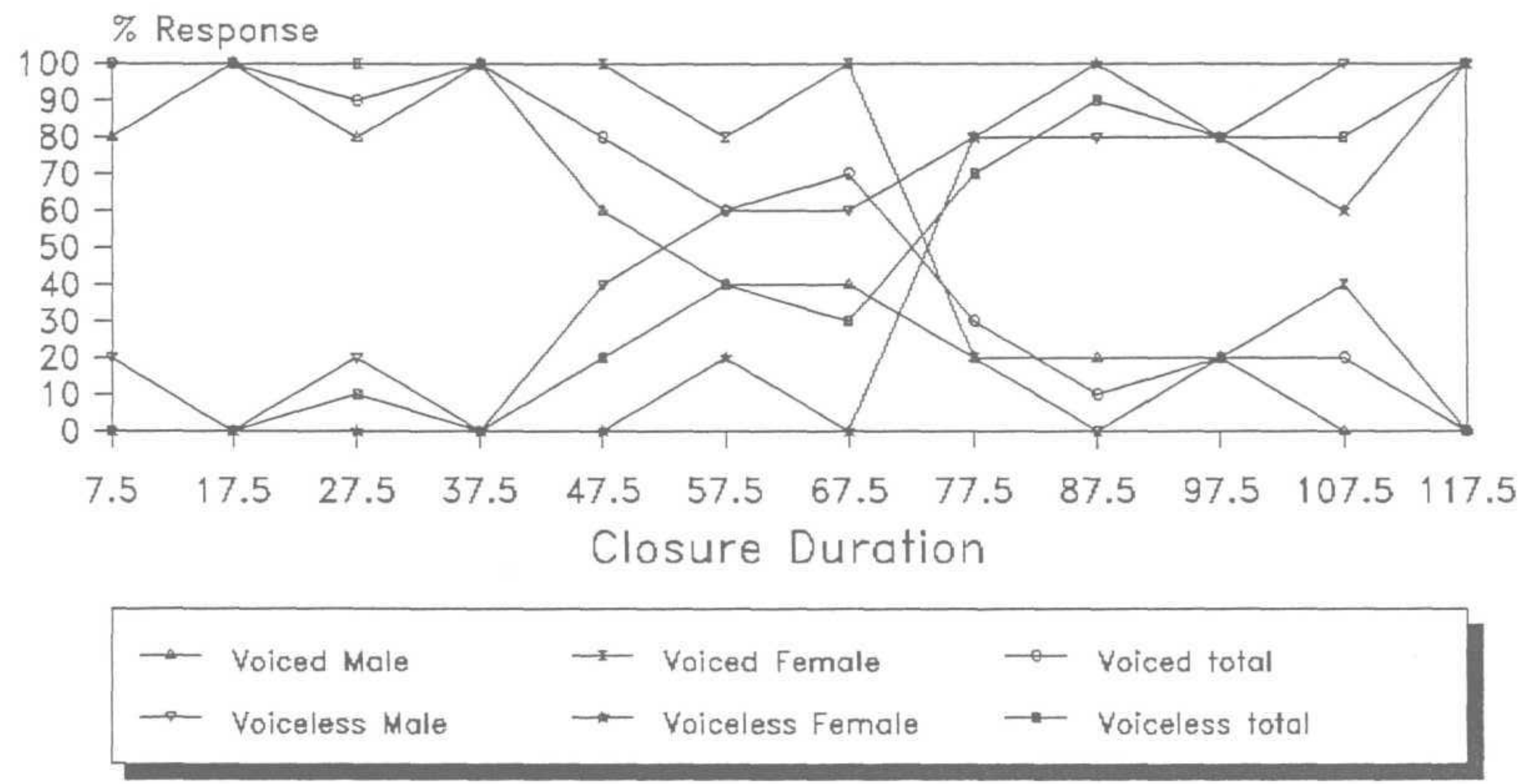


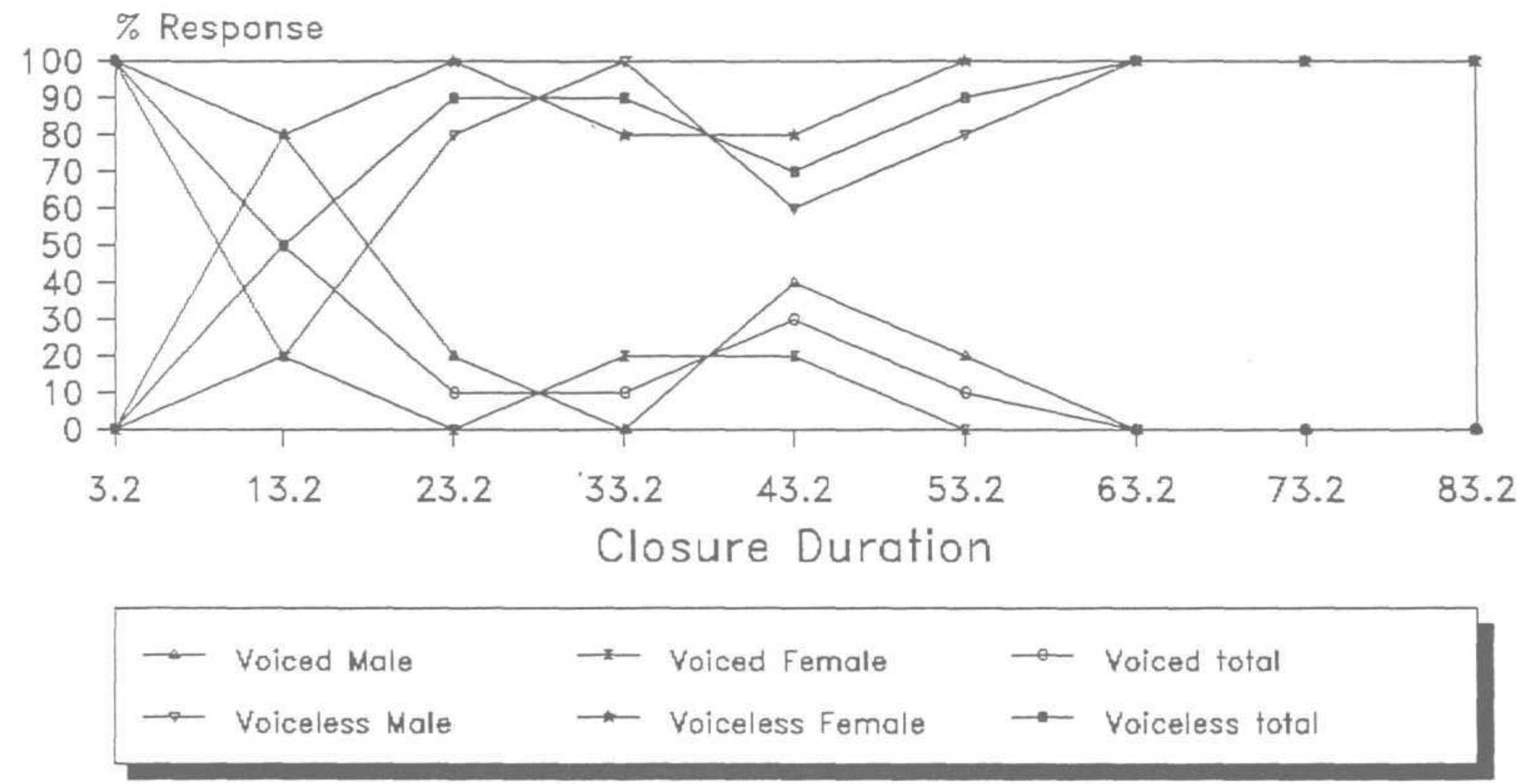
Fig-18. Identification & discrimination curve for /p/ in trisyllabic word tala*p*u for 4 to 5 years.

/Baka/ and trisyllabic word /Pakoda/ are given in Table 16

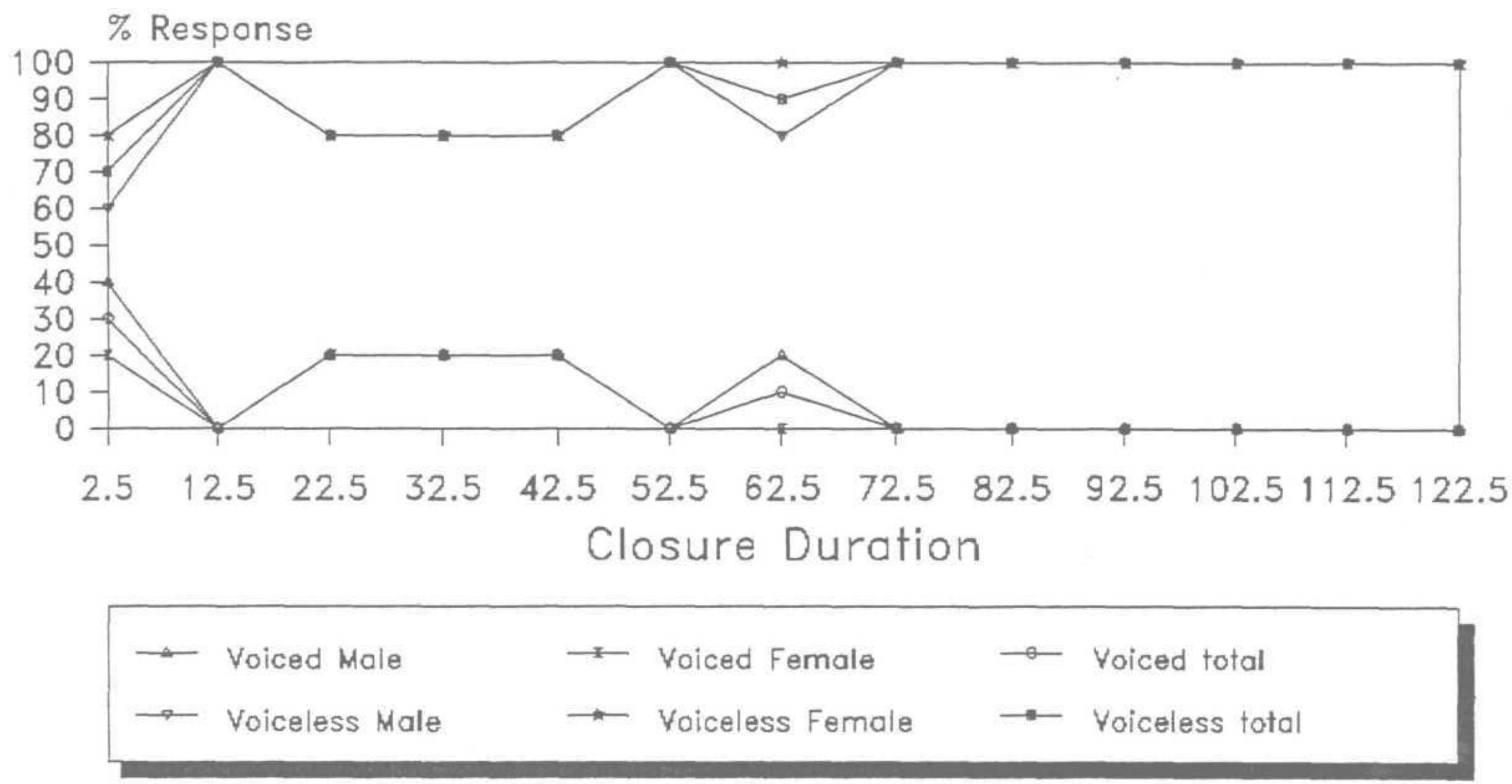
Sex	50% Crossover	Lower limit 75% voiced	Upper limit 75% voiceless	Phoneme Boundary Width
Male	18.2	14.2	22.2	8
Female	9.2	6.2	12.2	6
AVERAGE	13.2	10.2	17.2	7

Table-16: Various measures for /k-g/ percept in bisyllabic word (4-5 years)

In bisyllabic words, a shift in the perception from voiceless /k/ to voiced /g/ was noticed as the closure duration was reduced. However, no such shift was found in the trisyllabic word. In females, the crossover occured at a shorter duration than the males and the lower and upper limits were higher in males than in females. Also females exhibited shorter boundary width than males. Figure319 and 20 showp the identification and discrimination function for /k-g/. There was no change in percept in both male and female children from voiceless /k/ to voiced /g/ on reducing closure duration in trisyllabic word.



Fig—19. Identification & discrimination curve for /k/ in bisyllabic word ba*k*a for 4 to 5 years.



Fig–20. Identification & discrimination curve for /k/ in trisyllabic word pa*k*oda for 4 to 5 years.

5-6 year old age group:

/ṭ - ḍ/ Percept- Table 17 and 18 depicts various values for /ṭ - ḍ/ in bisyllabic and trisyllabic words respectively.

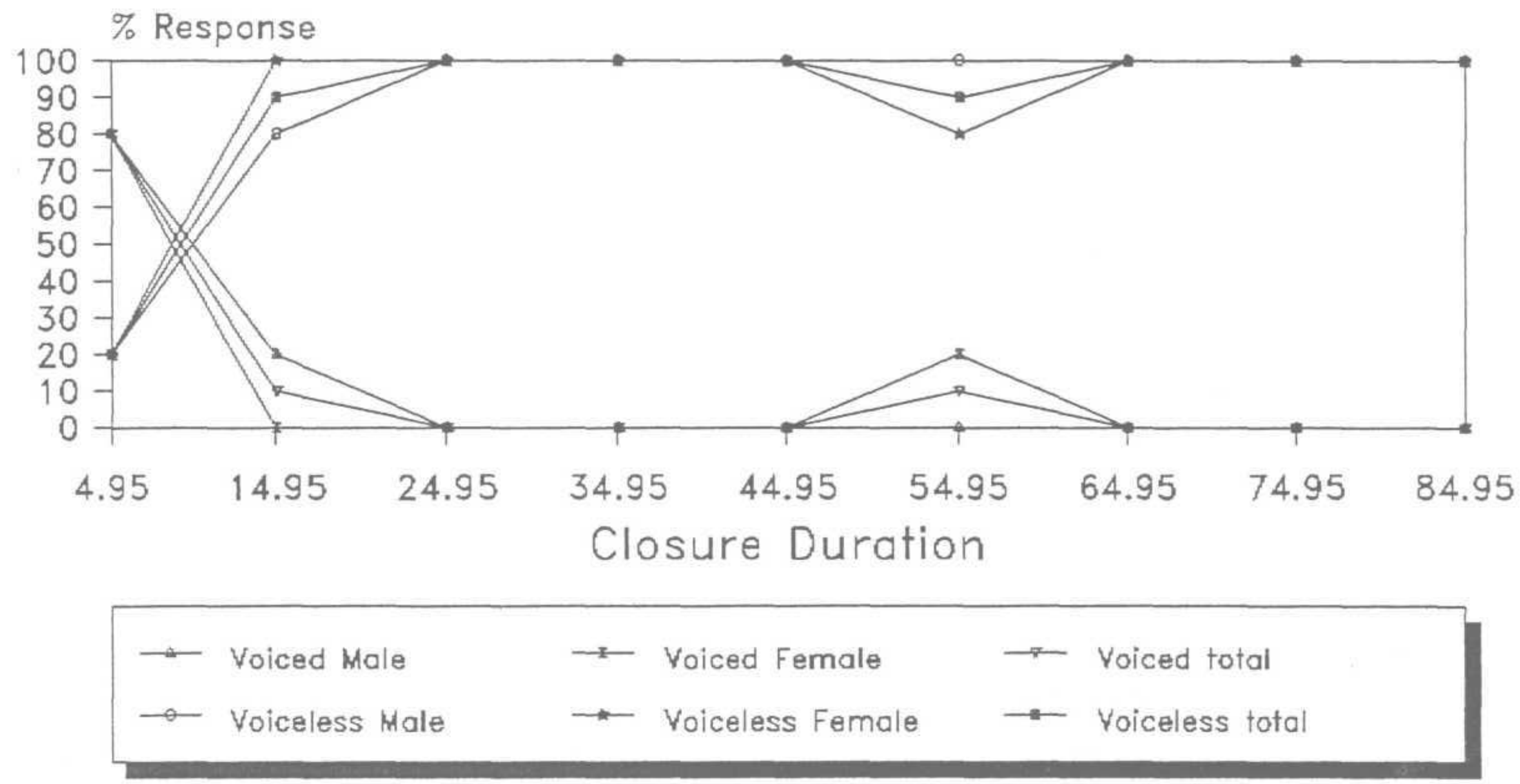
Sex	50% Crossover	Lower limit 75% voiced	Upper limit 75% voiceless	Phoneme Boundary Width
Male	9.95	5.95	13.95	8
Female	8	5.95	11.95	6
AVERAGE	9	5.95	12.95	7

Table-17: Various measures for /ṭ-ḍ/ percept in bisyllabic word (5-6 years)

Sex	50% Crossover	Lower limit 75% voiced	Upper limit 75% voiceless	Phoneme Boundary Width
Male	21.70	17.65	27.65	10
Female	38.65	34.65	42.65	8
AVERAGE	30.2	26.2	35.2	9

Table-18: Various measures for /ṭ-ḍ/ percept in trisyllabic word (5-6 years)

In both bisyllabic and trisyllabic words, the subjects showed a shift in their percept from voiceless / ṭ / to voiced ḍ / as the closure duration was reduced. In the bisyllabic word, for females the 50% crossover was at shorter closure duration than males. The upper limit and phoneme boundary width were shorter in females. In contrast, in the trisyllabic words, the 50% crossover, lower limit and upper limit were longer in



Fig—21. Identification & discrimination curve for /ṭ/ in bisyllabic word tuṭi for 5 to 6 years.

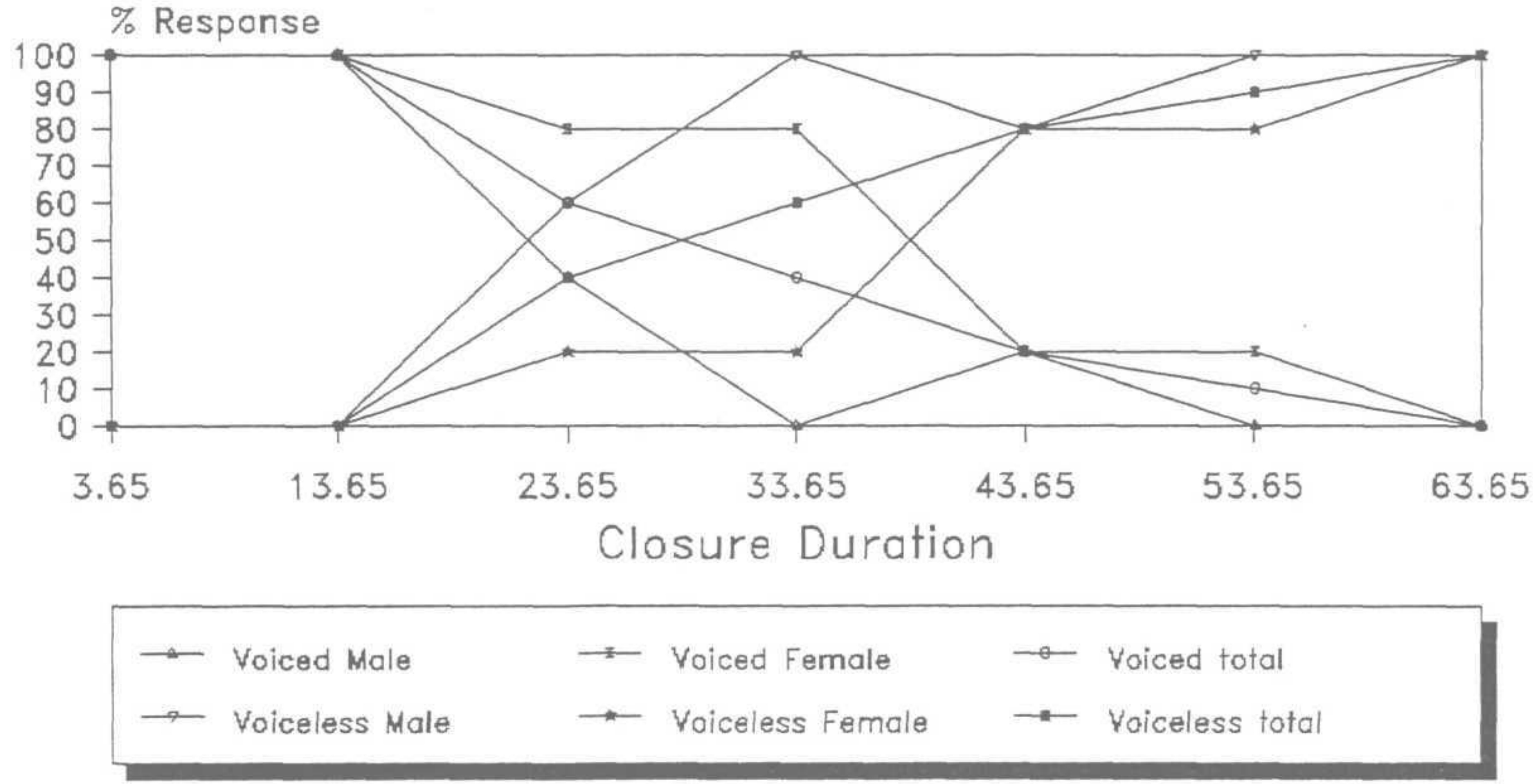


Fig-22. Identification & discrimination curve for /ṭ/ in trisyllabic word karaṭi for 5 to 6 years.

females. However, the width of the phoneme boundary was shorter. Figure-21 and 22 shows the identification and discrimination function for / ṭ - ḍ / .

/ t - d / Percept - In the bisyllabic word, only females exhibited a shift in the percept from voiced / t / to voiced / d/.

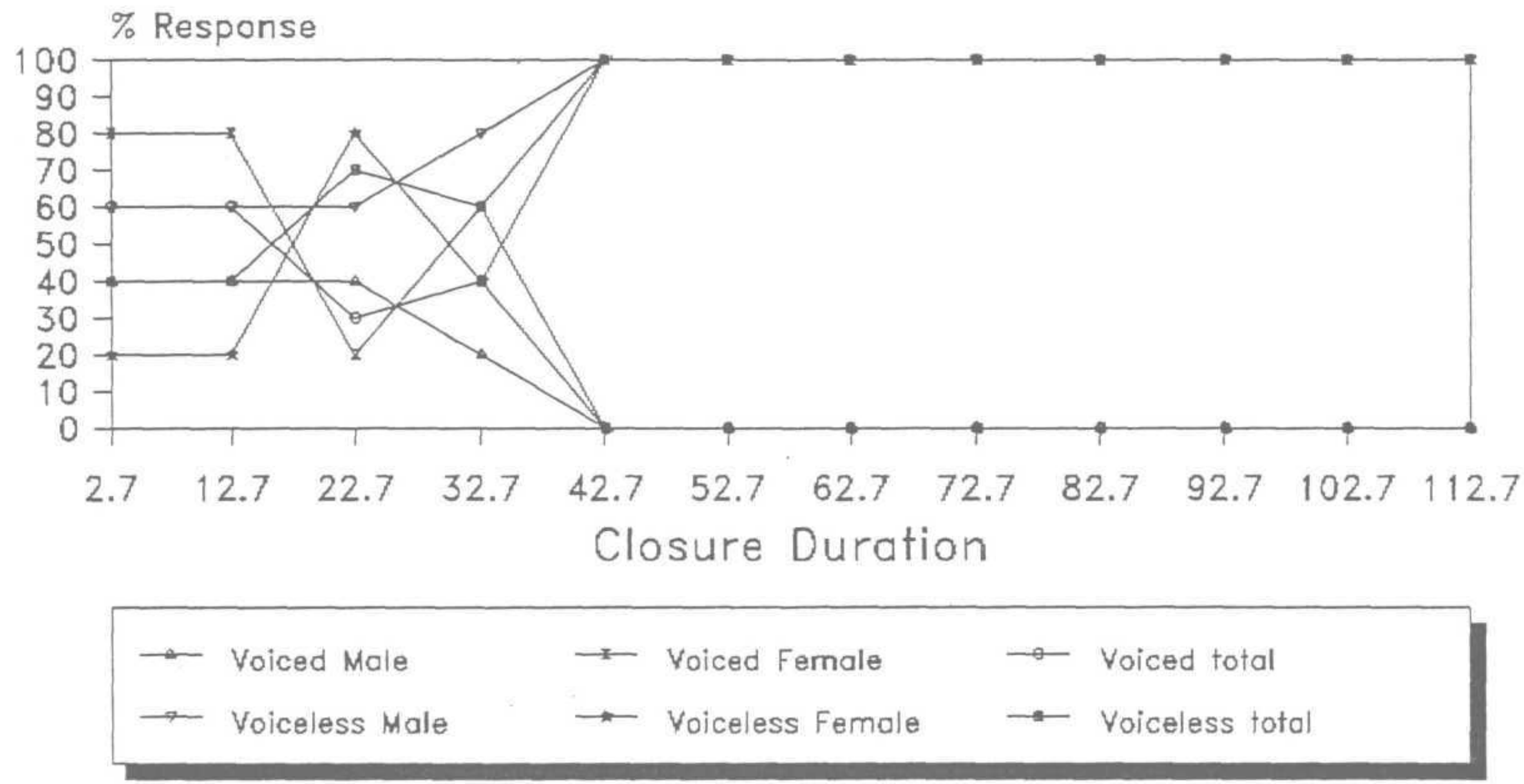
However, in the trisyllabic word both males and females showed a shift in the percept. In the trisyllabic wordz, while the 50% crossover and the phoneme boundary widths were longer, lower limit was shorter in females (TABLE 19 and 20) Figures 23 and 24 show the identification and discrimination function for /t/ & /d/.

Sex	50% Crossover	Lower limit 75% voiced	Upper limit 75% voiceless	Phoneme Boundary Width
Male	-	-	-	-
Female	17.7	12.7	38.7	26
AVERAGE	15.7	-	40.7	-

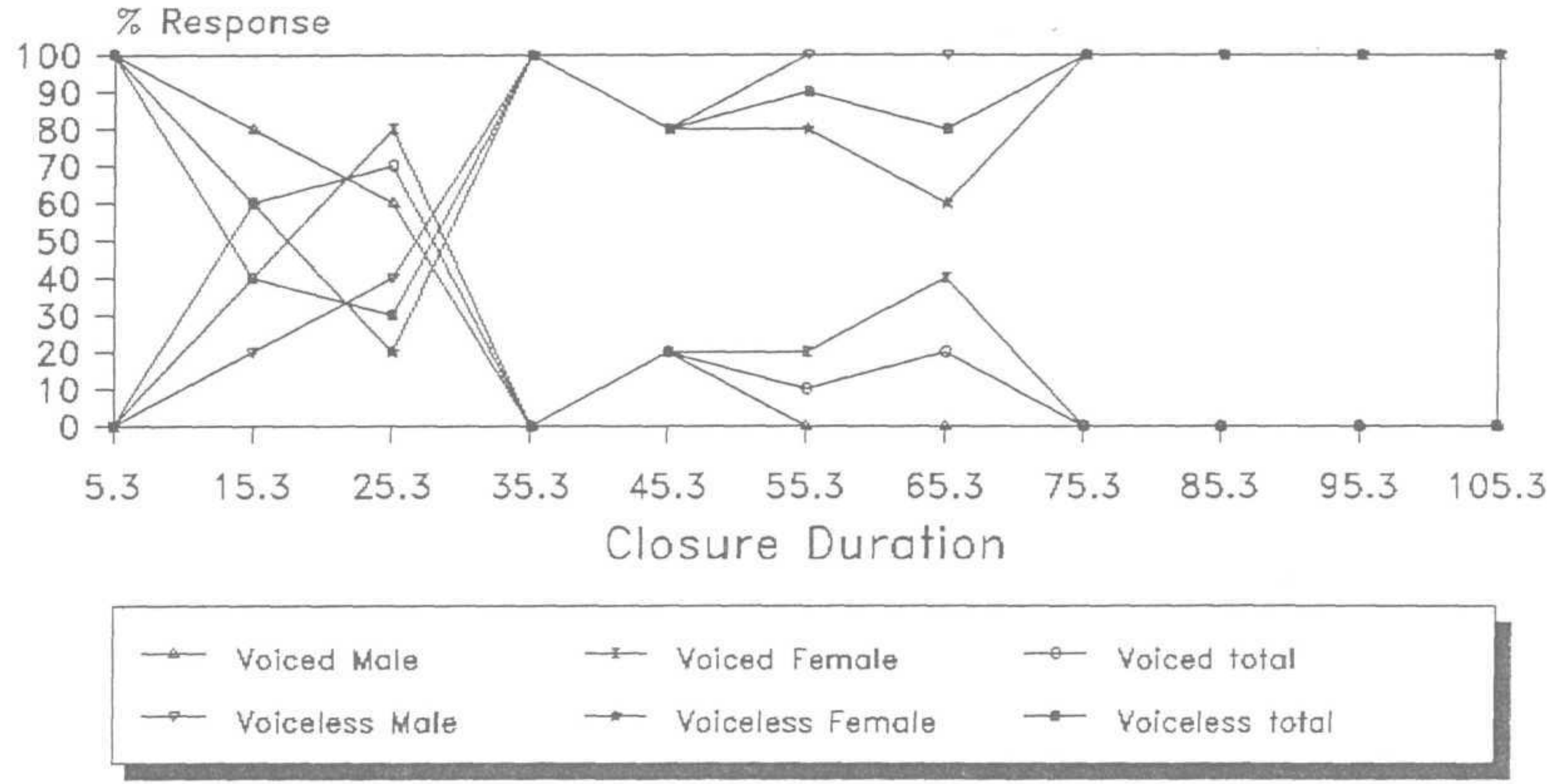
Table-19: Various measures for /t-d/ percept in bisyllabic word (5-6 years)

Sex	50% Crossover	Lower limit 75% voiced	Upper limit 75% voiceless	Phoneme Boundary Width
Male	26.8	17.3	31.3	14
Female	35.3	8.3	31.3	23
AVERAGE	31.05	12.8	31.3	18.5

Table-20: Various measures for /t-d/ percept in trisyllabic word (5-6 years)



Fig–23. Identification & discrimination curve for /t/ in bisyllabic word tiɦi for 5 to 6 years.



Fig—24. Identification & discrimination curve for /t/ in trisyllabic word Itara for 5 to 6 years.

/p-b/ Percept- /b/ percept was identified at closure durations shorter than 52.5msec. Both the limits and the boundary width were longer in females in the trisyllabic word (Figures 25 and 26).

Tables-21 & 22 show the various values for /p/.While in the bisyllabic word, the percept shifted to voiced only at a very low closure duration (7.1msecs) in the trisyllabic word the voiced percept was identified at longer closure durations also (52msec and below)

Sex	50% Crossover	Lower limit 75% voiced	Upper limit 75% voiceless	Phoneme Boundary Width
Male	12.1	-	25.1	-
Female	-	-	-	-
AVERAGE	7.1	-	25.1	-

Table-21: Various measures for / p / percept in bisyllabic word (5-6 years)

Sex	50% Crossover	Lower limit 75% voiced	Upper limit 75% voiceless	Phoneme Boundary Width
Male	52.5	40.5	70.5	30
Female	52.5	43.5	95.5	52
AVERAGE	52.5	42	83	41

Table-22: Various measures for / p / percept in trisyllabic word (5-6 years)

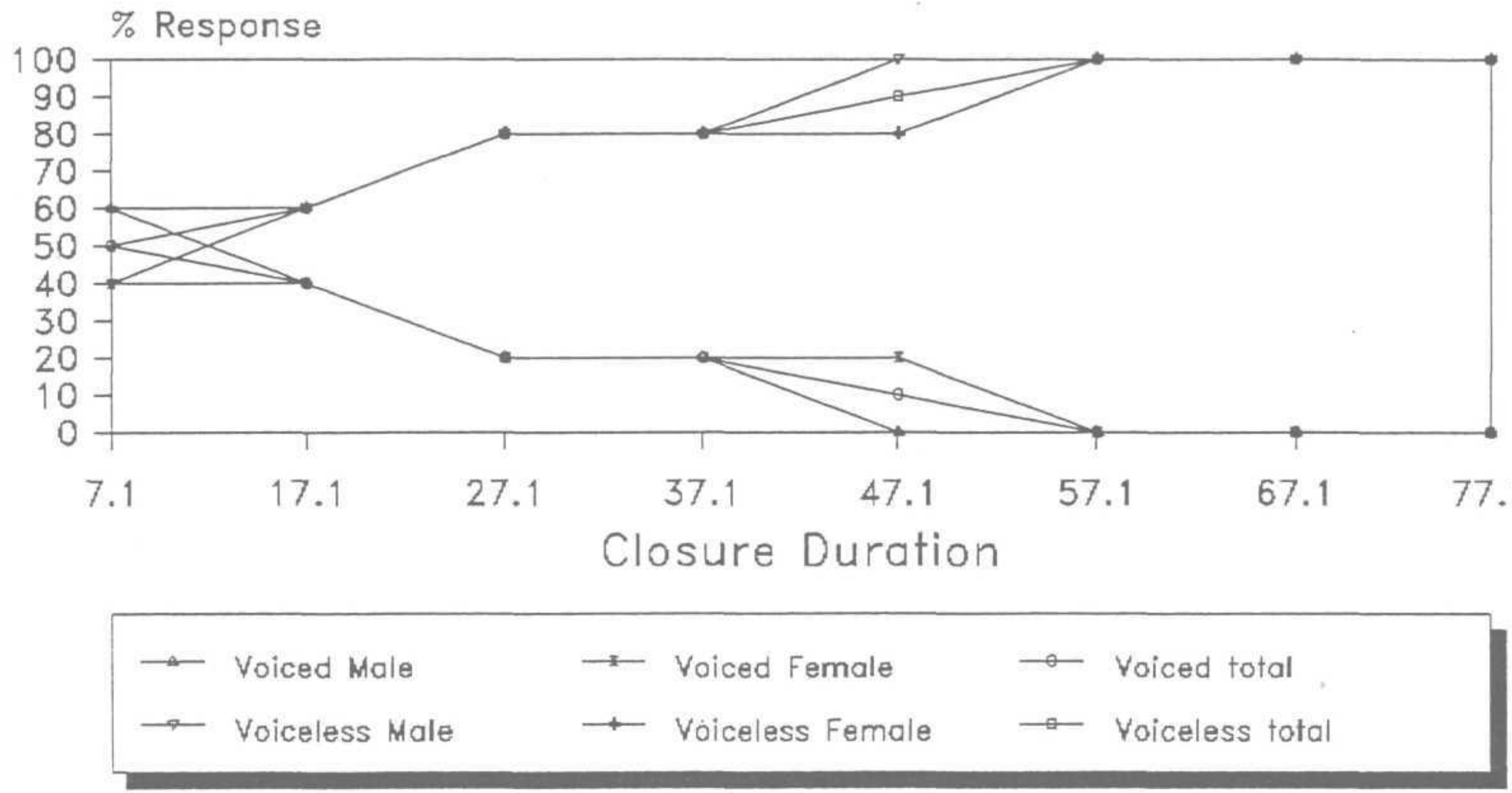


Fig-25. Identification & discrimination curve for /p/ in bisyllabic word wope for 5 to 6 years.

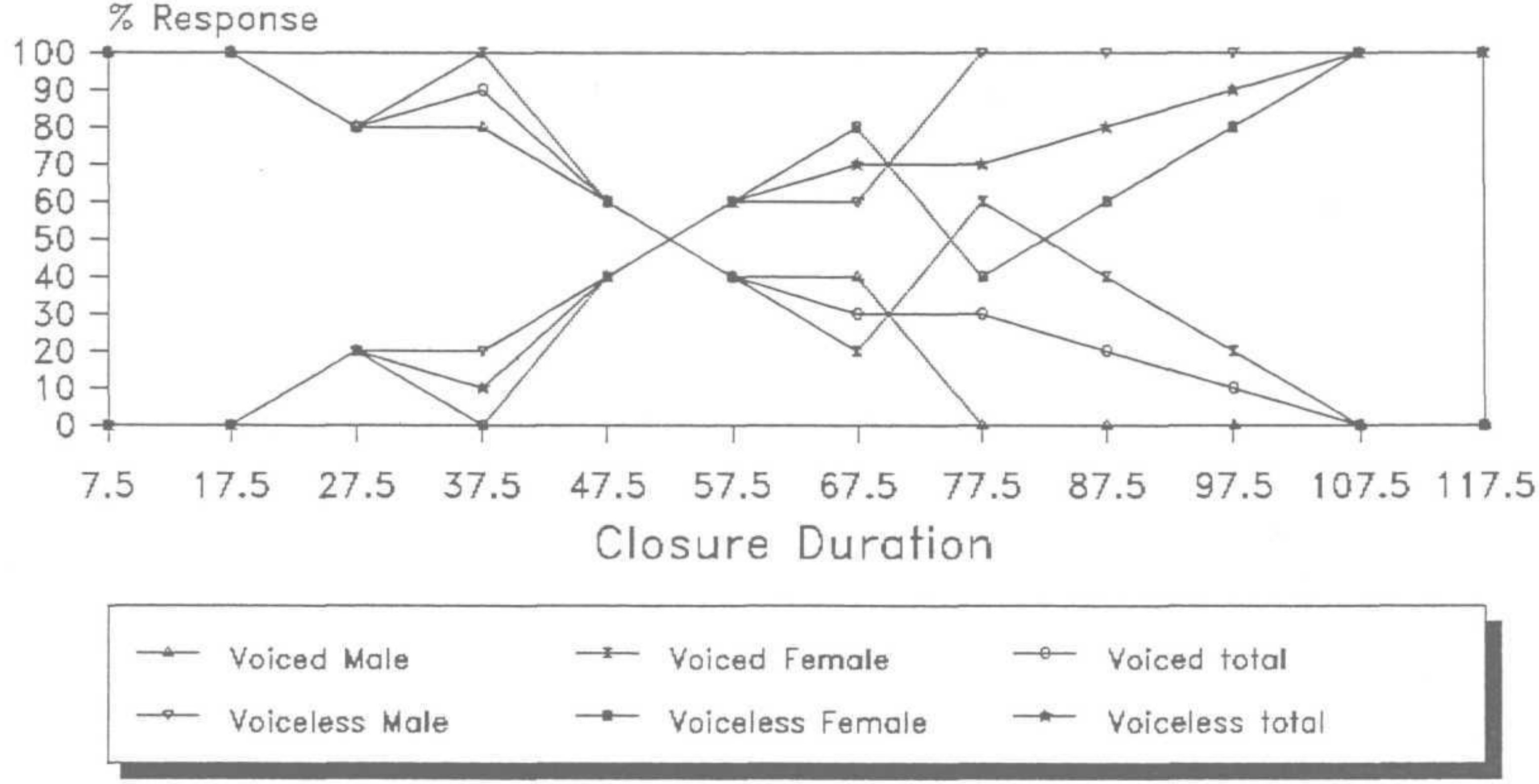


Fig-26. Identification & discrimination curve for /p/ in trisyllabic word ṭalapu for 5 to 6 years.

/ k - g/ Percept - Voiced percept was identified at shorter closure durations and in both bisyllabic and trisyllabic words and upper limit were longer in females (Tables 23 and 24). Figures 27 and 28. show the identification and discrimination function for /k-g/.

Sex	50% Crossover	Lower limit 75% voiced	Upper limit 75% voiceless	Phoneme Boundary Width
Male	8.2	-	20.2	-
Female	10.7	4.2	30.2	26.2
AVERAGE	9.2	-	28.2	-

Table-23: Various measures for / k / percept in bisyllabic word (5-6 years)

Sex	50% Crossover	Lower limit 75% voiced	Upper limit 75% voiceless	Phoneme Boundary Width
Male	7.2	-	29.5	-
Female	7.2	-	54.5	-
AVERAGE	7.2	-	44.5	-

Table-24: Various measures for / k / percept in trisyllabic word (5-6 years)

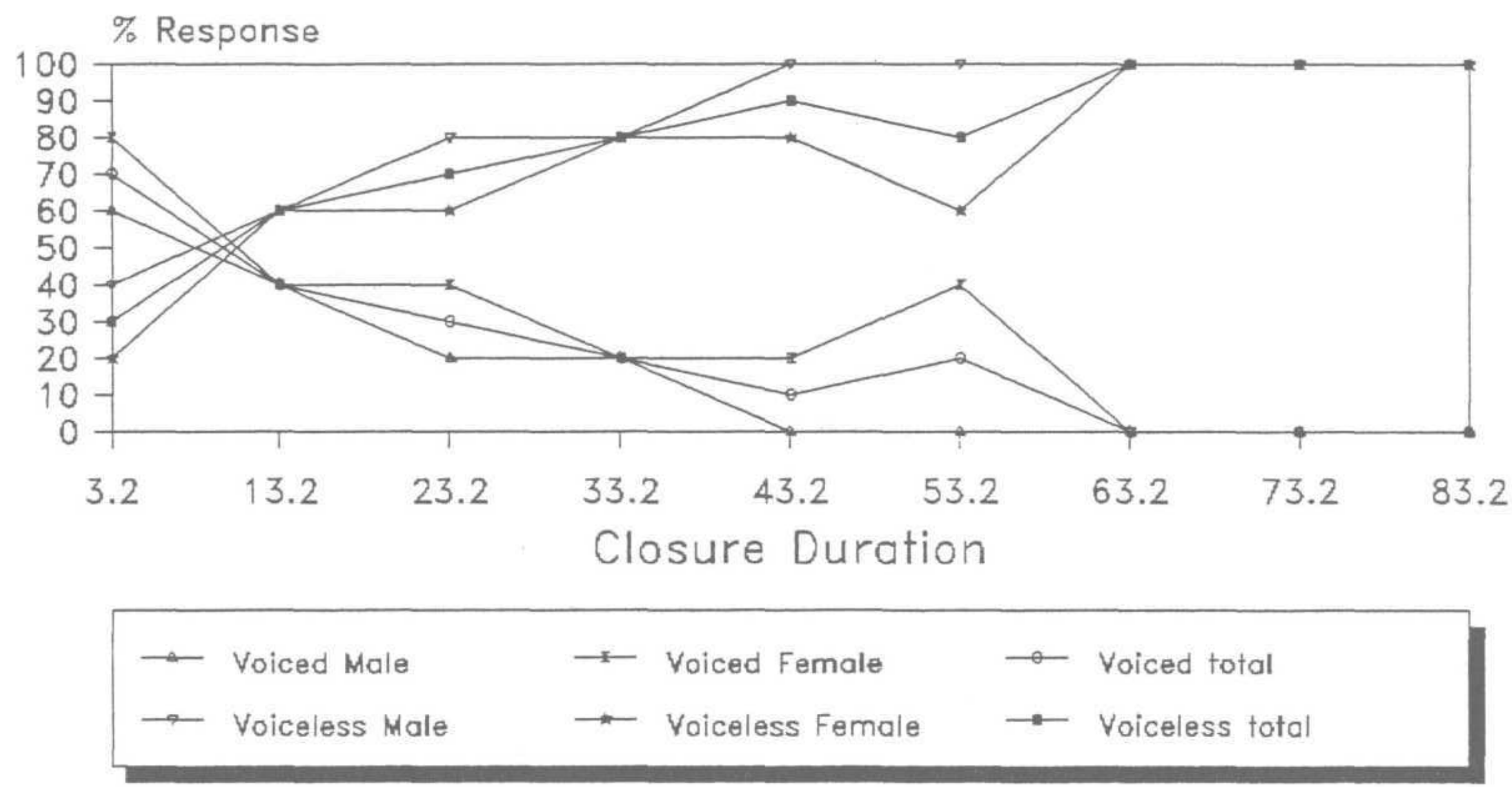


Fig-27: Identification & discrimination curve for /k/ in bisyllabic word baka for 5 to 6 years.

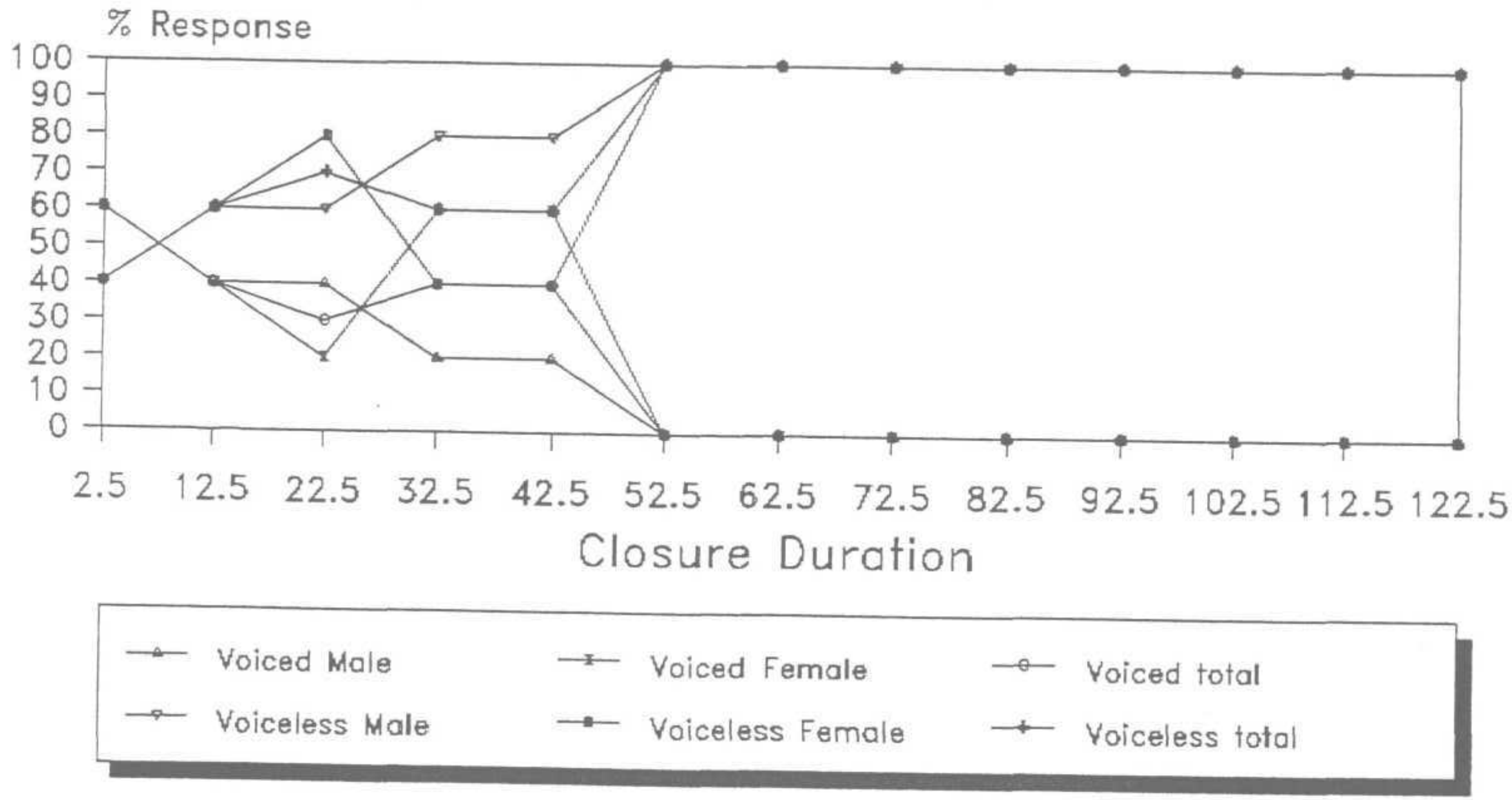


Fig-28. Identification & discrimination curve for /k/ in trisyllabic word pa*k*oda for 5 to 6 years.

To summarize, the results reveal the following findings.

(1) At shorter closure durations voiced percept was identified and at longer closure duration voiceless percept was identified.

(2) As the age increased, the 50% crossover value reduced. (Figures 29 and 30)- i.e. longer closure durations were required at younger age groups to identify the voiced plosive than the older age group. Thus, a developmental trend was noticed.

(3) Within the various places of articulation, retroflexes required the shortest closure duration and the closure duration increases in the order of retroflex, velar, labial dental (Figure-30).This was found to be true only in the bisyllabic word context . In the trisyllabic context, no consistent trend was noticed (Figure-29)

(4) The lower limit decreased in retroflex and bilabials as the age increased and increased in dentals as the age increased (Figures 31 and 32)

(5) The upper limit decreased for retroflexes and bilabials in the bisyllabic context and for retroflexes in the trisyllabic context. Upper limit increased in dentals and bilabials in the trisyllabic context and was inconsistent in velar (Figures 33 and 34)

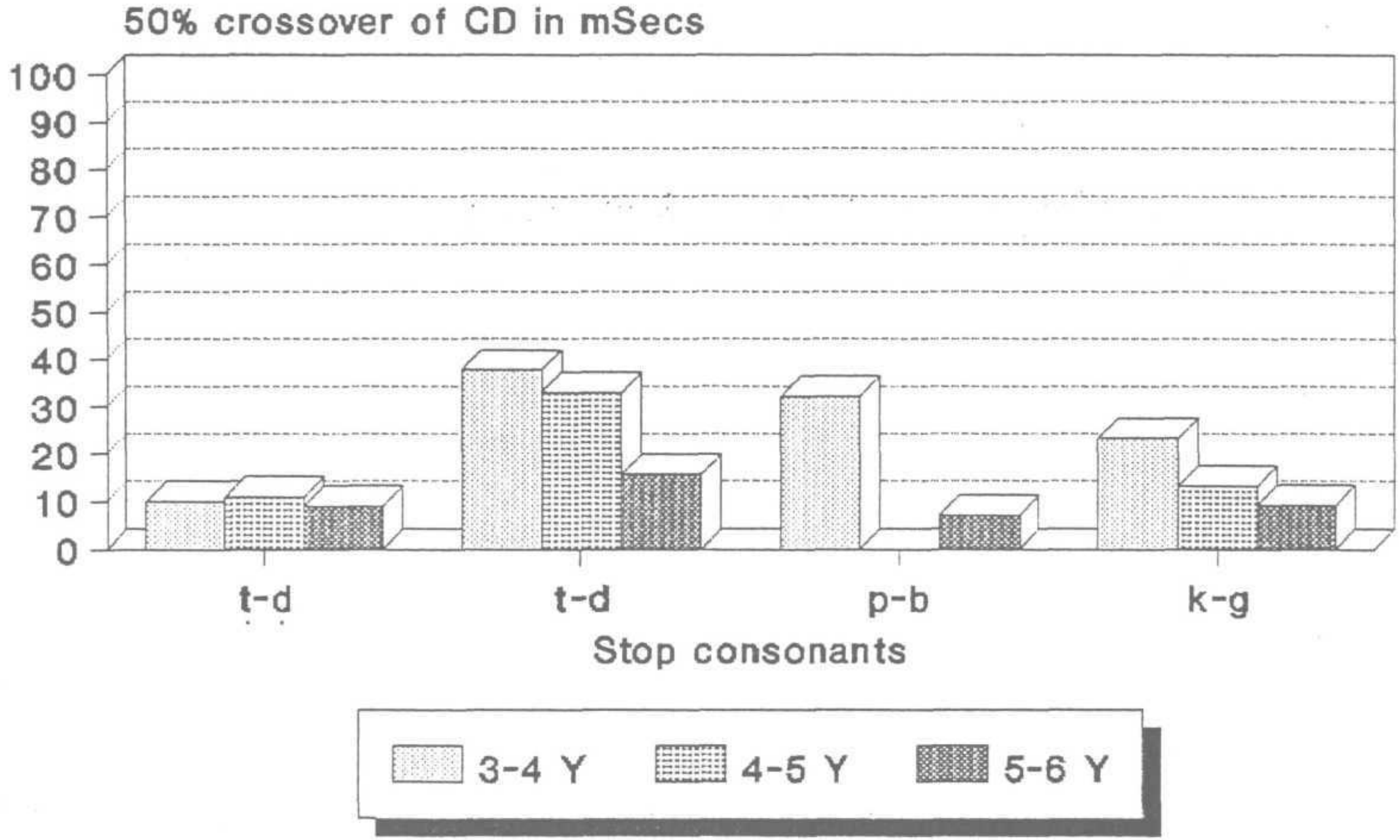


Fig-29: 50% crossover value for CD across age & place of articulation for bisyllabic words

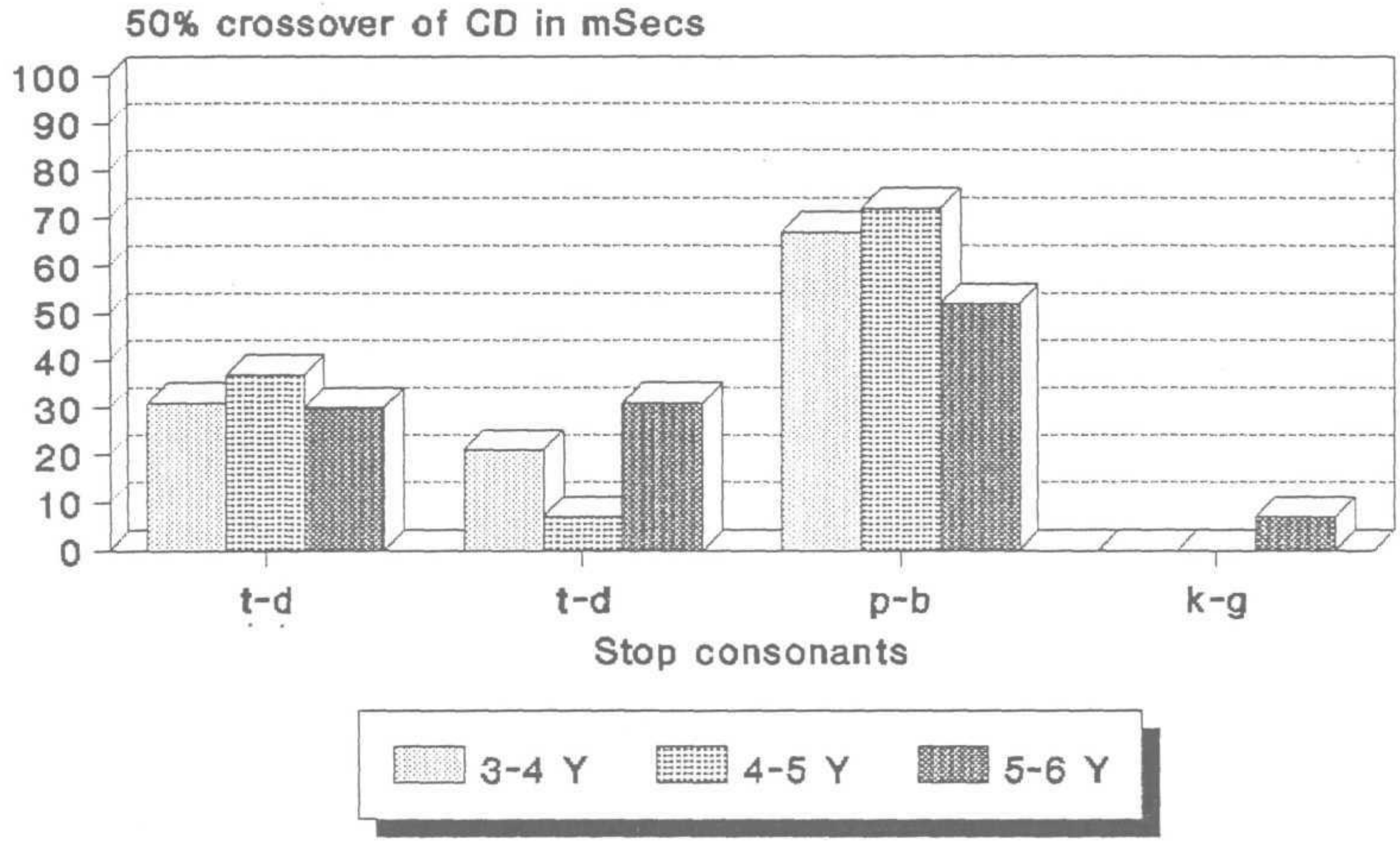


Fig-30: 50% crossover value for
CD across age & place of articulation
for trisyllabic words

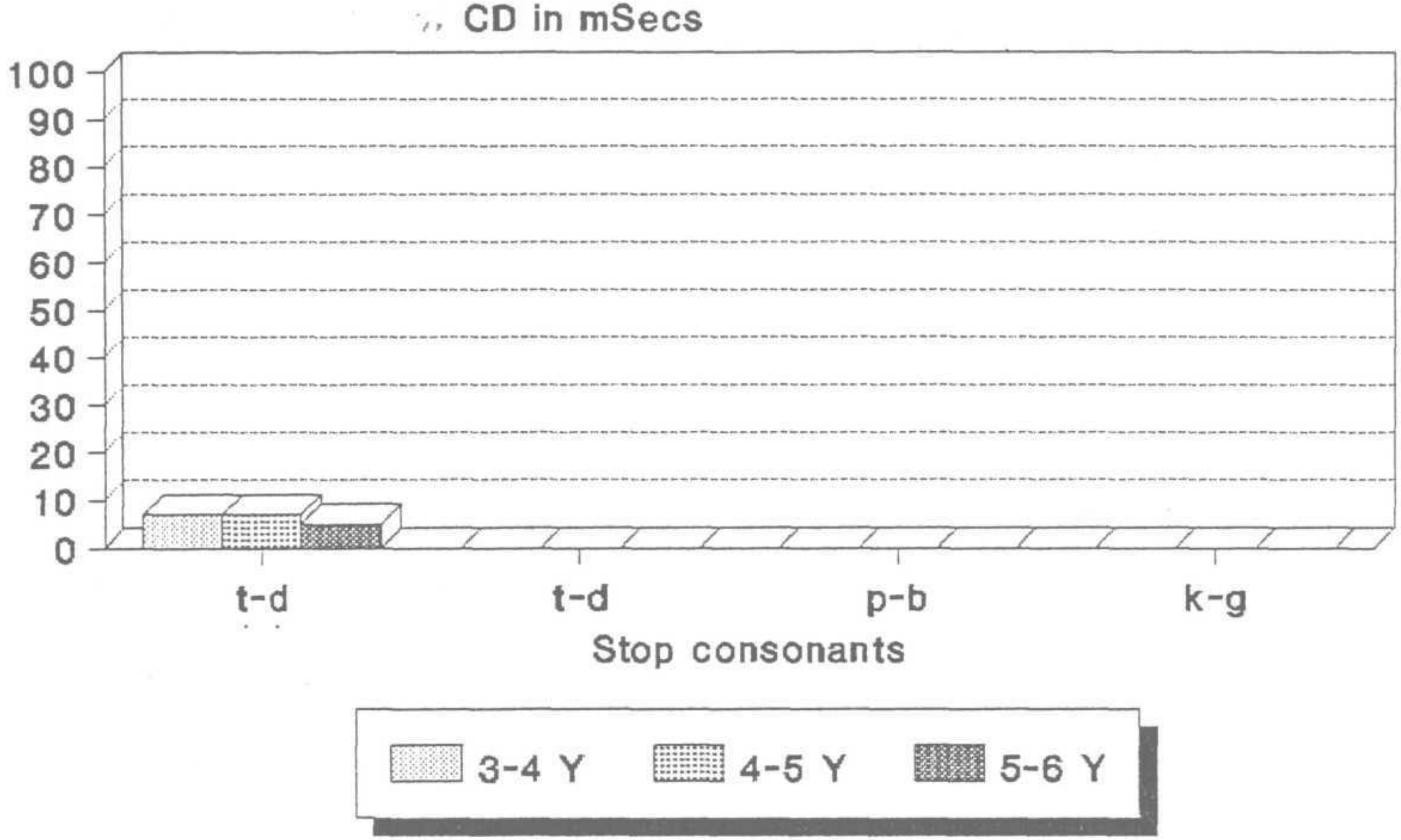


Fig-31. Lower limit value for CD across age & place of articulation for bisyllabic words

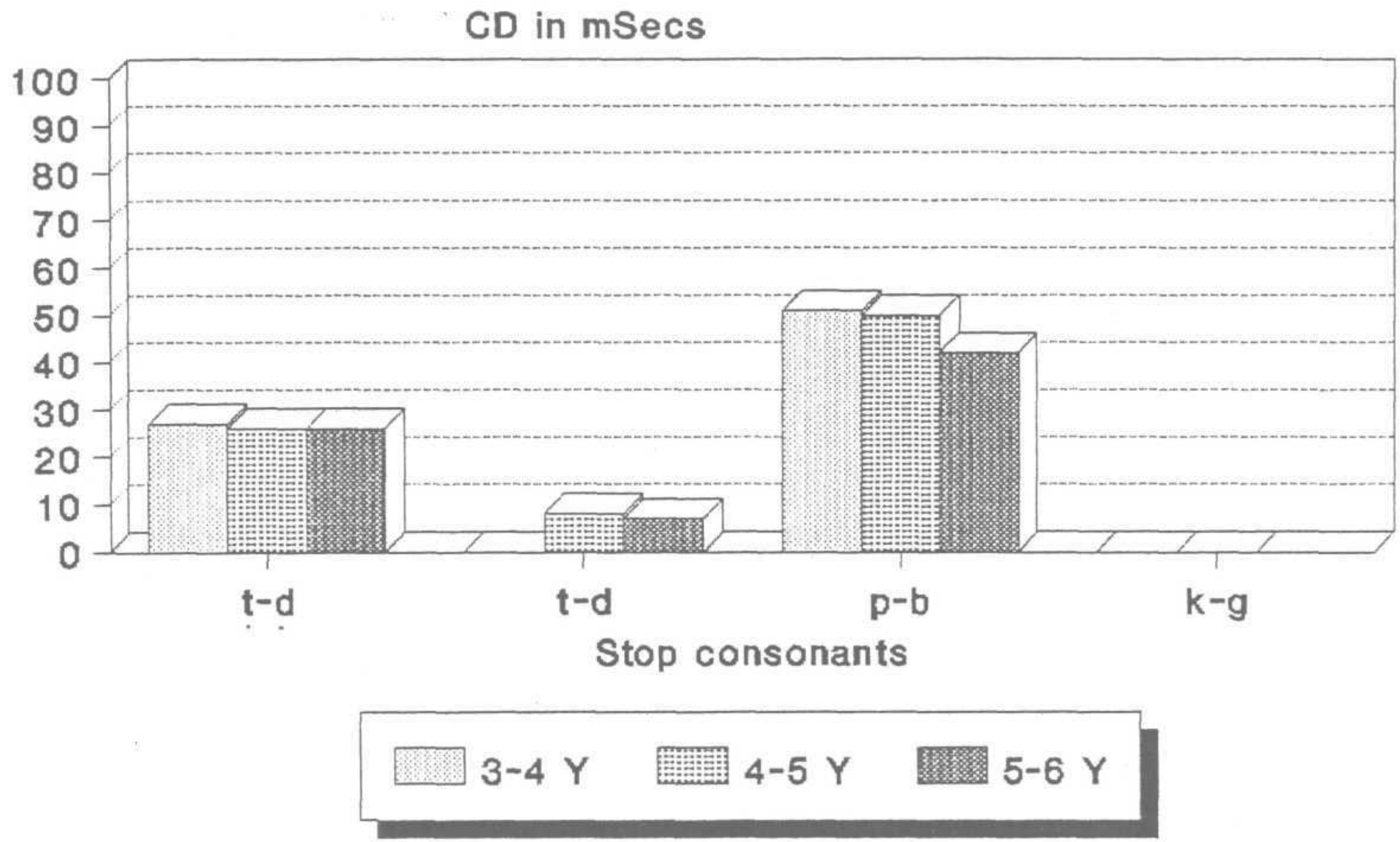


Fig-32. Lower limit value for
CD across age & place of articulation
for trisyllabic words

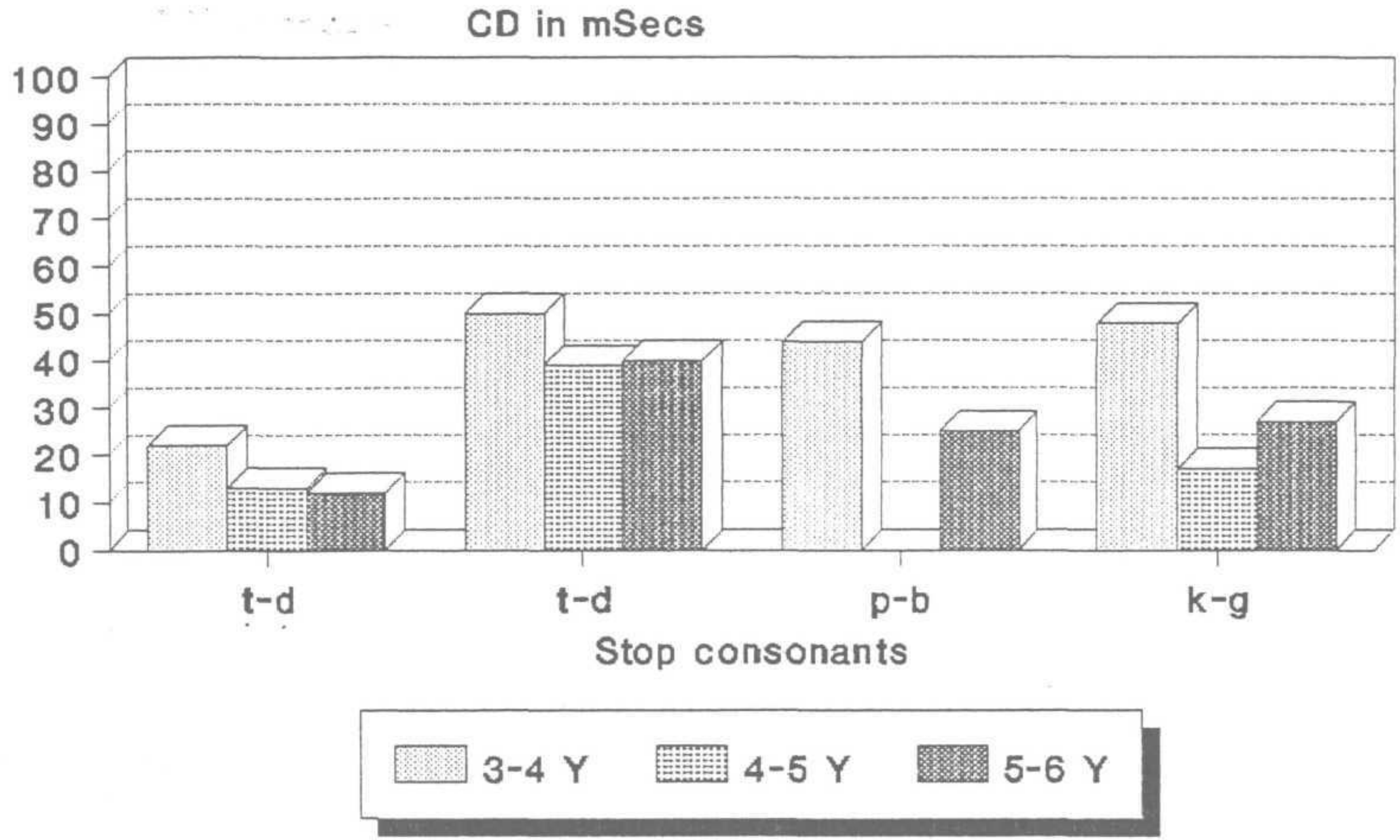


Fig-33. Upper limit value for
CD across age & place of articulation
for bisyllabic words

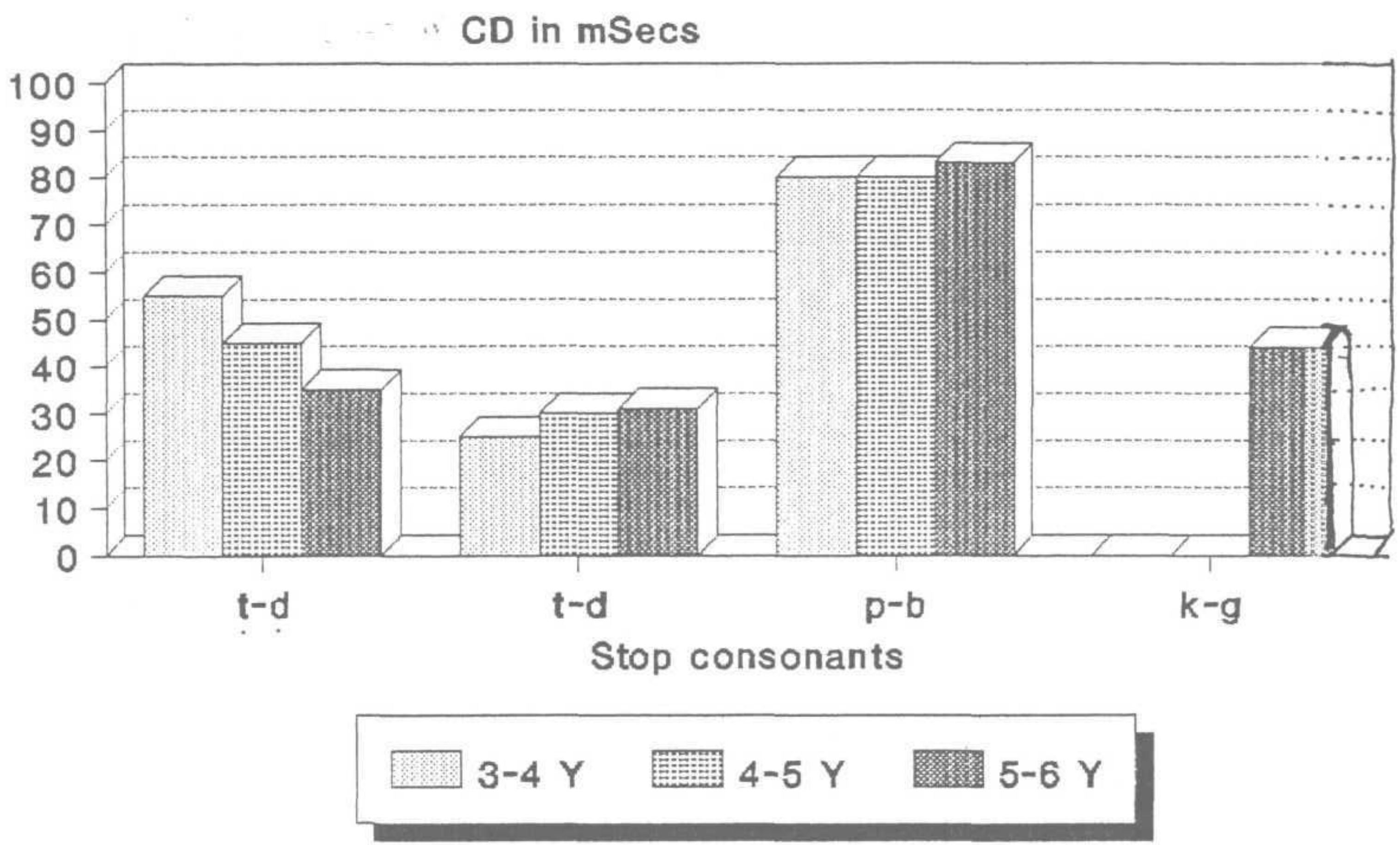


Fig-34. Upper limit value for
CD across age & place of articulation
for trisyllabic words

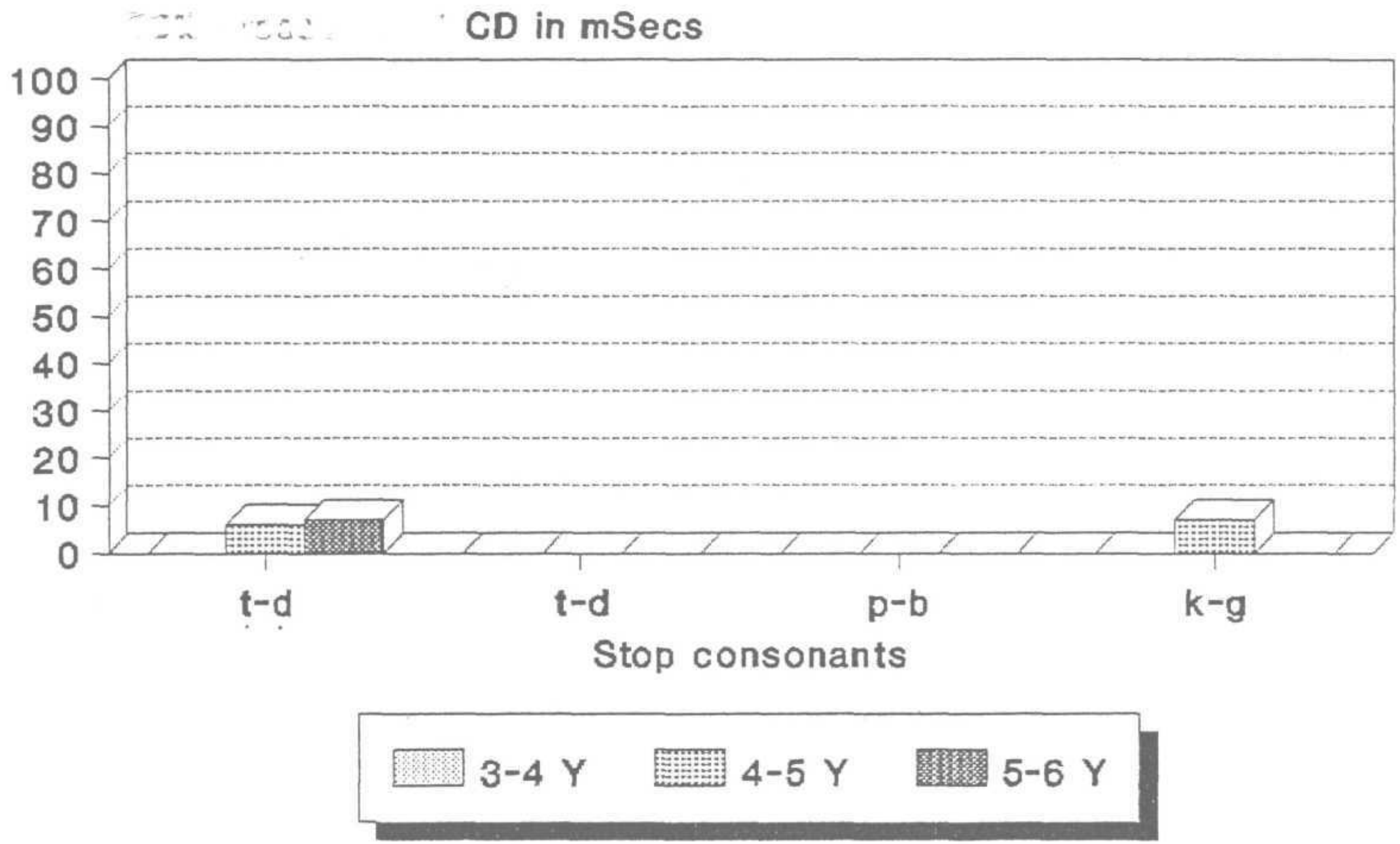


Fig-35. Phoneme boundary width for CD across age & place of articulation for bisyllabic words

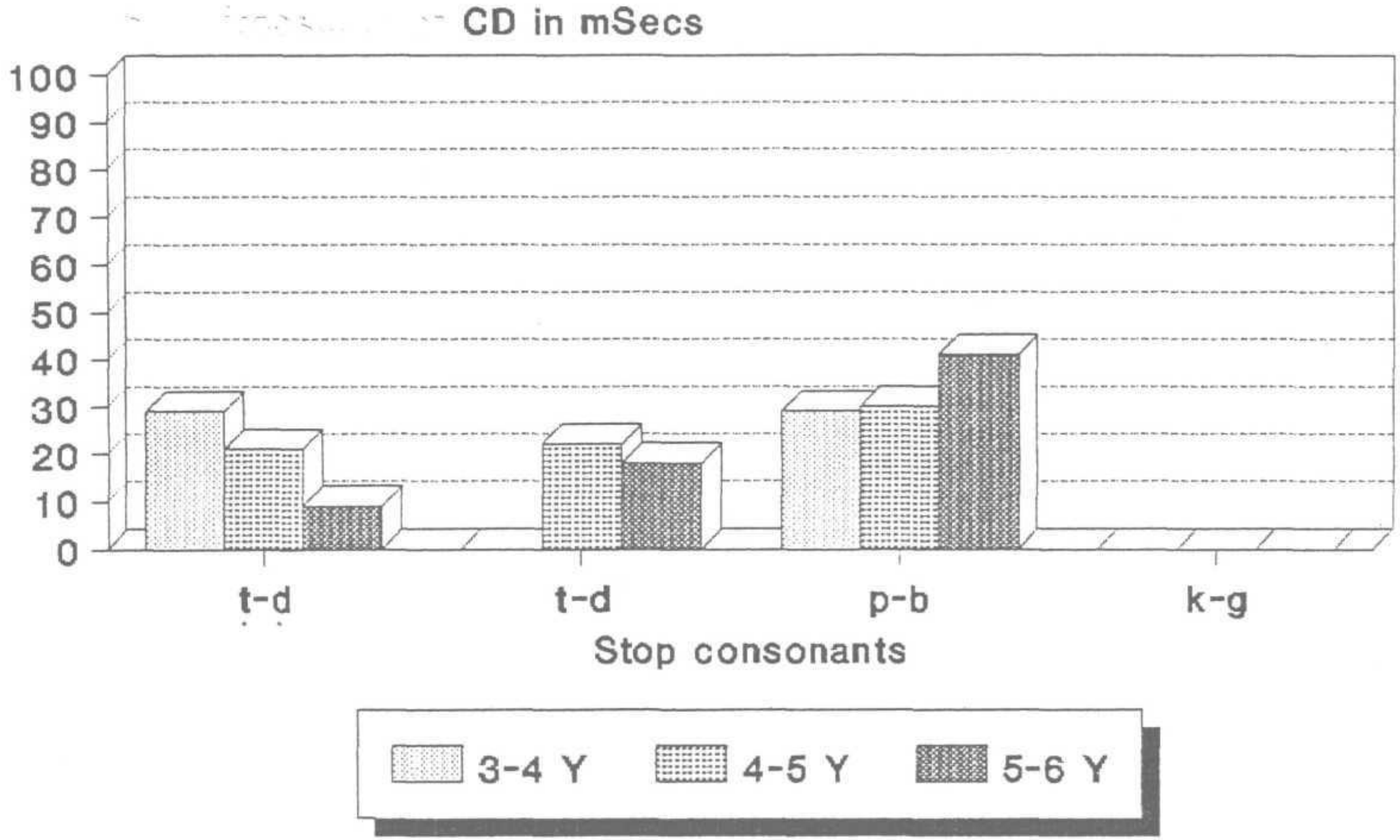


Fig-36. Phoneme boundary width for CD across age & place of articulation for trisyllabic words

(6) No consistent trend in the boundary width was noticed in the bisyllabic context. However, in the trisyllabic context the boundary width decreased for retroflexes and dentals as a function of age and in bilabials it increased (Figures 35 and 36)

(7) For retroflexes and bilabials the 50% crossover value was always shorter in the bisyllabic context than in the trisyllabic context.

DISCUSSION

The results reveal several interesting points. First of all, in children 3-6 year old, closure duration operates as a cue for voicing of stop consonants. While shorter closure durations cue voiced stops, longer closure durations cue voiceless stops. This is in cosonance with the results of the studies done on adults [Port 1980, Lisker 1967, Price & Simon 1984, Cazals & Palis 1991, Usharani 1989, Vinay Rakesh 1990] and in children [Wolf 1973, Simon 1974, Zlatin & Koenegnecht 1976].

It is interesting to note that in Kannada, the closure duration ratio between voiced and voiceless varies from 1:1.5 to 1:2.42 [Savithri 1992] and that of preceding vowel duraion varies from 1:1.02 to 1:1.21. The data from Sujatha's study on preceding vowel duration as a cue for voicing in children of 3-6 years indicates that preceding vowel duration was not a sufficient cue for voicing and the results of the present study indicate that closure duration is a sufficient cue for the distinction of voiced/voiceless stop consonants.The perception data is in consonance with the production data in Kannada in that in production data closure duration readily distinguishes voiced from voiceless stops whereas preceding vowel duration does not.

Second, a definite developmental trend in perception is evident. While at younger age groups (3-4 years), the closure duration required for the perception of voiced stop is longer, in the older age groups (5-6 years) voiced stops are perceived only at very short closure duration.

Comparing this with the closure duration production data (Table-25) for the voiced stop consonants in Kannada, it can be noticed that closure duration reduces from 3 - 6 years except for dentals. This supports the results of Wolf(1973) , Simon (1974) & Zlatin & Koegnigsknecht (1975, 1796) & Flege & Eefting (1986) in that the reduction in closure duration for voiced stops in production is also followed in perception.

Place of articulation	3 - 4 years	5 - 6 years
Velar	68	67
Retroflex	51	39
Dental	73	74
Bilabial	91	88

Table-25: Closure duration for voiced stop consonants.

Third, in majority of the phonemes studied ,there was a decrease in the lower limit of boundary as a function of age. Again this reflects that the closure duration difference magnitude required to distinguish voiced Vs voiceless stops decrease with age. This is in consonance with Zlatin & Koegnigsknecht(1975 & 1976).

Fourth, both the upper limit of the boundary and the boundarywidth did not show any consistent developmental trend. This does not support the results of Zlatin & Koegnignecht (1975, 1976), Wolf (1973) & Simon (1974), where they found a decrease in phoneme boundary width with an increase in age. However, they studied children in age groups of 2 years, 6 years and adults. The present study involved children from 3 to 6 years of age. This might explain the discrepancy between the results of the two studies. Also, the results indicate that the development of perception is not yet complete at the age of 6 years.

However, in the production data the range for voiced stop consonants decrease from 3-6 years. Thus the perception data on boundary width is not in consonance with the production data.(Table-26)

PLACE OF ARTICULATION	*PRODUCTION RANGE*		*PERCEPTION PHONEME BOUNDARY WIDTH*	
	3-4 YEARS	*5-6 YEARS*	*3-4 YEARS*	*5-6 YEARS*
Velars	*53*	*45.5*	– –	
Retroflex	*74*	*10*	*29*	*9*
Dental	*68*	*7.5*	–	*18.5*
Bilabials	*31*	*10.5*	*29*	*41*

Table-26: Range and Width of closure duration for various places of articulation (production and perception)

Thus, though a developmental trend is evident it is not found to be consistent. Further developmental research directed specifically to co-vary multiple acoustic parameters will be enlightening with respect to possible changes in the relative or combined strength of acoustic parameters as perceptual cues for voicing in Kannada. Such studies applied to both normal and clinical population will define processes for normal perceptual development and may have potential for direct diagnostic and therapeutic application with speech and language impaired children.

SUMMARY AND CONCLUSIONS

One of the basic unresolved issues in the study of speech and language is the complex relationship between production and perception. Applied to children, it is important to understand the modification process that the child undergoes to document the status of phoneme perception during the years the child is acquiring the phonology in production. Studies have suggested that a developmental or maturational differences in the closure duration phoneme boundary width in children [Simon 1974, Zlatin & Koenigsknecht 1975] are present . Several investigators have also obtained results in support of relation between perception and production of speech [Simon 1974, Eilers & Oiler 1975]. Other researchers claim that such a relation does not exist between perception and production [Bailey & Haggard 1972 Smith 1981]. Amidst these paradoxical results, there is a pressing need for experimental evidence on the development of perception in various languages to allow for priliminary generalisation about normal perceptual development. In this context, the present study was planned to investigate closure duration as a cue to voicing contrast of stop consonants in 3-6 years old Kannada speaking children.

Specifically the study aimed at determining:

(1) The developmental trend in the perception of closure duration as a cue to voicing of stop consonants [p,ṭ,t,k] in 3-6 year old Kannada speaking children.

(2) The effect of linguistic syllabic boundaries i.e. whether bisyllabic and trisyllabic boundaries influence the percept of voicing of stop consonants in medial position in 3-6 years old Kannada speaking children.

(3) The change across the place of articulation in closure duration needed for change in percept for 3-6 year old Kannada speaking children, and

(4) The concurrence of perception data with production data on closure duration for stop consonants.

Four plosives - Voicelss velar /k/, Voiceless retroflex /ṭ/, Voiceless dental /t/ and Voiceless bilabial /p/ were selected for the study as in four meaningful bisyllabic Kannada words [baka, tuṭi, titi & Wope] and four meaningful trisyllabic Kannada words [Pakoda, Karaṭi ,Itara & Talapu]. These words formed a minimal pair with a change from voiceless plosive to voiced plosive. These eight words with voiceless plosives in the medial position were uttered by a seven year old normal Kannada speaking male child and digitally recorded on a computer with 12 bit ADC at a sampling frequency of 20KHz. From the digitized waveform of each word, closure duration was measured and using the waveform editor DWSSLC, closure duration was cut in 10msec steps from the burst end until the closure duration was almost removed.

Each word with its synthetic tokens was considered as a test and within each of the eight tests the tokens were randomized and iterated twice and recorded on a metallic cassette with an inter stimulus interval of one second. Totally eight tests consisting of 81 synthetic stimuli were formed.

Ten normal Kannada speaking children [5 males and 5 females] each in the age range of 3-4 years, 4-5 years & 5-6 years served as subjects. Pictures representing the test words and minimal pairs (representing an alternate forced choice) were selected. Each child was tested individually after being initially conditioned to the pictures. The experimenter recorded the child's response on a response sheet immediately after the child's response.

The data thus obtained was tabulated and percent response for the stimulus was calculated. Identification and discrimination functions were drawn for each test word and four measurements viz. 50% crossover, lower limit of phoneme boundary width, upper limit of phoneme boundary width and phoneme boundary width were calculated from the identification functions.

The results obtained revealed the following points:

(1) At short closure duration, voiced percept was identified and at longer closure duration, voiceless percept was identified.

(2) As the age increased the 50% crossover value reduced i.e. longer closure duration were required at younger age group to identify voiced plosive than the older age group.

(3) Within the various places of articulation retroflex required shortest closure duration and the closure duration increased in the order of retroflex, velar, labial and dental. This was found only in the context of bisyllabic word. In trisyllabic context, no consistent trend was noticed.

(4) The lower limit decreased in retroflexes and bilabials as the age increased and increased in dentals as a function of age.

(5) The upper limit decreased for the retroflexes and bilabials in the bisyllabic context and for retroflexes in the trisyllabic context. Upper limit increased in dentals and bilabials in the trisyllabic context and was inconsistent in velars.

(6) No consistent trend in the phoneme boundary width was noticed in the bisyllabic context. However, in the trisyllabic context the boundary width decreased for retroflexes and dentals as a function of age and in bilabials it increased.

(7) For retroflexes and bilabials, the 50% crossover value was always shorter in the bisyllabic context than in the trisyllabic context.

The results of the study revealed that closure duration operates as a cue for voicing of stop consonants in children 3-6 years old. It is interesting to note that in Kannada, the closure duration ratio between voiced and voiceless varies from 1.5 to 2.42 [Savithri 1992] and that of preceding vowel duration varies from 1:1.02 to 1:1.21 . The perception data is in consonance with the production data in Kannada in that in production data closure duration readily distinguished voiced from voiceless stops whereas preceding vowel duration does not [Sujatha 1992].

A definite developmental trend in perception is evident. While at younger age groups (3-4 years), the closure duration required for the perception of voiced stop is longer, in the older age group (5-6 years), voices stops are perceived only at very short closure duration. This is in consonance with the result of the study by Wolf (1973), Simon (1974) & Zlatin & Koegnigsknecht(1975, 1976). Also there is an influence of the linguistic boundary, in that bisyllabic and trisyllabic words differed in the four functions across the places of articulation.

Thus, the results of the study indicate that closure duration acts as a cue to perception of voicing contrast in 3-6 year old Kannada speaking children. Also, the production data and perception data for closure duration in Kannada correlate well. There is a definite developmental trend in closure duration as a voicing contrast and development of perception is not yet complete by 6 years of age.

Further developmental research directed specifically to co-vary multiple acoustic parameters will be enlightening with respect to possible changes in the relative or combined strength of acoustic parameters as perceptual cues for voicing in Kannada.

. t-

Applied to communication disordered population, the controversial issue whether or not speech perception deficits exist in individuals who have no known organic disorders, but who exhibit deviant production skills could probably get an answer. Furthermore, attempts could be made to define the nature of perceptual deficit in relation to production deficits in the communication disordered children.

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APPENDIX-I

RESPONSE SHEET

NAME: Vibhas SEX: Male AGE: 4.2yrs

	Pakoda	Pagoda
1. Pakoda 122.55		
2. Pak 30		
3. Pak 100		
4. Pak 20		
5. Pak 80		
6. Pak 10		
7. Pak 40		
8. Pak 110		
9. Pak 60		
10. Pak 120		
11. Pak 90		
12. Pak 50		
13. Pak 70		
	Baka	Baga
14. Baka ori 83.2		
15. Baka 30		
16. Baka 20		
17. Baka 80		
18. Baka 10		
19. Baka 40		
20. Baka 60		
21. Baka 50		
22. Baka 70		

	tuṭi	tudi
23. tuti(84.95)		
24. tuti 30		
25. tuti 20		
26. tuti 80		
27. tuti 10		
26. tuti 40		
29. tuti 60		
30. tuti 50		
31. tuti 70		

NAME:

	Karati	Karadi
32. CKRT (63.65)		
33. KRT 30		
34. KRT 20		
35. KRT 10		
36. KRT 40		
37. KRT 60		
38. KRT 50		

	Itara	Idara
39. Itara 105.30		
40. Itara 30		
41. Itara 100		
42. Itara 20		
43. Itara 80		
44. Itara 10		
45. Itara 40		
46. Itara 60		
47. Itara 90		
48. Itara 50		
49. Itara 70		

	Titi	Tidi
50. titi(112.7)		
51. titi 30		
52. titi 100		
53. titi 20		
54. titi 80		
55. titi 10		
56. titi 40		
57. titi 110		
58. titi 60		
59. titi 90		
60. titi 50		
61. titi 70		

	Talapu	Talabu
62. talapu 117.5		
63. talapu 30		
64. talapu 100		
65. talapu 20		
66. talapu 80		
67. talapu 10		
68. talapu 40		
69. talapu 110		
70. talapu 60		
71. talapu 90		
72. talapu 50		
73. talapu 70		

	Wope	Wobe
74. Wope 77.1		
75. Wope 30		
76. Hope 20		
77. Wope 10		
78. Wope 40		
79. Wopw 60		
80. Wope 50		
81. Wope 70		