TRADING RELATION BETWEEN SPECTRAL AND TEMPRAL CUES FOR THE PERCEPTION OF STOP CONSONANT IN KANNADA

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TO GUIDE

CERTIFICATE

This is to certify that this Dissertation entitled: TRADING RELATION BETWEEN SPECTRAL AND TEMPROAL CUES FOR THE PERCEPTION OF STOP CONSONANT IN KANNADA Is a bonafide work done in part fulfilment for the degree of M.Sc.,(Speech and Hearing)for the student with Reg.No.M9113.

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This is to certify that this Dissertation entitled: TRADING RELATION BETWEEN SPECTRAL AND TEMPROAL CUES FOR THE PERCEPTION OF STOP CONSONANT IN kANNADA has been prepared under my super-vision and guidance.

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Declaration

This Dissertation entitled: TRADING RELATION BETWEEN SPECTRA AND TEMPROAL CUES FOR THE PERCEPTION OF CONSONANT IN KANNADA is the result of my own work undertaken under the guidance of Dr. Savithri S.R Lecturer in Speech Sciences, All India Institute of Speech and Hearing, Mysore-6 and has not been submitted earlier at any University or Institution for any other Diploma or Degree.

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CHAPTER-1

Stop consonants are produced by occluding the oral cavity by an articulator. Air is held behind the articulator for sometime and ia than released. The stops represent the non-linearity 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 of listener's use of the acoustic overlapping of phonemes in the speech system. Also they have consistently produced evidence for phonetic level processing. They appear to be most highly encoded speech sounds (Day and vigorite, 1973).

The salient features of a stop consonant 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 the release of the occlusion.

!. A very brief (0-10 msec.) period of friction as articulators separate and air ia blown through a narrow constriction, as in the homorpanic fricative.

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

5. voiced farmant transitions reflecting the final stages of atticulatory movement into the vowel during the first few cycles of laryngeal vibration.

Stop conaonants have been considered to have multiple spectral and temporal cues. The spectral cues are as follows:

(1) Burst anplitude

(2) Burst frequency

(3) Double burst release

(4) Fo changea in the succceding vowel

(5) Frequency of formants 1, 2, and 3

(6) Bandwidths of formants 1, 2, end 3

(7) Amplitudes of formants 1, 2, and 3

(9) Direction of second and third formant (F_2 and F_3) tranaitions

(9) Voicing during closure etc.

The temporal parameters are -

(a) Preceding vowel duration

(b) Closure duration

(c) voice onset time

(d) voice offset time

(e) stop consonant duration

(f) Off-glide duration of the first formant (F_1)

(g) Off-glide duration of the second formant (F_2)

(h) Burst duration etc.

It has been well-known for many years that sevaral cues may signal a single phonetic contrast (Danes, 1955). Thus, it is possible to demonstrate that when the perceptual utility of one cue is attenuated, another cue may take on primary effectiveness in signeling the contrast under scrutiny because both cues, it is assumed, are equivalent. This is called phonetic trading relationship (Repp, 1992).

Several experiments have been conducted in the past and the results of these experiments have indicated that there is a trading relationship between several temporal and spectral parameters especially in the stop consonants.

Fitch at al. (1980) examined the trading relation between silent closure duration and vocalic formant transition Onset as cue to stop manner in the /slit/ - /split/ distinction and found a trading relationship between the two. Fitch et al (1981), Repp at al. (1983) observed a trading relationship between silence and burst as the cues for discrimination of stop consonants. Summerrfield at al. (1931) conducted a study taking silence duration and duration of fricatives along with vocalic segments as trading cues. They found that more silence was required both when the durations of the fricative and vocalic segments were increased and when the intensity fall time of the fricative was reduced.

Liberman etal(1981) investigated the duplex perception of cues for atop consonants, considering vocalic formant transition and burst along with closure duration and found a trading between them.

Best et al.(198l) undertaking onset frequency of the lowest tone as spectral cue and duration of the closure interval as temporal cue observed that they trade each other. Repp et al. (1983) in a series of studies considered cues like release burst and silence duration. Varying the quality of the burst (as changing amplitude and introducing noise etc.) they traded spectral and temporal cues.

Barbera et al. (1984) found a trading relationship between silence duration as temporal cue and F_1 onset freqquency as spectral cue.

In a study by Pastore et al. (1984), the relation between silence and auditory separation based upon the selective late-ralization of the stimuli components created by an interaural phase shift was traded.

Repp et al. (1964) examined the hypothesis that "temporal changes in signal portions proceeding and following the silence may/may not be equally relevant. Further in the same year they traded other two cues, burst amplitude and silence duration; for stop consonantt perception.

On the basis of the results of the studies on trading relationship, the Haskins group believe that there exists specialized speech processor. However, Massaro et al. (1980) deny it.

They offer an alternative account of trading relations that explicitly denies say specialized processing. In their model, speech perception is viewed as a "Prototypical instance of pattern recognition". Briefly Message and Oden argue that multiple features corresponding to a given phonetic contrast are extracted independently from the wave form aad then combined in the decision processor according to logical integration rules. These rules operate oa fuzzy sets so that Information regarding a given feature may be more or less present or sort of present. This aspect of their model, than stresses continuous rather than all or none information. Thus, features are assigned a probability value between .o and 1.0 indicating the extent to which a given feature is present. Subsequently the degree to which this featural information matches a stored prototype is determined according to a Multiplicative combination of the independent features. The fact that multiple features are evaluated independently, and that these features can assume ambiguous values (eg. .5), can account for the finding that the perceptual utility of two cues may trade off in rendering a given phonetic percept.

Researchers in the domain of speech perception for the past few years have shown that the perception of phonetic distinction relies on a multiplicity of acoustic cues, when which human observers are presented with speech signals in/these cues are redundant they respond typically as linguistic entities. Thus, speech signals are categorized and labelled almost with reference to the listeners linguistic back-ground and exposure/experience. Support for this comes from the study of Lotz et al. (1960), Singh and Black (1966). Stevens and Blumstein (1975), strange and Fenkins (1978), Fox and Lehiste (1984), Usha Rani (1989) and Vinay Rakesh (1990).

These studies have indicated that the language of the speaker/listener plays a very important role. In Kannada, the structure of stop consonant is different in that final stop consonants do not exist thus relegating the preceding vowel duration cue to the back-ground. Under these conditions, the trading relationship will also be different. In this context, the present study was planned. The aim of the present study was to find out the trading relationship between the temporal and the spectral parameters of stop consonants in Kannada. Specially, silence and burst are traded with each other.

CHAPTER-II

REVIEW OF LITERATURE

ThE perception of most if not all phonetic distinction ia sensitive to multiple acoustic cues, the relevance of which can be predicted from comparisons of typical utterances exemplifying the phonetic contrast of interest. Provided the cues are adjusted so that each has an opportunity to influence the perception of the relevant phonetic distinction, it can easily be demonstrated that a little more of one cue can be traded against a little less of another cue, without changing the phonetic percept. This is called a phonetic trading relation, whenever two acoustic cues contribute to the same phonetic distinction, they can also be traded against each other within a certain range. Thus, this trading relations are a manifestation of a more general perceptual principle of cue integration (Repp, 1983). That is in phonetic perception the information conveyed by a variety of acoustic cues is integrated and combined into a untitary perceptual experience that can be described in terem of linguistic categories.

The integration of cues and the ensuing trading relations are due to auditory interactions. Phonetic classification is a form of pattern recognition. Speech signals may be thought of as points or traces in a multidimensional auditory space that also harbors the appropriately tuned category prototypes and phonetic categories are selected on the basis of some distance metric. Trading relations among the various acoustic dimensions of this auditory phonetic space are an obvious consequence, what make speech special, is act the processes/ mechanise employed in its perceptual but the unique structure of the patterns that age to be recognized which reflect in turn the special properties of the production apparatus sad the language specific conventions according to which it is operated (Repp, 1983).

On one hand phonetic trading relations are speech specific, but on the other hand they are act special as a phenomenon. They are speech specific because their specific form can only be understood by examining the typical patterns of a language. They are not special because once the prototypical patterns are known in any perceptual domain, trading relation among the stimulus dimensions follow as the inevitable product of a general pattern matching operation. Thus, speech perception is the application of general perceptual principles to very special patterns (Repp, 1983).

It has been well-known for many years, that several cues may signal a single phonatic contrast (Denes, 1955). Thus, it is possible to demonstrate that when the perceptual utility of one cue is attenuated, another cue may take on primary effectiveness in signaling the contrast under scrutiny because both cues, it is assumed are equivalent. This is called phonetic trading relationship (Repp, 1983).

In recent years, phonetic trading relations have been cited as evidence for a specialized speech mode of perception, There appear to be two reasons for this view (i) some demonstrations of phonetic trading relations involve both spectral and temporal cues that are distributed over a relatively long temporal interval, (2) the second line of evidence for specialization of speech perception involves demonstrations that phonetic trading relations do not apparently arise for non-Speech sound (Repp, 1983). Such evidence is therefore, taken to be proof that the integration of multiple cues giving rise to trading relations some-how or other/is peculiar to processing speech signals.

Several researchess have been interested in the trading relationships of the cues for stop consonants and experiments have been conducted in this regard. The experiments reported by Dorman et al. (1979) have in common a concern with silence as one of the cues for the perception of stop consonants. The experiments were carried out to answer the following questions'

1) In what circumstances is silence a cue?
2) Does silence has it's effect exclusively in the auditory domain, or also at some more abstract (phonetic)remove where perception is constrained as if by knowledge of what a vocal tract does when it makes linguistically significant gestures.

3) If the latter, then whole vocal tract provides the constraint?

The first experiment was designed to assess the role of silence in the perception of stop manner prevocalically in the syllables (ʃpɛ) and (ʃkɛ) and second to determine whether the fricative noise of (ʃ) masks or interacts with information carried-on the transmission cues for the stops when those are isolated from the rest of the syllable and are heard as nonspeech. It was found that silence was a necessary condition for the perception of stops in pervocalic portion.

Experiment 2(a) and (b) were designed to findout if silence is a1so a necesary condition for the perception of steps in post vocalic position. It was again concluded that silence is also important for the perception of stops inthe post vocalic position.

The third experiment was designed to determine whether the perception of /split/ could be induced by inserting silence between the fricative noise of /s/ and the syllable /lit/. The results reported that at silent intervals of less than 60 msec. listeners reported /slit/ but at longer intervals - about 450 msec. - they reported /split/.

The purpose of experiment four was to determine whether silince can be a sufficient condition for fricative - affricate contrast in the naturally produced utterances. The results revealed that when the silent interval exceeds 30 msec. 'drop' ersponses (affricate) began to appear and by 70 msec. they account for 75% of the responses.

Experiment five was carried out to determine whether the silent cue can be sufficient in syllable-final position, as in 'dish' vs 'ditch', it was apparent from the results that silence is sufficient to cue the distinction between fricative and affricate post vocally. At the short intervals of silence, the stimuli in both condition of fricative noise duration were heard as 'dish', while at the longest intervals of silence, they were heard as /ditch/.

The purpose of experiment six was to discover whether the effect of inter-syllabic silence on the perception of syllable final stops in the disyllables//babda/ aad /bagda/ ia different when the syllables are spoken by two speakers rather than one. At short intervals of slience, listeners did not hear syllable final stops, these were heard with 75% accuracy only when silent interval was about 45 sec. in duration.

The purpoee of the experiment seven was to determine if the affect of slience in converting "sayshop" to "saychop" is different when the words on either side of the silence are produced by two talkers instead of one . The results indicated that the fricative in the word shop was heard as the affricate to the word /chop/ when the silent intarval between it and the immediately preceding word exceeded about 45 msec. In contrast, tha silence had no effect in the different talkers condition. Increases in the silent interval did not convert /shop/ to /chop/.

Esickson et al. (1977) investigated tha perceptual effects of independent variation in two different cues for the presence of absence of the medial stop consonants in /split/ vs /slit/. One was a temporal cue specially, the donation of silence between the /s/ noise and vocalic part of the syllable the other was spectral specially, the presence or avsence of those formant transitions that distinguish /plit/ and /lit/. The result was that tha amount of temporal cue the duration of silince needed to convert /slit/ to /spilt/ was about 25 msec. less (more) when the spectral cue was present (absent) indicating a trading relationship.

Mann et al. (1979) reported the effect of a preceding fricative on the perceived place of stop consonant articulation in three experiments. In the first experiment, the goal was to demonstrate that /ʃ/ and /s/ differentially affect listeners identification of following step consonants (t-k continuum) and explore the conditions that might influence the magnitude of this effect. The results were that the subjects heard more velar stops following /s/ than following /S/ (or in the absence of any fricative). The second experiment was designed to explore further the temporal limits of the context effect, observed in experiment-1(experiment-1 demonstrated a decrease in the magnitude of the pereceptual context effect with increased temporal separation of fricative and cv portions, and wtth introduction of a syllable boundary after the fricative). Experiment-2 suggested that although the effect daclines initially with temporal separation, it may persist in reduced form, ever intervals as long as 375 msec. Experiment-3 was designed to answer whether the effect of fricative on the following stop was primarily a function of the fricative noise spectrum or of its perceived phonetic category. The results show a strong effect of perceived fricative category but little effect of fricative noise spectrum on the perception of the following stop consonants. Neither auditory contrast nor noise offset cues to place of stop occlusion were involved to any significant degree. It also revealed that context effect was categorical in nature and depend primarily on phonetic category assigned to the- fricative, rather than onthe specific spectral properties of the fricative noise.

Fitch et al. (1980) undertook discrimination task for the trading relation between silent closure duration and vocalic formant transition onset as cues to stop manner in the /slit/ - /split/ distinction. This type of work had also been done by Best et al. (1981) in the 'say' - 'stay' contrast. First they determined in an identification task how much slience was needed to compensate for a certain difference in formant onset frequency. Then they devised a discrimination task containing three different types of trials: on single cue trails, the stimuli to be discriminated differed only in the spectral cue (forrsant onset frequency); they had same setting of the temporal cue (silence). On co-oparating cues trials, the stimuli differed in both cues, such that the stimulus with the lower formant onsets (Which favour split and stas percepts) also had the longer silence (which favour the some percept). On conflicting cues trials, the stimuli again differed in bath cues, but now the stimulus with the lower formant onsets had the shorter silence, so one cue favoured 'split' (stay) and other 'slit' (say). Because the silence difference chosen was the one found to compensate exactly for the spectral difference in the identification task, the stimuli in the conflicting cues condition were (on the average) phonetically equivalent.

The results of these experiments showed a clear difference among the three conditions; subjects discrimination performance

in the category boundary region was beat in the co-operating cue conditions. Thus, it is true that approximately phonetically equivalent stimuli - namely, those in the conflicting
as
cues condition - are difficult to discriminate. /they "sound the same ", where as the stimuli in co-operating condition sound different, even though they exhibit the same physical differences on the two relevant dimensions The pattern of discrimination results follows that predicted fram identification data, showing that stimuli that differ on two auditory dimensions simultaneously are still categorically perceived (given that the perception is categorical when each of these dimensions
the
is varied separately). It is likely that'listeners could be trained to become more sensitive to the physical differences that do exist between phonetically equivalent stimuli, and the interesting questions arises whether discrimination on co-operatirg cues trails would continue to be superior to that on conflicting cues trails.

Fitch et al. (1981) synthesized two syllables, one having formant transitions biasing perception of the syllable /lit/ and another the syllable /plit/. /s/ frication was appended to the beginings of each syllable and two series of stimuli were generated by varying the closure interval between the /a/ frication and the vocalic portion of each syllable. One series of stimuli was thus composed of /s/ + /lit/ and another of /s/ + /plit/, with both series varying in the duration of the closure interval. Fitch et al. presented these sets of stimuli to subjects for identification. For both series, stimuli with sufficiently short closure duration, were heard as /slit/ and stimuli with sufficiently long closure durations were heard as /split/. Thus, Pitch at al. demonstrated that inspite of the forment transitions, the duration of closure interval could induce identification of the stimuli from both series as either /slit/. However, their results also showed that on the average, relatively more silence (approximately 20 msec) was required for identification of /split/ for the /s/ + /lit/ series than for the /s/ + /plit/ series.

In two experiments, conducted by summerfield et al. (1981) the minimum duration of silence between /s/ and /lit/ reguired to perceive /split/ was Shown to vary. More silence was required both when the durations of the fricative and vocalic segments were increased and when the intensity fall time of the fricative waa reduced. The effect of segment duration is consistent with demonstration of perceptual sensitivity to variations in speech rate found for other contrasts distinguished by temporal parameters. The effect of intensity fall time can be added to the set of temporarily distributed acoustical consequences of the articulation of a stop consonant to which perceptual sensitivity can be demonstrated.

Liberman et al. (1981) investigated the duplex perception of cues for stop consonants and the results indicated that when the vocalic formant transitions apprepriate for the stops in a synthetic approximation to /spa/ or /sta/ were presented to one ear and the reminder of the acoustic pattern te the other listner reported a duplex percept. One side of the duplexity was the coherent syllable (/spa/ or /sta/) that was perceived when the pattern was presented in its original, undivided form, the other was a nonspeech Chirp that corresponded to what the transitions sound like in isolation. The result showed that the silence cue affected the formant transitions differently when, on the side of the duplex percept, the transition support the penception of stop consonants and when, on the other, they are perceived as non-speech Chirps. This indicated that the effectiveness of the silence cue was owing to distinctively phonetic (as against generally auditory) processes.

To further buttress the claim that phoetic trading relations (and the conicommitant notion of phonetic equivalence) are peculiar to speech processing, Best et al (1981) performed an experiment using sine-wave analogs of 'say' and 'stay' a contrast for which they demonstrated a similar trading relation to that of slit and split. Two versions of stimuli were constructed; in one, the sine-wave portion of the stimulus had a law onset of the lowest tone and in another a high onset of lowest tone. Noise was than append to the beginning of each stimulus to simulate /s/ frication and test continue were generated by varying the closure interval. They presented these stimuli to subjects for identification using an AXB procedure. In this procedure, A and B are and points of the continum and X any one of the items from the continue subjects responded by indicating whether X is more like A or B. According to post-hoc interviews of the subjects, the subjects were partitioned into two groups - speech listeners and non-speech listeners.

Identification functions for the 'speech' or 'say-stay' listeners revealed a trading relation; those who failed to hear the stimuli as speech, however, failed to display identification functions of a trading relation. In addition the subjects who heard the stimuli as non-speech were further subdivided into two groups. One group which attended to spectral cues (ie. onset frequency of the lowest tone) and one which attended to temporal cues (duration of the closure interval). Thus, the non-speech listeners were unable to trade the two cues and attended to either the spectral cue or the temporal cue. Apparently subjects who heard the stimuli as speech perceived the stimuli in a phonetic mode in which the temporal and spectral cues were somehow integrated into a unitary percept, thus giving rise to the observation of a trading relation; those subjects hearing the stimuli as non-speech were presumably perceiving the stimuli in an auditory mode in which integration of the two cues was impossible.

The role of /s/ release burst as a cue to the parception of step consonants following /s/ was investigated in a series of studies. The purpose of Experiment -1 was to demonstrate the relative importance of an alveolar release burst as a stop manner cue, and to create a trading relation between burst and slience cues by varying the duration of both in natural speech stimuli. This study demonstrates a perceptual trading in which as the burst was cut back further, increasing amounts of silence were necessary to achive a percept of 'stay'. The truncation of the release burst introduced, not only create variations in burst duration but also changes the overall burst amplitude, in its onset amplification characteristics and perhaps correlated spectral changes.

The purpose of experiment-2 was to demonstrate a trading relation between release burst amplitude and closure duration as joint cues to stop manner perception. Phis study showed trading relation and it also showed that severely attenuated (and truncated) bursts still have a perceptual effect.

The purpose of experiment-3 was to find out, whether the perceptually relevant aspect of burst amplitude is it's absolute magnitude or its magnitude, relative to the surrounding signal portions. Attenuating the burst;s environment did not have the same effect as amplifying the burst by the same amount. Contrary to expectations, attenuation of the vocalic portion did not increase stop responses. Perhaps, the additional step manner cue, maintained in that portion (initial formant transaction and amplitude envelope) was weakened by the attenuation, thus counteracting the gain in burst salience, relative to it's environment.

The purpose of experiment-4 was to examine the effects ef fricative noise and vowel attenuation separate from their effects on the relative salience of the burst. Both experiment 3 and 4 suggested, that absolute, not relative, burst amplitude is important. While the preceding fricative noise may exert a slight masking effect on the burst, the amplitude of the following vocalic portion. Seems to have it's perceptual affects primarily by changing the relative salience of cues contained is that portion, itself.

Experiment-5 examined the point at which a burst becomes ineffective and ceases to trade with closure silence and whither it actually coincides with the auditory threshold detection threshold for the burst. It also examined whether the detectibility of the burst was increased when the preceding fricative noise was removed. Sensitivity to the burst was at least as great in phonetic labelling than in auditory discrimination. This result provides strong evidence of the sensitivity of phonetic categorisation processes to very subtle changes in acoustic information. Burst detection was somewhat improved, when the initial /s/ noise was removed but only at the two weakest burst intensities. Thus, there may have been a slight auditory washing effects of the fricative noise on the burst.

The purpose of experiment-6 was to demonstrate a trading relation bewteen burst amplitude and closure duration for the perception of a labial stop consonant. The effect of burst attenuation or elimination demonstrates that labial bursts too, have a function as stop mannar cues. The absence of any effect of burst amplification, suggests that slit-split boundary cannot be easily pushed towards shorter values of silence. Amplitude increment was either ignored by listeners or Channelled into decisions about stop place of articulation rather than stop manner. These results called for a replication experiment.

Experiment-7 was similar to experiment-6 except for difference in stimuli and the ranges of closure duration and burst amplification values. The findings replicate the results of experiment-6. Attenuation of the burst necessitated a longer interval of silence, whereas burst amplification did not have the opposite effect, rather amplified bursts seem to function like slightly attenuated ones. In this experiment release burst was a more powerful manner cue than that in the previous experiment.

In an experiment by Barbara et al. (1984), five year old children were tested for perceptual trading relations between a temporal cue (silence duration) and a spectral cue (F_1. onset frequency) for the say-stay distinction. Identification functions were obtained for two synthetic say-stay continue, each containing systematic variations in the amount of silence following the /s/ noise. In one continuum, the vocalic portion had a lower F_1 onset than in the other continum and children showed a smaller trading relation than with adults. They did not differ from adults, however, in their perception of an 'ay-day' continuum forced by varying F_1 onset frequency only. The results of a discrimination task in which the two accustic cues were made to co-operate or conflict phonetically supported the action of perceptual equivalence of the temporal and spectral cues along a single phonetic dimension. The results indicate that young Children, like adults, perceptually integrate multiple cues to a speech contrast in a phonetically relevant manner, but that they may not give the same perceptual weights to the various cues as do adults.

Pastore et al. (1964) carried out a study to find out whether silence can simply separata speech components or does it play a role in the perception of stop consanant. The hypothesis was that silence creates a separation between different camponents of a speech stimlus, thus reducing the auditory interaction between the stimulus components. The relation between silence and auditory separation based upon the selective lateralization of the stimulus components created by an interaural phase shift, was traded. Two experiments were conducted with SAY-STAY and SLIT-SPLIT as stimuli. In experiment-1, SAY-STAY boundary was initially determined by varying the silence duration between 's' and 'day'. In the random sequence, half of the trials presented 's' diotically (centered) and half presented it lateralized, while the day always was presented diotically. The results indicated that the phase shift did not affect the location of the category boundary.

Experiment-2 was like experiment-1 and phase was varied only for 'slit' while 's' was always diotic. Next 's' was the lateralized portion while 'slit' was diotic. The results indicated that the phase shift did not affect the location of the category boundary, but these boundaries are at much longer silence duration than in experiment-l. The authors concluded that the acoustic separation hypothesis no longer seemed tenable as an explanation for the role of silence in the perception of post silence stops.

Repp (1984) to examine the hypothesis that "temporal changes in signal portions preceding and following the silence may/may not be equally relevant", conducted a study where the duration of fricative noise and of the lateral resonance were varied independently. Experiment-1 used a 'slash-splash' continuum for which the average category boundary happened to be around 25 msec. of silence. The question was, whether either /s/ duration or /l/ duration or both have any effect an a short silence /s/ - /spl/ boundary. Increasing silence duration had the expected effect of increasing the percentage of 'splash' responses. The amount of silence needed to hear a 'p' increased aas the duration of /s/ noise increased. The reverse effect of /l/ duration was totally unexpacted. Since /l/ duration in natural speech does not seem to convey with the presence vs. absence of a preceeding /p/, it was unlikely the /l/ duration had any direct cue values for stop manner perception, in the way that /s/ duration had. Rather than affacting stop manner perception directly, /l/ duration may have its effect by altering the perceived relative duration of the /s/ noise.

's' noise may sound longer before a short /l/, and shorter before a long /l/. This explanation assumes that the intervening silence does not engage in such contrastive interaction with the surrounding signal portions. This assumption is suppertedly the absence of any effect of increases or decreases in both /s/ and /l/ duration.

In experiment-2, the duration of /s/, /l/ and of final /æ / portion were varied independently, so as to determine their seperate effects on the splash-slash boundary. The amount of silence needed to perceive 'splash' increased as the /s/ duration increased and decreased as /l/ duration increased. The effect of /a/ duration was longer than the opposite effect of /l/ duration which supported the hypothesis that the later effect was indirect and decreased with increasing temporal seperation between /s/ and /l/, relative te the effect of /s/ duration. The effect of /æ /duration was reversed with respect to that of the /l/ duration, longer /æ / duration leading to longer category boundaries, except in the condition where both /s/ and /l/ were long. However /s/ duration had the dominant effect.

The perception of stop consonant was studied in a constant neutral /s-l/ context. Truncated natural /p/, /t/ and /k/ release bursts as two intensitites were preceded by variable silent closure intervals. The bursts, though spectrally distinct conveyed little specific place information but contributed to the perception of stop manner by reducing the amount of slience required to perceive a stop (relative to a burstless stimulus). Burst amplification was a cue for both stop manner and place, higher amplification favoured /t/, lower amplification favoured /p/ responses. The silent closure interval, a major stop manner cue, emerged as the primary place cue in this situation and short intervals led to t and long ones to /p/ responses. All these perceptual effects proably reflect listeners tacit knowledg of systematic acoustic differences in natural speech.

The demonstration of trading relations constitutes the newest source of evidence for the existance of a specialized speech mode in which knowledge of articulation comes to bear in the perception of speech. According to Repp (1982), "trading relations may occur because listeners perceive speech in terms of the underlying articulation and resolve inconstance, in the acoustic information by perceiving the most plausible articulatory act. This explanation requires that the listener have atleast a general model of human vocal tracts and of their ways of action. Thus based in part on demonstration of phonetic trading relations, researchers, particularly those associated with Haskins Laboratories, have gone again renewed their efforts to argue for articulation - based specialized phonetic processing.

However, the results of these stuides are equivocal. They neither support phonetic level processing nor oppose it. Most of these studies are applied to English language and as the phonetic system of the language are different the importance of cues should be different. Hence there is a need to investigate the trading relationships in languages different from English. In this context, the present study was aimed at identifying the trading relationship between silence and burst in Kannada language.

CHAPTER-III

TRADING RELATION & DISCRIMINABILITY

Two experiments were conducted to find out the trading relation between silence and burst and the discriminability of the stimulus. These two experiments will explained separately.

EXPERIMENT-I: Trading relation between temporal and spectral cues.

The aim of experiment -I was to find out the trading relation between silence and burst.

Subjects - Ten native Kannada normal speakers (graduate) students at ALL INDIA INSTITUTE OF SPEECH AND HEARING) in the age range of 18 to 26 years participated in the study. All of them had normal hearing with PTA below 20 dB (IS Standard). Table-1 shows the subjects details.

Age Sex	18-20	20-22	22-24	34-36	Total
Male	2	1	1	-	4
Female	1	2	2	1	6
Total	3	3	3	1	10

Table-I: Subject details.

Material: A male Kanada speaker uttered /s/ (voiceless dental fricative) and the words /uṭa/ and /puṭa/ into a microphone (cardiode, unidirectional 33-992 A) kept at a distance of 10 cms from his mouth. While the utterance /uta/ did not provide any spectral cue for the plosive, the utterance /puta/ provided the spectral cue. Thus, while the introduction of silence between /s/ and /u/ of /uta/, provided a temporal cue for the plosive, the same between /s/and /p/ of /puta/ - provided both spectral and temporal cues. These words were specifically used to find out the trading relation between the spectral and the temporal cue.

These were digitized and stored at 16000 Hz sampling frequency at 12 bit rate. Using the program DSW developed by the voice and speech systems, Bangalore, 200 msec. of /s/ was truncated and concatenated to the words/ and /puta/ in the initial position. Silence in 10 msec.steps was introduced between /s/ and /u/ in /s-uta/ and /s/ and /p/ in /s-puta/ till 140 msec. to creat 30 (15 synthetic stimuli each) synthetic stimuli. Figure-1 shows the spectrogram of stimuli. These 30 synthetic files were randomized and six sets of randomized were prepared to make 180 tokens.
All these 180 stimuli were audio recorded on to a metallic cassette with an interstimulus interval of three seconds, which formed the test material.

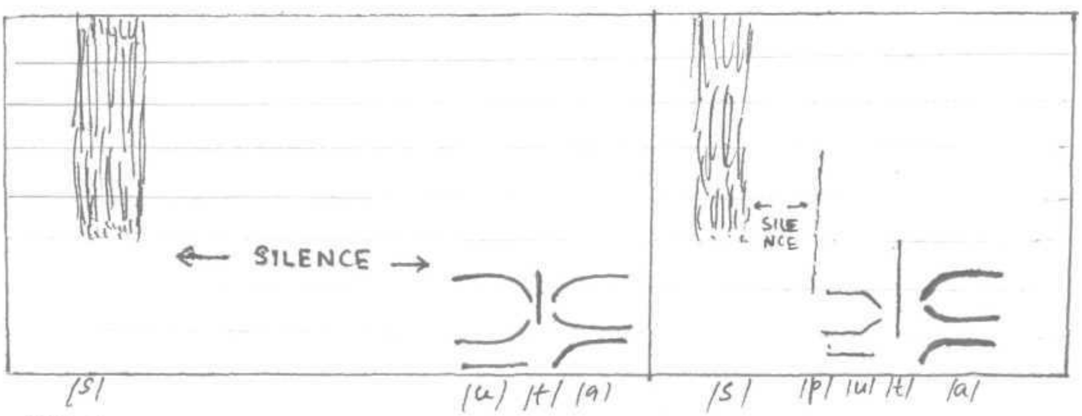

FIG-I

Method: Each set of stimuli was audio presented to the subjects in succession through earphone. (UHER W.770) in a sound treated room. Subjects were instructed to listen to the word carefully and respond to a forced choice by either selecting /suṭa/ or /spuṭa/. The responses of all the subjects were tabulated and the percent identification of each token was calculated by the following formula -

$$\frac{\text{Number of tokens identified correctly}}{60} \times 100$$

For example, if all the 10 subjects identify all the six interaction of a token correctly then the percentage of identification would be 100% or $\frac{60}{60} \times 100 = 100\%$. On the basis of these percet identification, identification and discrimination functions were plotted.

Results: The variation in silent duration was effective in producing a perceived contrast between /suṭa/ and /spuṭa/, as is apparent in Fig.2 for both series ('s' + /uta/ and s + /puṭa/). Judgement shifted from /suṭa/ to /spuṭa/ as the silent interval increased. The phonetic boundary (here defined as the point where the interpolated function (rosses the 50% level) was at about 30 msec. of silence for /spuṭa/ while for the serios (s+/uṭa/) the boundary waa about 50 msec. Thus in the presence of the spectral cue (burst) short duration of silence (30 msec.) was sufficient to generate the percept

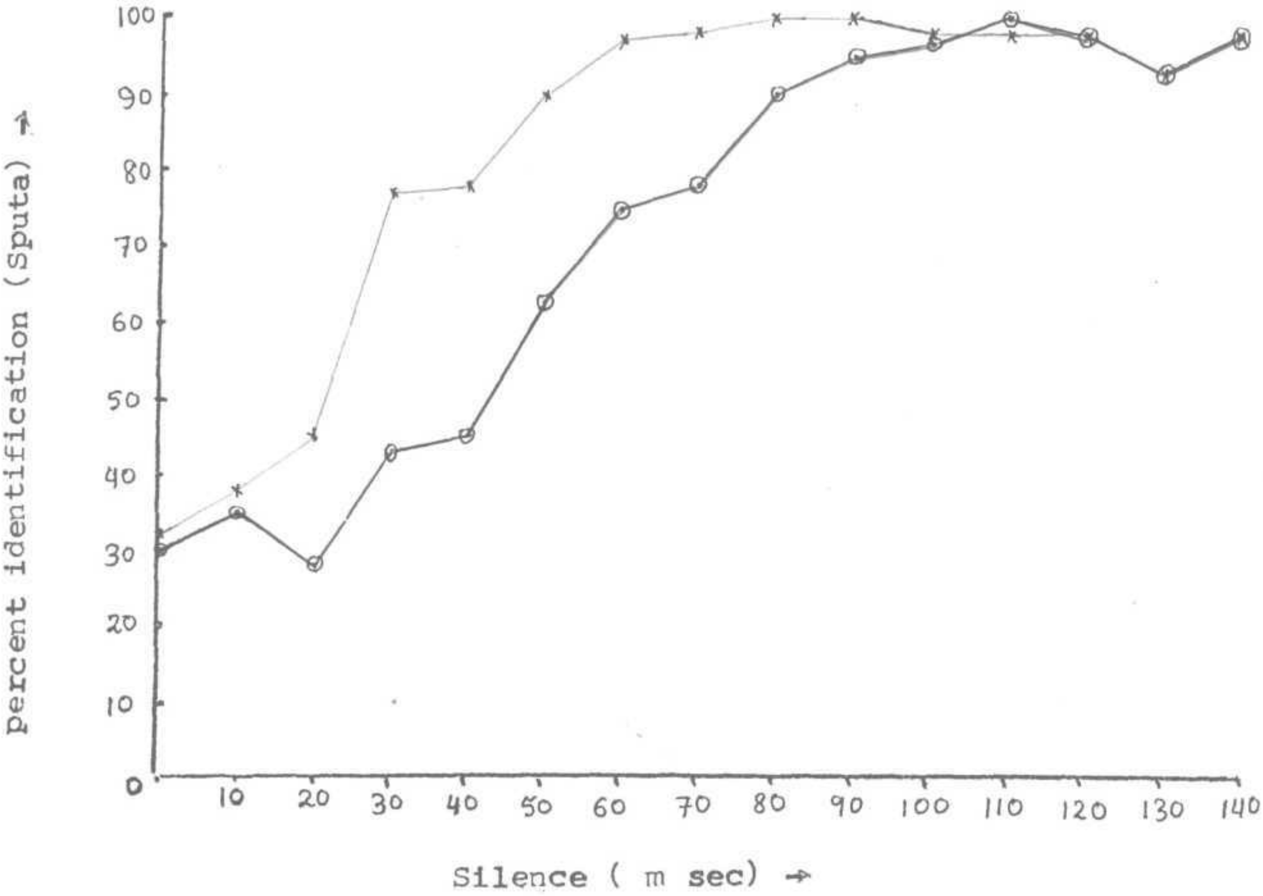

Fig percent identification of /S-uta/&/Sputa/ as/Sputa

x-x-x - S - Puta

o-o-o - S - Uta

/sputa/, while in the absence of the spectral cue longer silence duration was essential to elicit the percept /sputa/.

Considering the individual perforamnce of subjects it was observed that five subjects performed poorly and the remaining five performed well at shorter silence duration. However, all of them performed equally well at longar silence duration for both the token /s-uta/ and /sputa/. The phonetic boundary changed from subjects to subject. For /suta/ it was 50, 50, 90, 80, 20, 90, 80, 60, 110 and for /sputa/ it was 30, 20, 70, 50, 50, 50, 60, 60, 60, 10. Figure-3 and Table-2 shows the individual responses.

Thus, the results indicate a trading ralation between silence and burst. Within the limits of that relation these two very different acoustic cues appear to have equivalent effects on perception.

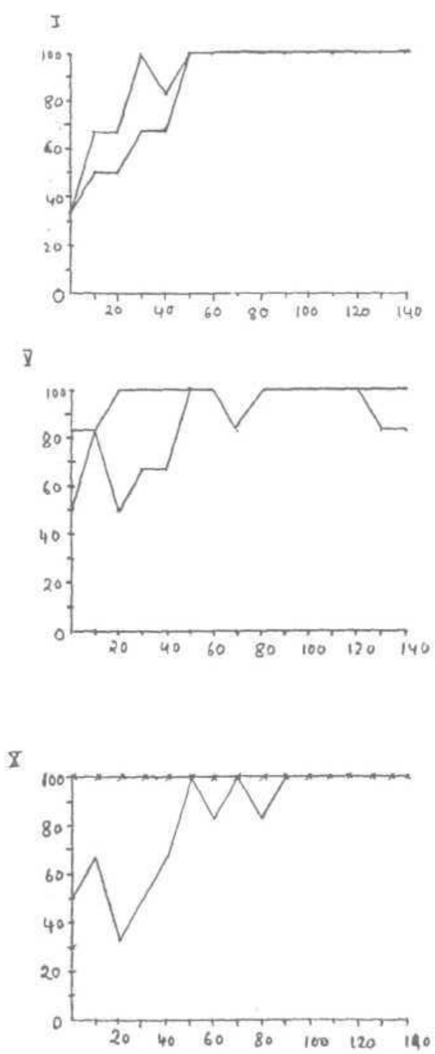

Fig.3(a): Shows 5
(I,II,V,VIII,X) best
% identification score
Y - % identification
X - Silence duration

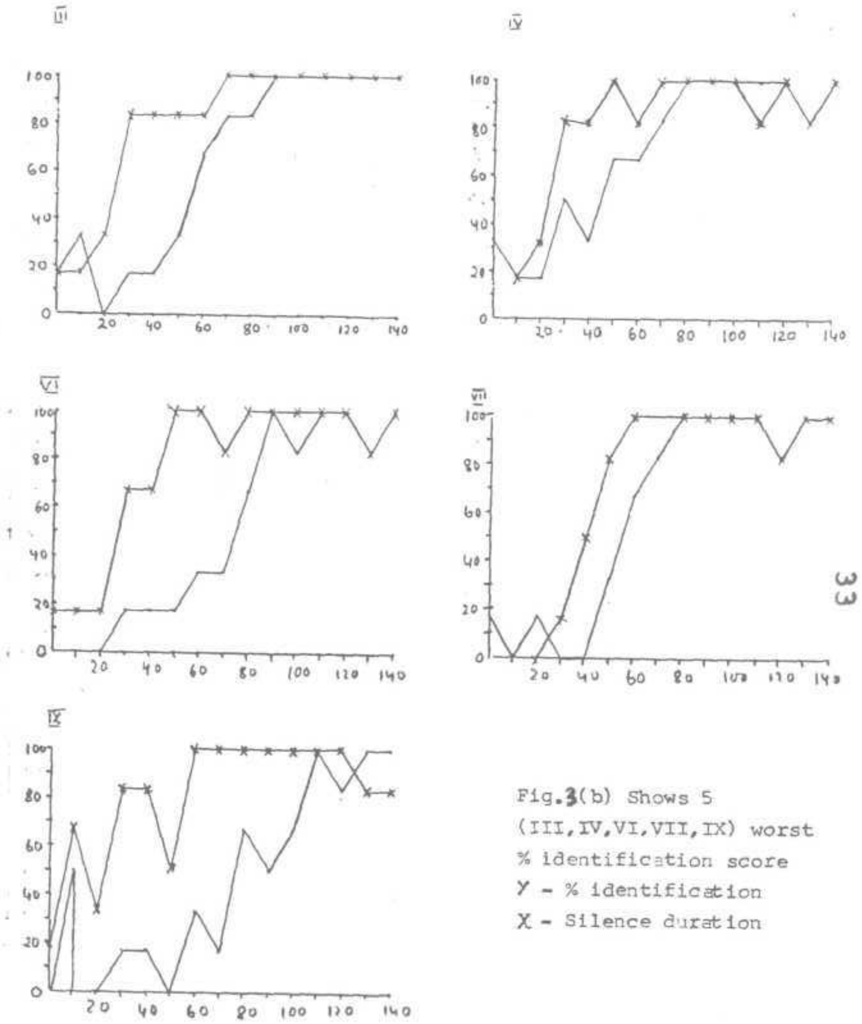

Fig.3(b) Shows 5
(III,IV,VI,VII,IX) worst
% identification score
Y - % identification
X - Silence duration

SUTA	I	II	III	IV	V	VI	VII	VIII	IX	X	Percentage
S 0 uṭa	33	50	17	33	83	0	17	17	0	50	30%
S 10 uṭa	50	50	33	17	83	0	0	0	50	67	35%
S 20 uṭa	50	50	0	17	100	0	17	17	0	33	28%
S 30 uṭa	67	100	17	50	100	17	0	17	17	50	43%
S 40 uṭa	67	100	17	33	100	17	0	33	17	67	45%
S 50 uṭa	100	100	33	67	100	17	33	87	0	61	63%
S 60 uṭa	100	100	67	67	100	33	67	100	33	83	75%
S 70 uṭa	100	100	83	83	83	33	83	100	0	100	78%
S 80 uṭa	100	100	83	100	100	67	100	100	67	83	90%
S 90 uṭa	100	100	100	100	100	100	100	100	50	100	95%
S 100 uṭa	100	100	100	100	100	100	100	100	67	100	97%
S 110 uṭa	100	100	100	100	100	100	100	100	100	100	100%
S 120 uṭa	100	100	100	100	100	100	87	100	100	100	98%
S 130 uṭa	100	87	100	83	100	83	100	100	83	100	93%
S 140 uṭa	100	100	100	100	100	100	100	100	83	100	98%

SPUTA

SPUTA	I	II	III	IV	V	VI	VII	VIII	IX	X	Percentage
S 0 puṭa	33	50	17	33	52	17	0	0	17	100	32%
S 10 puṭa	87	67	17	17	33	17	0	0	67	100	38%
S 20 puṭa	87	100	33	33	50	17	0	17	33	100	45%
S 30 puṭa	100	100	83	83	67	67	17	67	83	100	77%
S 40 puṭa	83	100	83	83	67	67	50	67	83	100	78%
S 50 puṭa	100	100	83	100	100	100	83	83	50	100	90%
S 60 puṭa	100	100	83	83	100	100	100	100	100	100	97%
S70 puṭa	100	100	100	100	100	83	100	100	100	100	98%
S 80 puṭa	100	100	100	100	100	100	100	100	100	100	100%
S 90 puṭa	100	100	100	100	100	100	100	100	100	100	100%
S 100 puṭa	100	100	100	100	100	83	100	100	100	100	98%
S 110 puṭa	100	100	100	83	100	100	100	100	100	100	98%
S 120 puṭa	100	100	100	100	100	100	100	100	83	100	98%
S 130 puṭa	100	83	100	83	83	83	100	100	100	100	93%
S 140 puṭa	100	100	100	100	83	100	100	100	100	100	98%

Table-2: Shows discrimination performance (in percentage) of ten subjects.
x axis indicates subjects
y axis indicated percent score identified as spuṭa with respect to various stimuli.

The aim of this experiment was to compare the discriminability of stimuli of Experiment-1 in the three conditions of cue combination.

<u>Material</u>: In one condition the membres of each pair "to be discriminated stimuli" differed by only one of the two cues (spectral cue). In the other two conditions, the members of each pair differed by both cues, temporal as well as spectral. For one of these later conditions, these two cues were combined so as to Co-operate, - one member of each pauir had both cues biased toward the other had both cues biased toward . The anticipated effect of such co-operating cue, would be to place the percepts more clearly on opposite sides of the phonetic boundary and thus, given any region of uncer tainity at that boundary, to increase discriminability by comparision with pairs that differ by one cue alone. For the remaining condition in which the pairs differed by both cues, the arrangement of the cues was such as to put them in conflict: one member of each pair had one cue biased towards 'sputa', the other towards In the other members of the pair, their effect on the same perceived dimension, then this combination ought, by a kind of neutralization, to decrease

discriminability by comparison with the condition in which the two cues co-operate and even indeed, by comparison with the condition in which the pair differ by only one cue. 3 depicts the stimuli.

Pair	Description of stimuli: Silent interval	Description of stimuli: Vocalic portion	Percept	Temporal	Spectral	Characterisation of cues: Temporal	Characterisation of cues: Spectral
1 's'	short long	/uta/ /uṭa/	suṭa sputa	-p +p	-p -p	Different	Same
2 's'	short short	/uṭa/ /puta/	suṭa sputa	-p -p	-p +p	same	different
3 's'	short long	/uṭa/ /puta/	suṭa sputa	-p +p	-p +p	different	different
4 's'	short long	/puṭa/ /uta/	sputa sputa	-p +p	+p -p	different	different

Table-3: Illustrating the phonetically equivalent effects of spectral and temporal cues the phonetically different effects of combining these cues in two ways.

For the condition in which the pairs differed by only the spectral cue - "one cue condition" - the members of each pair had the same setting (duration) of the temporal cue, but the setting of that cue varied among the pairs. Thus at one end of the range there was a pair comprising the stimuli ('s'-o-msec, silence /uṭa/) vs. (s-o-msec. silence /uṭa/, at the other end there was the pair ('s' - 100 msec. silence /uṭa/ vs. ('s'-100 msec. silence

/puṭa/. Between these two extremes there were similar pairs for all intermediate settings of the temporal cue (As the stimuli with more than 100 msec. of slience had all been perceived as sputa, they were emitted).

In both the other two conditions, where the members of each pair differed always by both cues, the procedure was somewhat more complex. If first conditions is considered in which the cues were arranged so as to co-operate, it could be called "two-co-operating cue" condition. As in the one cue

condition" each pair had one member made from and one member made from ṭa/, but in the "two co-operating cue condition" the puta member of each pair had a silent interval 30 msec. longer than the member. Thus, at the one and of the continuum of silent interval, the stimulus (/'s' - 10 msec. silence was paired with ('s' - 40 msec. silence- /puṭa/ and similar pairing were arranged through the entire range of silent intervals upto the pair ('s' - 70 mesec. seilence - /uṭa/) vs ('s' - 100 msec. silence /puṭa/) .

Finally, the other condition in which both cues differed, but to such a way as to be in conflict/contrast. It could be called as "two conflicting cue condition". Now, the pair wise arrangement of "to be discriminated stimuli" was here exactly the same as that for the two co-operating cue condition, except that, to produce the conflict, each /puṭa/ member had 30 msec. less silence than its /uṭa/ comparison, Thus, at one end of the continuum ('s' - 40 msec. silence - /uṭa/) was paired with ('s' - 10 msec, silence /puṭa/), and similar pairings were made at all increasing values of the silent interval through the pair ('s' -100 msec. silence- /uṭa/) vs. ('s' - 70 msec. silence- /puṭa/) .

For the two co-operating cues and the two conflicting cues conditions, choosing the amount of silence by which the members of each pair differ is, of course, critical, if the experiment is to reveal m ost sensitively such differences indiscriminability as there may be between the two conditions, that amount of silence would be equal to the amount by which the two perceptual identification functions - the one for stimuli made of /uṭa/, the other for stimuli made of /puṭa/ are displaced (As in Fig. 2 of Experiment -1); Since that is the amount of silence that according to identification judgements, just compensates for bilabial burst, ideally the amount of silence would be adjusted appropirately for each subjects.

An oddity test was used to measure the discrimnability of the members of these pairs, on each trial, one member of a pair was presetned twice and the other member once. The listener was to determine which of the three stimuli was the odd one. For each pair of stimuli to be tested, six different oddity triplets - that is all possible permutations were generated.

There was one sec. silence between successive words. in a trial, and 3 sec. between trials. After each 6 trials 5 sec. gap was given instead of 3 sec. Thus for test-1 a total of 66 stimuli, for test-2, 4 stimuli and 42 stimuli for test-3 ware generated (Appendix -I) which were audio-recorded on to a metallic cassette and thus formed the material for Experiment-2.

Subjects: The same subjects who participated in Experiment-1 participated in Experiment-II.

Method: The subjects were individually tested and were audio-presented with the stimuli through headphones. They were instructed to listen to the triplets and indicate the odd one in the response sheet provided to them (Appendix-II). All the data were tabulated and analysed for percent response. Further the identification and discrimination functons were plotted.

Results: The result of discrimination tests are presented in Fig. 4. In the one cue condition - that is the condition in

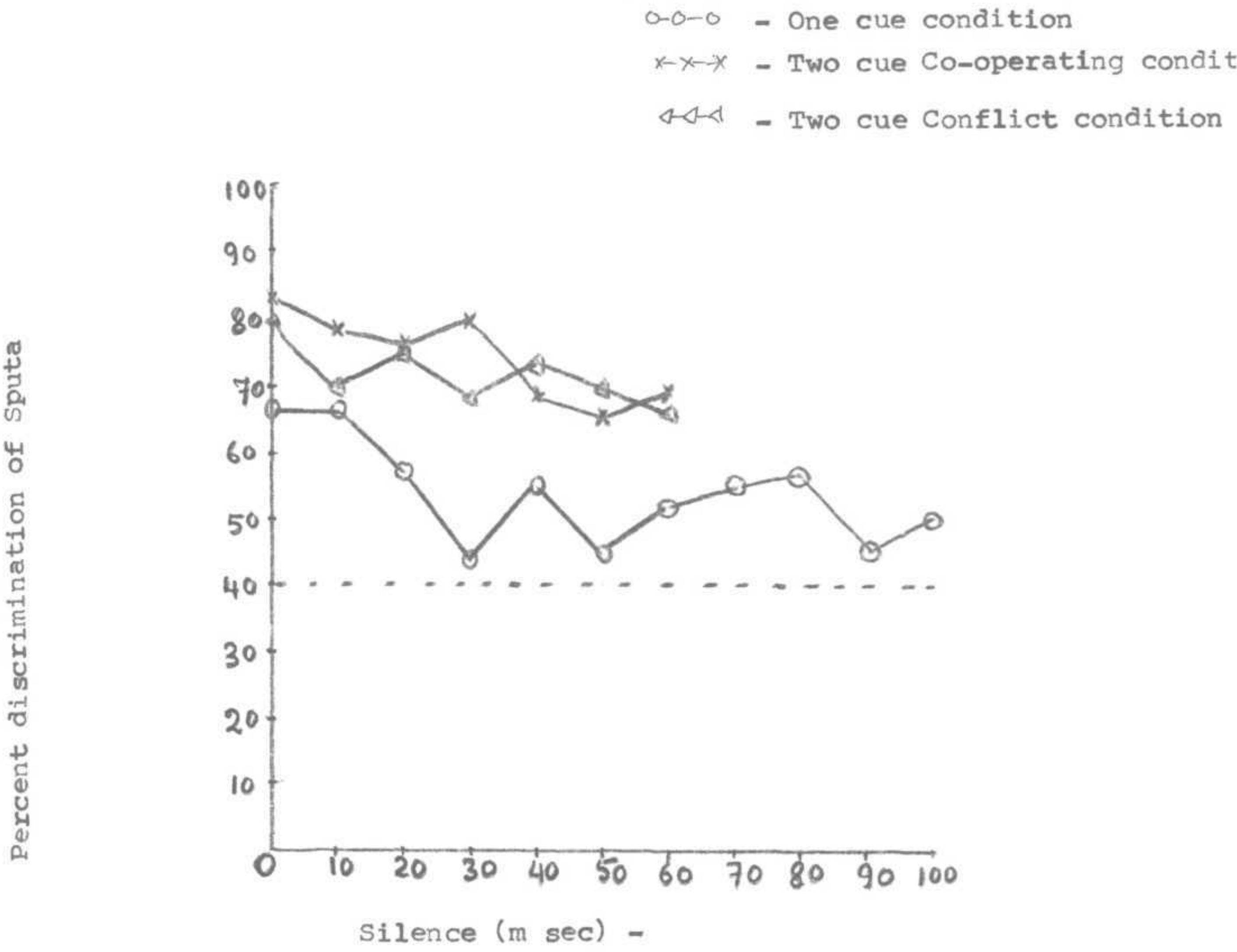

Fig -4 percent correct descrimination for three types of stimulus pairs.

which the pairs of stimuli to be discriminated differed only in the spectral cue-at the beginning of vocal section - examining the appropriate data, represented in redline, it can be observed that the discrimination is relatively high at short intervals of silence. The percent discrimination decreases as the duration of silence is increased and has a sharp peak at 40 msec. of silence and at 80 msec. of silence. However, both the peaks at 40 msec. and 80 msec. were below the discri mination level than what of 0 msec. of silence.

The results obtained in the two conditions in which the patterns to be discriminated differed by two cues are in Fig. 4 It should be remembered that in one of these two cue conditions-the one called two co-operating cues - the spectral and temporal cues were so arranged that, based on the identification data of Experiment-1, It was expected that they should reinforce each other resulting in enhanced discriminability by comparison with the one cue condition. The results, indicated that the % discrimination was higher at shorter silence duration and decreased as the duration of silence increased. Also, out of the three conditions, the two cue co-operating condition had the highest percent discrimination. when individual performances were considered, it was observed that subject six (6) and subjects nine (s9) were poor performers and S1 and S2 were the best performed. The individual responses are in Fig.3.

ln the two cue conflicting condition it was noticed that the spectral and temporal cues were arranged, so that, based on the identification data of Experiment-1, it was expected that they would neutralize each other and thus make discrimiantion difficult. The discrimiantion was infact, difficult, apparently, than it the two cue co-operating condition, but better than in the one cue condition. Also, the percent discrimiantion reduced as the silence duration increased. Also s6 and s9 were poor performers and S1 and S2 were the best performers.

Thus*, taking as the base the condition in which the stimuli to be discriminated differ only by the spectral cue, it could be found that it is possible to add a fixed difference in the temporal cue so as to increase discriminability or to decrease it.

Thus, the results indicated that (1) of the three, performance was best for the two cue co-operating condition followed by two-cue conflicting condition and one-cue condition and (2) the percent response in all the three conditions decreased as the slience duration increased.

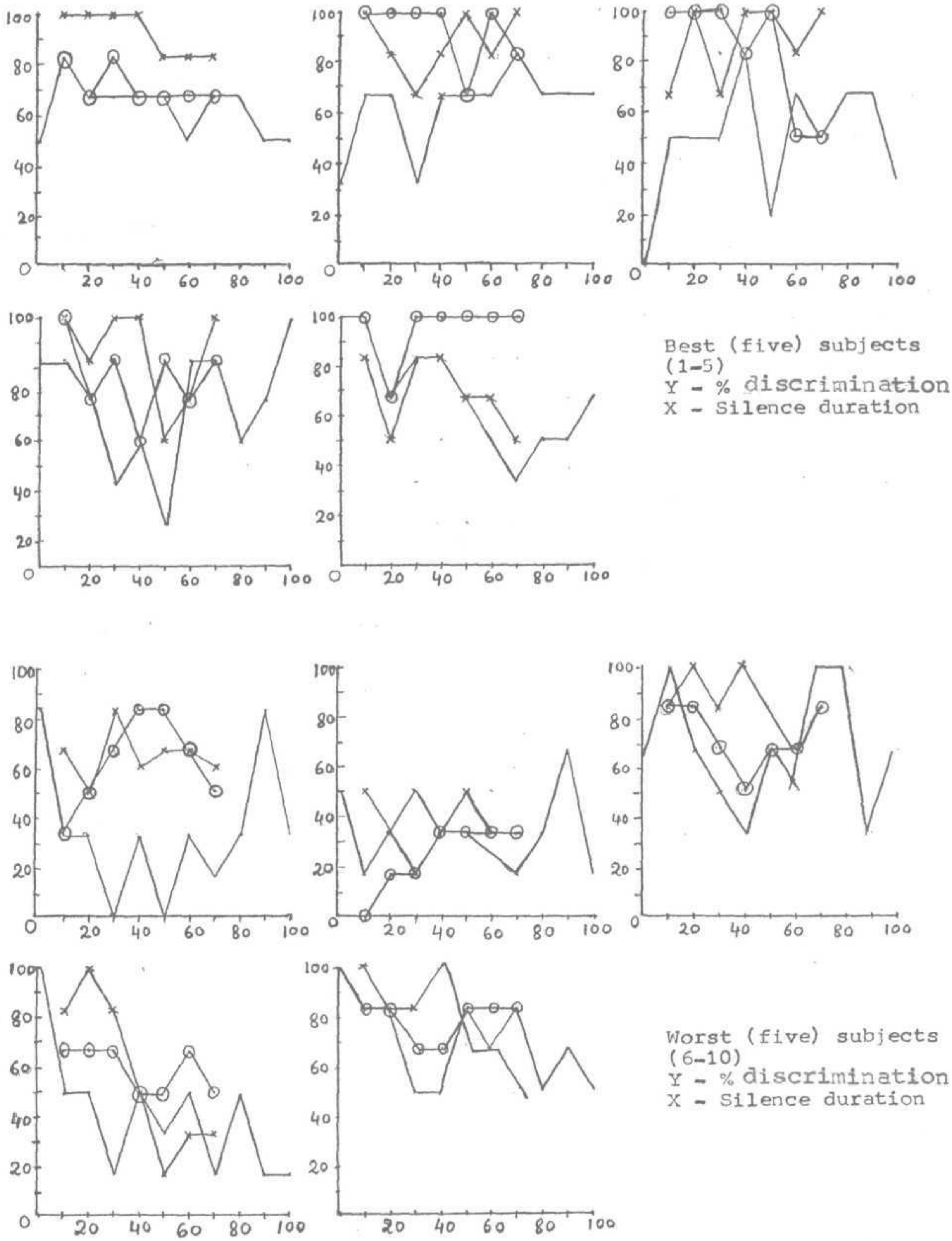

Fig. 5: Individual responses for varying duration of silence in /suta/ and /sputa/

—·—·— One cue condition
×—×—× Two cue cooperating condition
o—o—o Two cue conflicting condition

DISCUSSION

The results indicate three points of interest. First, a trading relationship between silence and burst seem to exist. As pointed out in the introduction the several cues for a pheonetic contrast are typically found, in perceptual studies, to engage in a trading relation; given a phonetic contrast for which each of two cues is relevant, the effects of varying one cue can, within limits, be compensated for by appropriate variations in the other. Such trading relations are of interest if only because they imply an equivalence among aspects of stimulation that are often quite different from an acoustic point of view. They are the more interesting if one is right in supposing that the equivalence relfects a sensitivity to the common origin in articulation of the different acoustic cues - that is, to processes that are distinctively phonetic. The trading relation observed here is novel only in that it is another token of a type. Surely, the token is a striking one, for the contrast between the cues that trade is very great indeed; one of them is silence, the other is burst. But even that contrast is not entirely new, Several investigators have shown same type of trading in English language. The results support those of Erickon (1977) in that only 25 msec. less (more) of silence duration was needed to convert /slit/ to /split/ when the spectral cue was present (absent) indicating a trading relationship.

Fitch et al. (1981) reported same type of study and reported that only 30 msec. of silence duration was sufficient for compensating the spectral cue, While Repp et al. (1984)) proved the phonetic boundary could be 25 msec. to convert /slash/ to /splash/. In another study they proved that for different stop consonants (/p/, /t/ and /k/) the silence duration was different to perceive. The results also support that of Summerfield and Bailey (1981) and Fitch et al.(l980). However, the results are not in consonance with that of Dorman et al.(1979),, where they reported a phonetic boundary to be as high as 450 msec. to convert /slit/ to /split/.

Second, as the slience duration increased, the subjects ability to discriminate between /p/ and /u/ decreased. This is expected as the introduction of longer silences between /s/ and /u/ would result in the perception of /p/ leading the subjects to identify all the three tokens as /sputa/. Thus, the discrimination ability decreases. The two cues (silence and burst) did not have adequate neutralization effect in Kannada words /sputa/ and /suta/ when combined with each other.

The two cue co-operating condition obtained highest percent discrimination. This partly agreed with the results of the study by Fitch et al. (1980) in which superior discrimination was always obtained for the two cue co-operating condition.

However, it contrasts the findings of Fitch et al.(1980), in that the two cue conflicting condition showed poorest discrimination score while in the present study it was not so. Thus, the two different cue, (silence and burst) could not neutralize each other efficiently to lower the discrimination score ie. they are not equivalent. This might be attributed to the subjects discrimination ability or the language differences.

If relative discriminability of the pairs are examined in the one cue, two co-operating cues and two conflicting cues conditions, it was seen that the discrimination occured primarily at the phoneme boundary, But the phoneme boundary varied slightly from subject to subject, eventhough it was always located near the middle of the range.

For every subject, the order of difficulty from easies discrimination to most difficult, was (1) The condition of two co-operating cues (2) The condition with two conflicting cues and (3) The condition with one cue. Thus, the group result plotted in Fig. 4 accurately reflects the performar of each one of the subjects.

Having seen the relative order of difficulty in discriminating the different types of syllable pairs, whether spectral and temporal cues are equivalent or not could be predicted from the perception of /p/ in /sputa/ If two conflicting cues condition is considered and if the two cues are truely equivalent in phonetic perception, then it

should be possible to arrange them so that they effectively neutralize each other, producting two words - for example, /sputa/ and - that sound exactly alike. But while that should have been possible in principle, in practice it would have required that a precise adjustment of the cues be made separately for each subjects to take account of the individual differences in the exact value of the trade off between the cues. Morever, it would have required that each subject be perfectly. Consistent in the value for the trade off between the cues. Also, it would have required that each subject be perfectly consistent in the value for the trade off. The result is that the patterns could not be expected to be perfectly indiscriminable rather better discriminable than the one cue condition.

So it could be concluded that (1) either both the cues in two cue conflicting condition could not neutralize each other to make it not discriminable or (2) subjects were superior in discrimination task.

Third, it appears that the introduction of silence gives a cue to the listener that the acoustic information is absent which is possible only in the production of a stop consonant. Liberman and Mattingly (1985) have claimed that the listener actually perceives the stop consonant by articulatory reference ie. complete closure of the oral tract for a stop. Though the results of the present study support this notion, it need not be articul-latory in nature, it could as well be acoustic. Also the experience of the present experimenter on several other pairs (/s-kanda/ va /s-anda/), (/s-paṣṭa/ vs /s-aṣṭa/) revealed no such perception of the stop consonant when silence was inserted between the fricative and the vowel. However, in the pair /s-uṭa/ and insertion of silence brought about the perception of stop consonant/p/. Thus, it appears that the trading cannot be generalized. but it may be specific to certain pairs.

CHAPTER-IV

SUMMARY AND CONCLUSIONS

Stop consonants have several spectral and temporal cues. It has been well-known for many yaers that several cues may signal a single phonetic contrast (Danes, 1955), thus it is possible to demonstrate that when the perceptual utility of one cue is attenuated, another cue may take on primary effectiveness in signaling the contrast under scrutiny because both cues, it is assumed, are equivalent. This is called phonetic trading relationship (Repp, 1983).

This study was conducted with an interest to see that whethe the spectral (burst) and the temporal (closure duration) cues are equivalent and trade each other or not in Kannada stop consonant perception.

Two experiments were conducted to find out the trading relation between silence and burst. Two synthesized words, one where only temporal cue for the plosive as in (s-silence- and the other where both temporal and spectral cues as in were taken. In both the stimuli /s/ was of 200 msec. and the silence was introduced in 10 msec. steps till 140 msec. Thus, 30 stimuli (15 from s-silence and 15 from s-silence-puta) were prepared and presented to ten native Kannada speakers (who had normal hearing, according to0 Is-Standards) through tha earphone (UHER-W-770). They were instructed to identify /sputa/, among the 30 stimulus. Each stimuli was presented six times with an interval of 3 msec. and the percent identification score was calculated for each stimuli. The average score of ten subjects showed that at a particular silence duration more than 50% of the stimuli were perceived as /sputa/. It is also seen that as s-silcacs uta had only temporal cue, those stimuli took longer silence of 50 msec, and as s-silence -puta had both temporal and spectral cues and they take only 30 msec. of silence duration to perceive it as /sputa/. Thus, in the absence of the spectral cue, the temporal was compensated for step perception

The second experiment was designed to find out whether the above mentioned two cues (closure duration and burst) were equivalent or not to neutralite and discriminate each other. Three types of teat stimuli being presented were as -

(1) One cue condition - The member of each pair "to be discriminated" stimuli differed by only one cue of the two cues ie. spectral cue.

(2) Two cue co-operating condition - one member of each pair had both cues biased toward /sputa/, the other had both cues biased toward suta.

(3) Two cue conflicting condition - one member of each pair had one cue biased toward sputa, the other taward suta in the other member of the pair the cues (and thair biases) were reversed.

Totally 150 synthetic stimuli were presented. TheY were in triplets and were iterated six times.

An oddity test was administered an ten aubjects of native Kannada normal speakers where they were instructed to listen to the triplets and indicate the odd one in the response sheet provided to them. All the data were tabulated and analysed for percent response.

Further, the identificatton and discrimination scores were plotted. The results indicated that the discrimination was high at shorter duration and decreased the length of slience increased. And also of the three conditions two cue co-operating condition received the highest present discrimin-nation.

In the two cue conflicting condition, contrary to the expectation both the cues did not neutraluize each other But to some extent they neutralized each other as the over all response decreased.

Thus, it appears that the burst and the silence trade with each other. However, the experience of the experimenter with other pairs of words in Kannada indicated that it may not be so. It could be concluded that this trading may be specific to some word pairs and cannot be generalized.

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APPENDIX-I

EXPERIMENT-I - Synthetic material

Numbers between s - uta/puta indicate the silence duration

Sl.No.	T_1	T_2	T_3	T_4	T_5	T_6
1.	S140 uta	S40 uta	S100 uta	S120 uta	S10 uta	S0 uta
2.	S120 uta	S0 uta	S140 uta	S110 uta	S30 uta	S20 uta
3.	S90 uta	S80 uta	S0 uta	S10 uta	S110 uta	S50 uta
4.	S50 uta	S60 uta	S40 uta	S20 uta	S80 uta	S90 uta
5.	S0 uta	S110 uta	S90 uta	S70 uta	S60 uta	S140 uta
6.	S20 uta	S100 uta	S70 uta	S80 uta	S50 uta	S120 uta
7.	S30 uta	S130 uta	S60 uta	S50 uta	S100 uta	S110 uta
8.	S40 uta	S50 uta	S20 uta	S30 uta	S130 uta	S70 uta
9.	S100 uta	S10 uta	S130 uta	S140 uta	S0 uta	S40 uta
10.	S130 uta	S30 uta	S110 uta	S100 uta	S20 uta	S10 uta
11.	S110 uta	S20 uta	S120 uta	S130 uta	S140 uta	S30 uta
12.	S80 uta	S90 uta	S10 uta	S0 uta	S120 uta	S60 uta
13.	S60 uta	S70 uta	S30 uta	S40 uta	S140 uta	S80 uta
14.	S70 uta	S140 uta	S50 uta	S60 uta	S90 uta	S100 uta
15.	S10 uta	S120 uta	S80 uta	S90 uta	S70 uta	S130 uta
16.	S140puta	S100 puta	S40 puta	S120 puta	S0 uta	S10 puta
17.	S120 puta	S140 puta	S0 puta	S110 puta	S20 puta	S30 puta
18.	S90 puta	S0 puta	S80 puta	S10 puta	S50 puta	S100 puta
19.	S50 puta	S40 puta	S60 puta	S20 puta	S90 puta	S80 puta
20.	S0 puta	S90 puta	S110 puta	S70 puta	S140 puta	S60 puta
21.	S20 puta	S70 puta	S100 puta	S80 puta	S120 puta	S50 puta
22.	S30 puta	S60 puta	S130 puta	S50 puta	S110 puta	S100 puta
23.	S40 puta	S20 puta	S50 puta	S30 puta	S70 puta	S130 puta
24.	S100 puta	S130 puta	S10 puta	S140 puta	S40 puta	S 0 puta
25.	S130 puta	S110 puta	S30 puta	S100 puta	S10 puta	S20 puta
26.	S110 puta	S120 puta	S20 puta	S130 puta	S30 puta	S40 puta
27.	S80 puta	S10 puta	S90 puta	S0 puta	S60 puta	S120 puta
28.	S60 puta	S30 puta	S70 puta	S40 puta	S80 puta	S140 puta
29.	S70 puta	S50 puta	S140 puta	S60 puta	S100 puta	S90 puta
30.	S10 puta	S80 puta	S120 puta	S90 puta	S130 puta	S70 puta.

EXPERIMENT-II - Synthetic material

TEST - 1

Number between s - uta/puta indicate silence duration

S.No.	A	B	C	S.No.	A	B	C
1.	S 0 uta	S 0 puta	S o uta	34.	S50 puta	S50 puta	S50 uta
2.	S 0 uta	S 0 uta	S 0 puta	35.	S50 puta	S50 uta	S50 puta
3.	S 0 puta	S 0 uta	S 0 uta	36.	S50 uta	S50 puta	S50 puta
4.	S 0 puta	S 0 puta	S 0 uta	37.	S60 uta	S60 puta	S60 uta
5.	S 0 puta	S 0 uta	S 0 puta	38.	S60 uta	S60 uta	S60 puta
6.	S 0 uta	S 0 puta	S 0 puta	39.	S60 puta	S60 uta	S60 uta
7.	S10 uta	S10 puta	S10 uta	40.	S60 puta	S60 puta	S60 uta
8.	S10 uta	S10 uta	S10 puta	41.	S60 puta	S60 uta	S60 puta
9.	S10 puta	S10 uta	S10 uta	42.	S60 uta	S60 puta	S60 puta
10.	S10 puta	S10 puta	S10 uta	43.	S70 uta	S70 puta	S70 uta
11.	S10 puta	S10 uta	S10 puta	44.	S70 uta	S70 uta	S70 puta
12.	S10 uta	S10puta	S10puta	45.	S70 puta	S70 uta	S70 uta
13.	S20 uta	S20 uta	S20 uta	46.	S70 puta	S70 puta	S70 uta
14.	S20 uta	S20 uta	S20 puta	47.	S70 puta	S70 uta	S70 puta
15.	S20 puta	S20 uta	S20 uta	48.	S70 uta	S70 puta	S70 puta
16.	S20 puta	S20 puta	S20 puta	49.	S80 uta	S80 puta	S80 uta
17.	S20 puta	S20 puta	S20 puta	50.	S80 uta	S80 uta	S80 puta
18.	S20 uta	S20 puta	S20 puta	51.	S80 puta	S80 uta	S80 uta
19.	S30 uta	S30 puta	S30 uta	52.	S80 puta	S80 uta	S80 uta
20.	S30 uta	S30 uta	S30 puta	53.	S80 puta	S80 uta	S80 puta
21.	S30 puta	S30 uta	S30 uta	54.	S80 uta	S80 puta	S80 puta
22.	S30 puta	S30 puta	S30 uta	55.	S90 uta	S90 puta	S90 uta
23.	S30 puta	S30 uta	S30 puta	56.	S90 uta	S90 uta	S90 puta
24.	S30 uta	S30 puta	S30 puta	57.	S90 puta	S90 uta	S90 uta
25.	S40 uta	S40 puta	S40 uta	58.	S90 puta	S90 puta	S90 uta
26.	S40 uta	S40 uta	S40 puta	59.	S90 puta	S90 uta	S90 puta
27.	S40 puta	S40 uta	S40 uta	60.	S90 uta	S90 puta	S90 puta
28.	S40 puta	S40puta	S40 uta	61.	S100uta	S100puta	S100uta
29.	S40 puta	S40 puta	S40Puta	62.	S100uta	S100uta	S100puta
30.	S40 puta	S40Puta	S40 puta	63.	S100puta	S100uta	S100uta
31.	S50 uta	S50 puta	S50 uta	64.	S100puta	S100puta	S100uta
32.	S50 uta	S50 uta	S50 puta	65.	S100puta	S100uta	S100puta
33.	S50 puta	S50 uta	S50 uta.	66.	S100uta	S100puta	S100puta

EXPERIMENT II

TEST - 2

S.No.	A	B	C	S.No	A	B	C
1.	S10 uta	S40 puta	S10 uta	22.	S70 puta	S70 puta	S40 uta
2.	S10 uta	S10 uta	S40uta	23.	S70 puta	S40 uta	S70 puta
3.	S40 puta	S10 uta	S10 uta	24.	S40 uta	S70 puta	S70 puta
4.	S40 puta	S40 puta	S10 uta	25.	S50 uta	S80 puta	S50 uta
5.	S40 puta	S10 uta	S40 puta	26.	S50 uta	S50 uta	S80 puta
6.	S10 uta	S40 puta	S40 puta	27.	S80 puta	S50 uta	S50 uta
7.	S20 uta	S50 puta	S20 uta	28.	S80 puta	S80 puta	S50 uta
8.	S20 uta	S20 uta	S50 puta	29.	S80 puta	S50 uta	S80 puta
9.	S50 puta	S20 uta	S20 uta	30.	S50 uta	S80 puta	S80 puta
10.	S50 puta	S50 puta	S20 uta	31.	S60 uta	S90 puta	S60 uta
11.	S50 puta	S20 uta	S50 puta	32.	S60 uta	S60 uta	S90 puta
12.	S20 uta	S50 puta	S50 puta	33.	S90 puta	S60 uta	S60 uta
13.	S30 uta	S60 puta	S30 uta	34.	S90 puta	S90 puta	S60 uta
14.	S30 uta	S30 uta	S60 puta	35.	S90 puta	S60 uta	S90 puta
15.	S60 puta	S30 uta	S30 uta	36.	S60 uta	S90 puta	S90 puta
16.	S60 puta	S60 puta	S30 uta	37.	S100uta	S140puta	S100uta
17.	S60 puta	S30 uta	S60 puta	38.	S100 uta	S100uta	S140 puta
18.	S30 uta	S60 puta	S60 puta	39.	S140 puta	S100uta	S100uta
19.	S40 uta	S70 puta	S40 uta	40.	S140puta	S140puta	S100uta
20.	S40 uta	S40 uta	S70 puta	41.	S140puta	S100uta	S140puta
21.	S70 puta	S40 uta	S40 uta	42.	S100uta	S140puta	S140puta

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EXPERIMENT-II

TEST-3

S.No.	A	B	C	S.No.	A	B	C
1.	S 40 uta	S10 puta	S40 uta	22.	S40 puta	S40 puta	S70 uta
2.	S40 uta	S40 uta	S10 puta	23.	S40 puta	S70 uta	S40 puta
3.	S40 puta	S40 uta	S40 uta	24.	S70 uta	S40 puta	S40 puta
4.	S10 puta	S10 puta	S40 uta	25.	S80 uta	S50 puta	S80 uta
5.	S10 puta	S40 uta	S10 puta	26.	S80 uta	S80 uta	S50 puta
6.	S40 uta	S10 puta	S10 puta	27.	S50 puta	S80 uta	S80 uta
7.	S50 uta	S20 puta	S50 uta	28.	S50 puta	S50 puta	S80 uta
8.	S50 uta	S50 uta	S20 puta	29.	S50 puta	S80 uta	S50 puta
9.	S20 puta	S50 uta	S50 uta	30.	S80 uta	S50 puta	S50 puta
10.	S20 puta	S20 puta	S50 uta	31.	S90 uta	S60 puta	S90 uta
11.	S20 puta	S50 uta	S20 puta	32.	S90 uta	S90 uta	S60 puta
12.	S50 uta	S20 puta	S20 puta	33.	S60 puta	S90 uta	S90 uta
13.	S60 uta	S30 puta	S60 uta	34.	S60 puta	S60 puta	S90 uta
14.	S60 uta	S60 uta	S30 puta	35.	S60 puta	S90 uta	S60 puta
15.	S30 puta	S60 uta	S60 uta	36.	S90 uta	S60 puta	S60 puta
16.	S30 puta	S30 puta	S60 uta	37.	S100uta	S70 puta	S100uta
17.	S30 puta	S60 uta	S30 puta	38.	S100uta	S100uta	S70 puta
18.	S60 uta	S30 puta	S30 puta	39.	S70puta	S100uta	S100 uta
19.	S70 uta	S40 puta	S70 uta	40.	S70puta	S70puta	S100 uta
20.	S70 uta	S70 uta	S40 puta	41.	S70puta	S100uta	S70 puta
21.	S40 puta	S70 uta	S70 uta	42.	S100uta	S70 puta	S70 puta

APPENDIX – II

EXPt – I

T1 NAME : Rajeev. P   T2

AGE : 20yrs   SEX M.

(1)

	SPUTA	SUTA
1.	✓	140 (6)
2.	✓	120 (6)
3.	✓	90 (6)
4.	✓	50 (6)
5.	✓	0 (2)
6.	✓	20 (3)
7	✓	30 (4)
8.	✓	40 (4)
9.	✓	100 (6)
10.	✓	130 (6)
11	✓	110 (6)
12	✓	80 (6)
13.	✓	60 (6)
14	✓	70 (6)
15	✓	10 (3)
16.	✓	140 (6)
17.	✓	120 (6)
18.	✓	90 (6)
19.	✓	50 (6)
20	✓	0 (2)
21	✓	20 (4)
22	✓	30 (6)
23	✓	40 (5)
24	✓	100 (6)
25	✓	130 (6)
26.	✓	110 (6)
27	✓	80 (6)
28	✓	60 (6)
29	✓	70 (6)
30	✓	10 (4)

N.B. (1) ✓ INDICATES /SPUTA/ IS PERCEIVED

(2) NO/ (10-140) INDICATES SILENCE PERIOD BETWEEN /S/-/U/ IN (SUTA) & /S/ -/P/ IN (SPUTA/.

(3) NO/ IN (-) INDICATES THE INDIVIDUAL SCORE IN SIX TRIALS

(4) 1-3 WERE NOT DISCLOSED TO SUBJECTS.

Rajesh Age – 18 yr Male EXPT – II

SL. No.	Correct Response	Point Secured	A	B	C	SL. No.	Correct Response	Point Secured	A	B	C
1	B	0			✓	38	C	1			✓
2	C	1			✓	39	A	0		✓	
3	A	1	✓			40	C	1			✓
4	C	0		✓		41	B	0	✓		
5	B	0			✓	42	A	1	✓		
6	A	1	✓			43	B	0	✓		
7	B	1		✓		44	C	1			✓
8	C	1			✓	45	A	0		✓	
9	A	0			✓	46	C	1			✓
10	C	1			✓	47	B	1		✓	
11	B	1		✓		48	A	1	✓		
12	A	1	✓			49	B	1		✓	
13	B	0	✓			50	C	1			✓
14	C	1			✓	51	A	1	✓		
15	A	1	✓			52	C	1			✓
16	C	1			✓	53	B	0			✓
17	B	0	✓			54	A	0			✓
18	A	1	✓			55	B	0	✓		
19	B	0	✓			56	C	1			✓
20	C	1			✓	57	A	1	✓		
21	A	0			✓	58	C	1			✓
22	C	1			✓	59	B	0			✓
23	B	1		✓		60	A	0			✓
24	A	1	✓			61	B	0			✓
25	B	1		✓		62	C	1			✓
26	C	1			✓	*63	A	1	✓		
27	A	0			✓	*64	C	0	✓		
28	C	1			✓	*65	B	0	✓		
29	B	0	✓			*66	A	1	✓		
30	A	1	✓			67	B	1		✓	
31	B	0	✓			68	C	1			✓
32	C	1	✓			69	A	1	✓		
33	A	0		✓		70	C	1			✓
34	C	1			✓	71	B	1		✓	
35	B	1		✓		72	A	1	✓		
36	A	1	✓			73	B	1		✓	
37	B	0	✓			74	C	1			✓
						75	A	1	✓		

Serial No	Correct Response	Point Secured	A	B	C	Serial No	Correct Response	Point Secured	A	B	C
76	C	1			✓	113	B	1		✓	
77	B	1		✓		114	A	1	✓		
78	A	1	✓			115	B	0	✓		
79	B	1		✓		116	C	1			✓
80	C	1			✓	117	A	0		✓	
81	A	1	✓			118	C	1			✓
82	C	1			✓	119	B	1		✓	
83	B	1		✓		120	A	1	✓		
84	A	1	✓			121	B	1		✓	
85	B	1		✓		122	C	1			✓
86	C	1			✓	123	A	1	✓		
87	A	1	✓			124	C	1			✓
88	C	1			✓	125	B	0			✓
89	B	1		✓		126	A	1	✓		
90	A	1	✓			127	B	1		✓	
91	B	1		✓		128	C	1			✓
92	C	1			✓	129	A	0			✓
93	A	0		✓		130	C	1			✓
94	C	1			✓	131	B	0	✓		
95	B	1		✓		132	A	1	✓		
96	A	1	✓			133	B	1		✓	
97	B	0	✓			134	C	1			✓
98	C	1			✓	135	A	0			✓
99	A	1	✓			136	C	1			✓
100	C	1			✓	137	B	0	✓		
101	B	1		✓		138	A	1	✓		
102	A	1	✓			139	B	0	✓		
103	B	0	✓			140	C	1			✓
104	C	1			✓	141	A	0			✓
105	A	1	✓			142	C	1			✓
106	C	1			✓	143	B	1		✓	
107	B	1		✓		144	A	1	✓		
108	A	1	✓			145	B	1		✓	
109	B	1		✓		146	C	1			✓
110	C	1			✓	147	A	0			✓
111	A	0		✓		148	C	1			✓
112	C	1			✓	149	B	0	✓		
						150	A	1	✓		