DISTINCTIVE FEATURE ANALYSIS OF BENGALI CONSONANTS

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MAY" 1989

To,
My Baba & Ma

CERTIFICATE

This is to certify that the dissertation entitied

DISTINCTIVE FEATURE ANALYSIS OF BENGALI CONSONANTS

is the bonafide work in part fulfilment for the degree of Master of Science [Speech & Hearing], of the student with Register NO. M 8709

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CERTIFICATE

This is to certify that the dissertation entitied

DISTINCTIVE FEATURE ANALYSIS OF BENGALI CONSONANTS

has been prepared under my Supervision and guidance.

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DECLARATION

This dissertation is the result of my own study undertaken under the guidance of Dr. N.P. Nataraja, Reader in Speech Science, All India insutitute of Speech and Hearing, Mysore, and has not heen submitted earlier at any University for any other Diploma or Degree.

Mysore
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CHAPTER - I

INTRODUCTION

Language has been considered as a multi-level system. These levels are phonology, syntax and semantics. Within each level, there are sublevels that define the basic elements of the system.

Phonology deals with the sound system of a language. It is not concerned with sound as physical phenomenon but rather it is concerned with phonemes of the language.

According to Trebetzkoy (1939) " phonemes are the smallest distinctive sound unit (phonological unit) of a language which can not be further analyzed into smaller and simpler phonological unit". The consequence of the study of phoneme content gave rise to the concept of distinctive features which in turn was influenced by the European sturcturalism, specially that which was propounded by Ferdinand de Saussure. A phoneme was then considered as a bundle of distinctive features which in turn helped in distinguishing sounds of a language. The idea of contrastive relationship was the foundation for the theory of distinctive feature. Earlier sounds were differentiated in terms of phonemic contrasts but now distinctive features are used to distinguish them.

According to Sadanand Singh (1976) " Distinctive features are the physical (articulatory or acoustic) and psychological (perceptual) realities of a phoneme", this definition it is meant that each phoneme can be defined and differentiated in terms of a) articulatory features namely place and manner of articulation and voicing. b) Acoustic features namely frequency, intensity and duration of speech sounds. c) Perceptual features.

There are four ways of studing distinctive features systems. 1) Acoustic method 2) Articulatory method 3) perceptual method 4) using computer.

Acoustic method identifies features interms of a) VOT b) transition of formats c) concentration of energy, locus of energy and duration of energy.

Articulatory method uses phonetic description of sounds to define distinguishing qualities of speech sounds (Chomsky and Halle 1968). The perceptual method requires the study of perceptual responses to the sounds by the listeners (Miller & Nicely, 1955 ; Singh, 1968). The computer method involves developing a specific programe being given to the input for the features (Telage,1980).

There are two ways of establishing the feature system of a particular language. They are 1) Apriori and 2) Posteriori.

Miller & Nicely (1955) define the Apriori method as defining or proposing a system before the articulatory or acoustic or perceptual analysis is done. This method lacks flexibility but is less time consuming than the other method. In the Posteriori method a large sample is taken, using various techniques like spectrographic analysis or multi-dimensional scaling of perceptual data, then the features are traced out (Jetler & Singh,1972).

Speech and language pathologists are not only interested in the combination of various features in the phoneme but also in the way in which each of these 'features' are acquired and maintained in normal and abnormal conditions. According to Hanson (1983) distinctive feature theory has valuable application in developmental evaluational and treatment aspect of articulation disorders. There are many others who have similar opinion. According to them the knowledge of distinctive feature can be used in

1) developments aspects of language (Menyuk,1968; Leonard, 1973; Panagas et.al.,1979; sing et.at.,1981).

2) The evaluational (Oiler,1973; Mckeynolds & Huston,1971 ; Mckeynolds and Elbert,1981).

3. Treatment of articulational disorders. (Pollack and Reese, 1972 ; Mekeynolds and Bennet, 1972, Wintz,1972; Castello and 0nstine,1976;Ruder and Bunce,1981)

articulation disorders . Speech and Language needs to have a good understanding of the problem and particular language to be taught. Somasundaram (1972) stated that " the situation in India, with its multiplicity of linguistic groups, necessitates the study the study of language. Present additional problem is that the speech clinicians may have to work with languages non-native to him".

Thus the need to understand the distinctive features systems in Indian languages instigated the initiation of the study in Bengali. Bengali is a member of the Indic group of the Indo-Iranian or Aryan Branch of the Indo - European family of languages. 339 minimal pairs were made using 30 phonemes of Bengali consonants and were randomly presented in quite situation to 30 listeners whose mother tongue was Bengali and to another group of 30 listeners whose mother tongue was Tamil. Their responses were recorded and perceptual analysis was done by the experimenter. Later confusion matrices were constructed for the two groups. Information content of each feature was also found out.

In addition acoustic characteristics of the phonemes were detected through spectrographic analysis.

Statement of the problem :-

To establish a distinctive features system of Bengali consonants by perceptual and acoustic methods .

Hypothesis :

1. It is possible to propose a distinctive feature system in Bengali based on phonetic descriptions.

2. Consonants in Bengali language contain the following features a) Voicing b) Nasality c) Continuant d) Coronal e) Stridency f) Aspiration g) Lateral and h) Anterior.

3. Information carried by each feature varies.

4. Each feature has distinctive acoustic characteristics.

5. No significant difference will be found in the listening performance of Bengali and non Bengali speakers, when word pairs are presented in a quite situation.

Limitations

1. Distinctive features system has been proposed only for consonants.

2. Only a limited number of listeners (30+30 in each group) were used.
3. Only the experimenter served as the judge in the present study.

5. Apriori analysis has been used.

CHAPTER - II

REVIEW OF LITERATURE

Language is made up of large phonemic inventory. This variety of phonemic inventory of any language can be described by a smaller set of distinctive features. This has been widely accepted. This acceptance is well justified on both theoretical and empirical grounds. The distinctive feature concept has been incorporated into linguistic theories, sound change, morphophonemic variation and phonological systems. Experimental psychology has furnished support for the reality of distinctive features in studies of short-term memory, error in perception and psycho-physical scaling. Moreover, the distinctive feature concept in proving to be a powerful tool in "applied" areas such as speech pathology and automated speech recognition. Distinctive feature analysis in studies of language acquisition and deviant speech are common.

The development of distinctive feature theory has been associated primarily with the name of Roman Jakobson. There can be no doubt that the main impetus to feature analysis derived from Jakobson's two classic works *Preliminaries to speech analysis* (1952) with Gurner Fant and Morris Halle, and *Fundamentals of language* (1956) in which the theory rested on the sudden and brilliant flash of insight of one man alone. On the contrary the roots of distinctive feature theory are buried deep in Prague School of phonology. Another early phonologist, Nikoli Sergevic Trubetzkey figures centrally in its development. Distinctive features theory represents the combination of long years of phonological theorizing and practical work in typological studies and synchronic analysis of a wide range of languages.

The original term to denote feature was the German *distinctive or phonological relevant Eligen Schaft (distinctive or Phonologically relevant property.* Jakobson adopted the term distinctive feature from Bloomfield's *Language* (1933). However Bloomfield has used the term to denote a phoneme (Baltaxe, 1978). The concept of distinctive features represent a direct continuant of that development.

Definitions of Distinctive Features:

Sadanand Singh (1976) defines distinctive features as "physical (articulatory or acoustic) and psychological (perceptual) realities of a phoneme" By this definition it is meant that each phoneme can be defined and differentiated in terms of a) articulatory features namely place and manner of articulation and voicing b) acoustic features namely frequency, intensity and duration of speech sounds.

c) Perceptual features.

According to Jakobson, Fant & Halle (1952) the distinctive features are "the ultimate distinctive entities of language".

Jakobson (1962) has suggested an analogy between the musical cords and the phoneme and the distinctive features. This model has the capacity to represent the phoneme as one unit - the chord itself and the notes as the variety of components which are comparable to the features, a variety of materially produced acoustic properties. A chord is heard as one element and yet is made up of other elements. This transformation, a shift in emphasis form the unit to its subcomponents was the goal of distinctive feature theory.

According to Fant (1973) distinctive features owe really 'distinctive categories or classes with in a linguistic system' but just like in accepted phonemic analysis it is required that they are consistent with the phonetic facts and these phonetic facts on various levels have lost their name to the features. He also adds 'A distinctive feature represents the linguistics condensed' view of minimal unit for composing speech message.

Blach (1978) defines a distinctive feature as 'syntactic property that separates a subtest of element from each group'.

Parker (1974) defines the distinctive features in a closed continuum referring to the "binary characteristic" of its manifestation.

All the above mentioned definitions of distinctive features clearly bring out the following characteristics;

1) Its physical nature (articulatory and acoustic) (Singh, 1976)

2) Its psychological component (perceptual nature) (Singh,1976)

3) Binary property (parker, 1974)

4) Being a part and parcel of every phoneme (Blache, 1978)

5) Having acoustic characteristics (Jakobson, 1962)

Different methods of analysis of distinctive features have been used to arrive at the features. Accoustic method has been used by Jakobson, Fant and Halle (1952). They have proposed twelve binary, universal features using acpustic terms based on the spectrographic analysis. They have demonstrated clear acoustic distinction between consonants and vowels. They believe that in no language all these feature are used. Based on received pronunciation of English they specified seven features to describe the English language.

Liberman et al (1952), Soli (1979) Massaro and Oden (1980) have reported of acoustic cues which help to discriminate the speech sounds.

The spectrographic techniques introduced by Bell Telephone Laboratory are still most important means of knowing the characteristics of speech waves.

Acoustic cues important for the perception of speech segments:

These cues can be divided into those important to the (1) perception of manner (2) place (3) voicing.

Perception of Manner Articulation :- The periodic, harmonically structured classes (vowels, simivowels, or nasals) present acoustic cues in the energy regions that are relatively low in frequency. In contrast, the aperiodic, noisy classes of speech sounds (stops), fricatives or affricates) are cued by energy that is relatively high in frequency.

The semivowels, vowel and nasals are further distinguished by the relative intensity of formants and frequency changes. The nasal consonants have formants of abruptly lower intensity than semivowels and vowels. In addition, there is the distinctive low frequency resonance, the nasal murmur. Semi vowels have formants which in context glide from one frequency to another compared to the relatively steady state of the vowels and nasals. Some dipthongs glide as much as any semivowel, but the glides are generally more rapidly changed for semivowels.

Manner cues for the stops, fricatives and affricates, are the duration of the noise, which is transient for stops, but lasts longer for affricates and lasts longest for fricatives. Thus, the manner contrasts rest on relative frequency, intensity and timing.

Perception of place of Articulation :- This depends on frequency, for vowels and semivowels, the formant relationships serve to indicate tongue placement, mouth opening and vowel tract length. Vowel placement is reflected in the F_1 - F_2 acoustic, space, with F_1 frequency indicating tongue height or mouth opening and F_2 frequency indicating place of maximum approximation of the tongue with the walls of the vocal tract. Semivowel production is mainly reflected in the frequency changes in F_2. The semivowel / j / begins with the highest F_2, with/r/ and /l/ in the middle frequencies, and /w/ relatively low. Fa serves to contrast, the acoustic results of tongue tip placement for /r/ and /l/.

For stops, fricatives and affricates, two prominent acoustic cues or place of articulation are the Fz transitions into neighbouring vowels and the frequency of the noise components. In general the transition of the second formant with a low locus is perceived as labial, with a higher locus it is alveolar: and with a varied, vowel-dependent locus, it i+s palatal or velar. The F_2 transition is used to cue the difference between the labiodental and linguadental fricatives also.

The frequency of the noise itself indicates place of production. The low frequency cut off of noise for /s/ friction is often above 4000 Hz, while for the more retracted

/s/, it is more often 2500 Hz. If the friction covers a wide band of frequencies, it is more likely to be /f/, /o, or /h/. Frequency of the noise indicates place of articulation even when extremely brief as in stops or affricates, with frequency loci similar to those reflected in the F_2 transitions. Accoustic cues for consonant voicing depend more upon relative durations and timing of events than upon frequency or intensity differences. There is an exception, the cue of the presence or absence of a voice bar. The periodic sound of voicing itself, reflected in the voice bar, is important, but the fact that one can whisper, 'The tie is blue' and "the dye is blue' and perceive a voicing distinction despite the absence of vocalfold vibration indicates that timing is a critical cue to the perception of the voiced-voiceless distinction in consonants. Listeners perceive relatively long duration of the closure period (the silence before the burst), or of the time between the burst and the beginning of voicing for the following vowel as cues for the voiceless cognates /p/,/t/, or /k/. The voiced /b/, /d/ and /g/ are perceived when the stimuli have a relatively short closure period, aspiration, and delay between burst and voicing onset are seen.

Fricatives and affricates are perceived as voiceless when the friction is relatively long, and in the case of affricates, when the closure duration is also relatively long. Finally, duration of the vowel before a final consonant can cue the perception of differences in voicing, with vowels of longer duration perceived to be followed by a voiced consonant and vowels of shorter duration perceived to be followed by a voiceless consonant.

Chomsky and Halle (1968) describe the articulatory features of universal sounds. The features are binary and are defined by autonymus adjectives. The vocal mechanism is considered in terms of source, areas of vocal tract involved, position of the tongue in relation to different areas and also oral and nasal cavity differences in terms of volume. Chomsky and Halle (1968) believed that the features extracted by the articulatory method provide a representation of an utterance which can be interpreted as a set of instructions to the physical articulatory system.

Weiner and Bernthal (1976) proposed a set of phonetic features related to articulatory characteristics of speech sound production. The features were intended (1) to represent the essential articulatory characteristics of all speech sounds (2) to provide means for aberrant speech production.

Perceptual Method :- It deals with the question of perception of speech sounds in the framework of a theory of speech perception. It is believed that distinctive features are the bases on decoding auditory stimuli. The distinctive features play a great role in perception of speech stimuli. In this method the features are retrieved from various statistical analysis.

Perceptual method has been used by Miller and Nicely (1955) Singh and Black (1969), Singh (1968), Wickelgren (1966) Shepard (1972); Singh and Woods (1971) and Singh (1975). They described these perceputal methods as (1) designation of apriori features to predict perceptual responses (2) extraction of aposteriori features from perceptual responses.

In apriori designation of a feature system to predict perceptual responses, the experimenter determines the various dimensions in which the data is to be analysed. Thus a feature system is proposed and then the experimenter evaluates the strength of the proposed feature system based on perceptual responses.

The importance of distinctive features in a language is determined by presenting the distinctive feature in question in any of the following conditions.

1. In the presence of distorted noise and filtered stimuli (Miller and Nicely 1955).
2. Cross linguistic settings (Singh and Black, 1966).

3. Recall in short term memory (Wickelgren, 1966).
4. The utilisation of choice reaction time as a measure of distinctive feature differences between the phonemes. (Cole and Scott, 1972; Weiner and Singh, 1974).
5. The judgement of pairs and traids of speech stimuli utilising various psychological methods for eliciting perceptual responses (Singh. 1970b; Singh 1971; Singh and Becker, 1972; Wang and Bilger, 1973).

Singh (1976) stated that while all of the above studies prove unambiguously that all features of a given system are not of equal importance, they do not agree regarding the explanatory powers of a given feature system. Limitations of the above system are that (1) it chooses the features arbitrarily (2) it lacks flexibility (3) it does not have the provision of adding a new feature and eliminating a known one.

In extraction of aposteriori features from perceptual responses method one can overcome the disadvantages of apriori system. Here the features are retrieved with the help of various statistical measures from the perceptual data collected.

The various methods of collecting perceptual data are 1) Similarity judgement by triadic comparison (2) confusion matrices (3) magnitude estimation by seven point scaling (4) choice reaction time (5) same or different judgement.

The data collected by these various perceptual methods can be subjected to different statistical analysis methods, namely (1) Factor analysis: (2) Contingency tables : (3) Multidimensional scaling analysis : (4) Individual scaling analysis. (Wilson (1963): Johnson (1967): Shepard (1972): Peters (1963): Graham and House (1971): Singh Woods and Tishman (1972): Jeter and Singh (1972): Wish (1970): Pruzansky (1970): Singh and Singh (1972) : Mitchell and Singh (1974)) Weiner and Singh (1974) have extracted features by aposteriori method.

Computer Analysis:- It is the latest trend in studying misarticulation which has been used in describing errors with the help of computer technology. In order to provide a rapid accurate and efficient method, computer analysis will be of great help.

Telege (1980) reports on the computerised place manner distinctive feature program for articulation analysis, wherein the primary objective was to point out the patients articulatory behaviour that contributes maximum to misarticulation. Primary utility of the computerised analysis was to generate specific detailed information for developing individualised strategies for therapy.

Elbert, Laman and Bruce (1981) analysed misarticulations using computer technology. The computer program followed the steps of feature analysis given by McReynolds and Engmann (1973) based on feature system of Chomsky and Halle. After the data entry is complete (about 50,000 words) the program could calculate (1) the number of times each feature was used correctly for the phoneme tested. (2) the plus and minus aspects of each of the features. (3) the percentage of correct or incorrect responses.

The review of various methods of extracting features from a language reveal that articulatory, acoustic and perceptual methods can be used independently. It can be postulated that combination of more than one method may be useful in obtaining substantial results and it may also reveal the correlation of the results of one method to that of others.

Distinctive Features for Consonants

Distinctive feature systems have been given by different authors. Speech sounds are bundle of series of distinctive features. The basis of these features codes may be articulatory, perceptual or acoustic. Usually vowels and consonants have different distinctive features, because the production and perception of consonants and vowels have different bases. However, there are few feature systems that describe vowels and consonants in terms of the same set of features. But in these cases, the individual features of vowels and consonants do not apply to each other in any significant way (Chomsky and Halle, 1968). Some of the important consonant feature systems are given below:

1) Jacobson, Fant and Halle (1952) seeking to develop a universal system of phonology, devised a binary distinctive feature system based on acoustical features (1) Vocalic, (2) Consonantal, (3) Compact/diffuse, (4) Grane/Acute, (5) Flat/Plain, (6) Nasal/Oral, (7) Tense/Lax, (8) Interrupted/continuant, (9) Strident/Mellow, (10) Checked/ inchecked, (11) Sharp/Plain). Nine of these features were sufficient to define 23 consonants and six vowels in English. The clinical usefulness of this system was limited because the choice of feature pairs were not made for clinical purposes (Johnson, 1980).

Miller and Nicely (1955) have deviced a more practical system for speech/language pathologists. They selected five features: voicing, duration, affrication, place and nasality. All but place' were binary features. For '<u>place'</u> a tunary feature was proposed. (i.e, mouth was divided into front, mid and back). This feature system was based on perception studies. The efforts to achieve simplicity, resulted in its short coming, i.e, incompleteness. Nine of the 25 English consonants would not be adequately defined by their system (Johnson, 1980).

Singh (1976) expanded Miller and Nicely's system, substituting friction for affrication and adding three additional features, liquid, glide and retroflex. Singh made place quaternary by dividing '<u>mid</u>' into midfront and midback. His system is particularly well suited for application in the analysis and treatment planning of disorders of articulation (Hanson, 1983).

Chomsky and Halle (1968) : According to them phonological components form a system of rules that relates of the phonetic representation of the sounds of a language. They established distinctive features by examining different hierarchies of the linguistic rules. A sentence can be split into the following subdivisions, i.e., words into phonemic, and phonemes nito distinctive features. They describe the articulatory features of the universal sounds on the assumption that the configurations of the human vocal mechanism and speech reception mechanism are identical in all human being. Binary in nature. The five major categories in the universal phonetic features of the Chomsky and Halle are 1) Major clan features 2) Cavity features. 3) Manner of Articulation. 4) Source features and prosodic features. From this major categories their 13 features approach. Using these 5 major clam features they derived 13 other subfeatures. They are :-

1. <u>Vocalic:</u> The liquids (/r/&/l/) and all the vowels.
2. <u>Consonantal:</u> All the consonants including liquids.

3. Rounded: All vowel sounds that require a rounding of the lips.
4. Tense: The /l/ /B/ and diphihongs.
5. Nasal: /m/ /n/ and /y/.
6. Continuant: All consonants produced with only a partial obstruction in the vocal tract (all but the stop plosives).
7. Voiced: All consonants that require vocal cord vibration.
8. Strident: The fricatives and affricates.
9. Coronal: Consonants produced with the blade of the tongue in a higher than neutral position (all consonants produced by lingual contact with the teeth, alveolus or hard palate.
10. High: Sounds for which the body of the tongue is raised above the neutral position /l/, /u/, /w/ and most linguapalatal and linguavelar consonants.
11. Low: Sounds wherein the body of the tongue is lower than the neutral position /i/ /x/ / / & /h/.
12. Back: Sounds involving the retraction of the tongue from the neutral position. The back vowels the linguavelar consonants, the /w/ and dipthongs containing a back vowel element.
13. Anterior: Any sound produced in the part of the mouth anterior to the /s/ sound (bilabials, linguadentals, labiodentals and lingua alveolars).

Chomsky and Halle's feature system aroused the interest of a number of speech and language patholigists. A number of clinicians have made serious attempts to apply chomsky and Halle's system to the analysis and treatment of disorders of articulation. Particularly unworthy are the efforts of McReynolds and Engmann (1975). Although these workers make the 'system' fit for articulatory disorders, still it is an uncomfortable one. Hanson (1983) points out that the process of analysis using this system is cumbersome and also that the appropriateness of the system for describing disordered articulatory patterns is questionable. For eg. seldom would the features 'Vocalic', Consonaltal' or coronal be discriminative in the abnormal articulation of a child. The terms high' and back refer to such a heterogenous group of sounds ("high' for eg. would include the /w/, /s/ /k/ and /i/ sounds) and their usefulness in a single category seems negligible. The term 'low' refers only to the vowels and to the /h/. The term tense' also applies principally to the vowels, which may certainly to defective in severe articulatory disorders or in regional or foreign dialects, but which do not seem to deserve two categories ('Vocalic' and 'tense') Hamson (1983).

Johnson (1980), congnisant of the discrepancy in purposes between Chomsky and Halle, who were striving to develop a universal system, and speech and language pathologists, who are concerned principally with defective articulation of one language devised a very practical matrix of phonetic features, based on the place, voice and manner designations traditionally used by speech and language pathologists. (The features considered were: Voicing, Nasal, Plosine, Fricative, Affricate, Liquid, Glide, Labial, Labiodental, Linguadental, Alveolar, Palatal, Velar, Glottal).

All these various aspects of distinctive feature, including definitions, types characteristics and methods of analysis of distinctive features are primarily leased on one of the 2 theories

1) Phonemic.

2) Generative.

Phonemic theory

According to phonemic theory proposed by Jakobson et al (1952) there are two levels of phonological structure an abstract phonemic level and a phonetic level that is roughly equivalent to the speech signal (physical phonetics) Distinctive features are qualities contained in the speech signal itself that are necessary for the speaker - hearer to identify the phonemes of his language.

Phonemic theory implies the presence of nondistinctive feature in a language . These nondistinctive features are not precisely definable. Also makes the set of distinctive feature potentially infinite.

Since it prescribes language specific distinctive feature, language comparisons in terms of distinctive feature becomes difficult. It purports a linear and biunique relationship between phonemic and phonetic levels which is not very evident.

It assume that these phonemes are actually heard and produced by speakers which is not true.

Owing to these discrepancies between phonemic and phonetic levels of speech, Chomsky and Halle (1968) proposed Generative phonology.

Generative Phonology

It tries to discover the rules or laws governing pronunciation in a language and to the extent to which this can be accepted universally in all the basic drawbacks of the earlier system interms of linearity and biuniqueness. The authors state that " Generative Phonology are identical with the set of phonetic properties that can be in principal controlled in speech, representing phonetic capabilities of man and thus same for all language". This makes Distinctive features as empirical rather than an arbitrary phonemeness.

According to this theory, since phonemes are not directly observable that must be arrived by a discovery process. Enumeration of phonemes of a given language is a function of the algorithm, used to determine them. In the phonemic theory there is no way as to find out which of the two solutions for the phonemes is better. The generative theory obviates the problem by not insisting that each underlying form be associated apriori with a distinct set of phones.

Chomsky and Halle (1968) try to account for the type of phonological variation that exists between phonetic and abstract phonological forms. They recognized two abstract levels of phonological structure - a more abstract classificatory matrix and a less abstract one, both in terms of distinctive features. A quality parameter that is never significant in any natural language need not be specified in the phonetic matrix. The classificatory and phonetic matrices of any given utterances may differ radically in terms of number of segments and the feature specification of each segment necessitates a method of transferring one into another. Chomsky and Halle (1968) proposed an ordered set of context sensitive phonological rules that alter the feature specifications of the classificatory matrix to yield the phonetic matrix and vice verse. Thus, Parker (1976) proposes that generative theory is more flexible in describing certain linguistic phonemena. However, he points out that generative theory fails to connect the most basic elements of language (the phonetic matrix) with speech production.

Parker (1976) proposes distinctive features as a definer of points along a continuum. With this concept of the distinctive feature, the Speech/Language Pathologist can reach a level below the phoneme, and below the traditional, restrictive distinctive feature level, to the more basic consideration of relationships between phonetic productions and the linguistic significance of features (Parker, 1976). The important suprasegmental elements of a language would also fit into parker's paradigm.

Distinctive features and Speech Sound Perception :

The role of distinctive features in perception of phonemes is important [singh (1976)] because features are the underlying attributes of perceptual processing. Thus speech sound perception and speech sound discrimination can be measured, and quantified based on distinctive features.

Speech sound perception in normal hearing individuals has been studied extensively, under different conditions. Eg.l. under various signal to noise ratio (2) stimuli present only in (a) auditory mode (b) only in visual mode (c) in combined mode etc. Singh, 1968: Tannahill and McReynolds (1972): Singh and Blackman, 1974: Binnie, Montgomery and Jackson, 1974: Danhauver et al 1978: Miller and Nicely 1955 are among those who have worked in the this field.

Thier results indicate :-

1) The distinction of consonant pairs were differently affected by the number of opposing features contained in each pair.

a) Greater confusions occurred when feature contrast was minimum (i.e. either 0 or 1).

b) The percentage of errors decreased with the increase in the number of feature differences.

2) The percentage of errors (in speech sound perception) were few in quiet condition and the errors increased with different signal to noise ratio conditions.

3) The features nasality and voicing were least affected by noise and place of articulation was most affected by noise.

Speech Sound Perception in Hard of Hearing

Speech sound perception in hard of hear been subjected to investigation. Studies on hearing impaired population implies that they use same features as normals in speech sound perception but weigh these features differently. (Singh et al 1974: Danhaver and Singh, 1975: Doyle, Danhaver and Edgerton, 1981)

Danhaver and Singh (1975) examined speaking and listening performance of 36 severely hearing impaired individuals belonging to three different language groups. (English, Yugoslavian and French). Seven binary features were utilised for analysis. Their results showed similar ranking in all language groups and thus supported language universality concept. Sonorancy,. Nasality and voicing features obtained greater scores than place of articulation and labiality. The authors attribute the highest scores in nasality, voicing and sonorancy to low frequency residual hearing and dominance of low frequency components in the voicing nasality and sonorancy features.

Danhaver and Singh (1975) studied perceptual processing of CVCV type of stimuli in deaf subjects. Their results, indicate that when deaf individuals process CVCV type of stimuli, the vowel information is processed with residual low frequency hearing. They do not perceive consonant information. The consonants are then perceived as blanks in the temporal continuum by the hearing impaired. Since consonants are of characteristic lengths the subjects perform temporal analysis to detect consonants. eg. They perceive sibilants due to their long duration. They recognise voiced sounds by low frequency formant and if low frequency formant is absent they deduce voicelessness. In short, hearing impaired subjects used different perceptual strategy and derive comparable amount of feature information from minimal cues available.

Doyle, Danhaver and Edgerton (1981) analysed errors on nonsense Syllable test on ten normals and eight patients with sensory neural hearing loss. The stimuli were presented binaurally at six different sensation levels. The analysis revealed that voicing, place, friction and sibilancy were salient features in perception of speech sounds for both groups of listeners. This suggested that both groups use similar perceptual strategy but the patients with hearing loss make more errors.

Walden and Montgomery (1975) conducted a study on three groups of subjects - Normal, High frequency loss and Flat loss. The subjects were presented with consonant pairs and similarity judgements were obtained. Individual scaling analysis was used to group the subjects according to feature usage. The results revealed that high frequency loss cases used the feature sonorant was dominantly. The authors attribute this as due to low frequency formant in sonorant feature. For flat hearing loss subjects the feature sibilance was the dominant dimension and normals used both these features equally. Similarly Bilger and Wang (1976) found significant correlation between audiometric configuration and consonant confusions.

Blood, I.M. Blood. G.W. and Danhaver (1978) studied the spontaneous production of consonants in deaf children ranging in age from 8-14 years. The substitution errors were analysed by individual scaling analysis. The results revealed that the features were mainly related to place of articulation and indicated that current rehabilitation techniques focus primarily on those features while not exploiting others available in the speech signal.

Infant Speech Sound Perception:

In 1971 by Eimas, Siqueland, Jusczky and Vigorito, used a pacifier wired to a transducer which recorded infant sucking responses to synthetic speech sounds. It was 20 m.sec increments of VOT. Eimas and his colleagues concluded that infants as young as one month old seem to perceive acoustic changes in speech as well as the adult.

Kuhl (1975) has reported that 6 month old babies indicate perception of vowel contrasts and consonants contrasts even when variations are made in pitch, talker, and phonetic context.

Juscsky (1977) found that infants could perceive consonant contrasts in word-initial, medial, or final position in multi- syllabic as well as single syllabic stimuli. The result indicate that either these infants are lingustically tuned inately to defect speech sound differences or these differences are detected in the auditory system itself with out only reference to language. Under thus subject is studied in greater depth, the dilemma cannot be resolved.

Development of Speech Sound Perception

Slatin and Koenigsknecht (1975) investigated perceptual development of the voicing contrast in 2 years old children, 6 years old children and adults. The subjects were required to identify synthetic prevocalic stop consonants which differed with respect to acoustic cue i.e., voice onset time. The results indicated that the magnitude of VOT difference required to distinguish between prevocalic stop cognates decreases as a function of age. Developmental differences were most consistently revealed for velar cognates.

This finding supported the view of Liker, Libermann and Cooper (1962) that 'Distinctiveness of phonemes is not inherent in the acoustic signal but is acquired during the process of phonological development'.

Production and Perception:

Williams and McReynolds (1975) investigated the effects of production and discrimination on four subjects. Results indicated that production training was effective in treating both production and discrimination whereas discrimination training changed only discrimination.

Williams (1975) points out that greater sensitivity to the phonological contrasts is important in the language learning. Language being learned may be a hallmark of young language learners and provide an explanation of how they manage to learn to speak a new language with so little interference from their first language.

Goto (1971) indicates that adult bilinguals are often quite insensitive to perceptual distinctions in their non-native language, even if they can produce them. This suggest that perception of one's own speech made differ from perception of speech of others.

Aungst and Frick (1964) found that children with /r/ misarticulation could perceive misarticulations of others but failed to detect their own errors.

Kornfeld (1971) showed that children may substitute /w/ for /l/ and /r/ in glass or grass produce /w/ sounds in (gwees) for glass and (gwees) for grass which seem the same to adult listeners but may differ in spectrographic. This may reflect the basis on which the children make distinctions.

Surprisingly, Locke and Kutz (1975) found that of 75 children who said (Wig) in response to a picture of a ring, only about 20% of them pointed to the picture of a ring when they later heard their own misarticulation, while 80% pointed to a picture of a wing upon hearing their misarticulation. This implies that children with misarticulations are worse at discriminating their own error sounds than their error free sounds. (McReynolds, Kohn and Williams, 1975).

Kumudavalli (1973) studied the relationship between articulatory performance and discrimination in school going children and the results revealed that production always proceeded perception.

It may be that in learning phonemic contrasts, identification of phonemes in the speech of others develops before the ability to perceive one's own errors. Production and self perception developing in parallel, as motor maturity permits. The time course of perception -production interaction remains unclear. Children learning a first language or correcting misarticulations may evidence quite a different time course of perceptual and production interaction than do second language learners. (Borden and Harris 1980).

Dichotic speech sound perception:

Conducted a classic study in the neurophysiology of speech perception in terms of cerebral dominance using of dichotic stimuli. Kimura's (1961). He used spoken digits and found that subjects made fewer errors in reporting stimuli fed to the right ear than to the left ear. This effect is known as 'right ear advantage'. Based on anatomical evidence she concluded that the left hemisphere is specialised for speech perception.

Shankweiler and Studdert Kennedy (1970) in a series of studies have found that CV nonsense syllables, such as /ba/,/ta/ or /ga/ presented dichotically to right handed listeners, show that the right ear to have a small but consistent advantage. Steady state vowels, however, show no consistent ear advantage. Vowels, being more accessible to auditory analysis by virtue of their longer duration and higher intensity may be held longer in auditory memory and are less categorically perceived, and yield a weaker right ear advantage. Stop consonants, being less accessible to auditory analysis due to their brevity and relatively low intensity, may be held only briefly in auditory memory, are categorised immediately, and yield a stronger right ear advantage. These results have been explained by positing a speech processor in the left hemisphere.

Cutting (1973) and Day and Vigorito (1973) have shown the right ear advantage to be strongest for contrastive stops, less advantageous for liquids, and least, if at all for vowels.

Blustein, Tartter and Michael (1973) studied perceptual reality of manner features in dichotic listening. The findings showed that the right ear advantage was more for fricatives and stops than nasality.

One finding of interest is the normal listeners presented with a pair of dichotic stimuli having a stimulus onset asynchrony (SOA) estimated to be about 100 m.sec. could identify the second stimulus with more accuracy than the first. This was called the lag effect. It is an example of backward masking: the second syllable masks the first. Pisoni and McNabb (1974) have demonstrated that more acoustically similar the vowels of the syllables are to one another, the more pronounced is the backward masking. Consonant feature sharing seems to facilitate perception and migh the explained on either a phonetic or an auditory level.

Hayden, Kirstein and singh (1979) evaluated the role of distinctive features in 21 dichotically presented syllables. The ear advantage was the greatest for stops and varied as a function of manner class. The number of feature difference between the consonants also affected identification. There was dominance of unmarked specification over marked one. This may be due to the fact that the stress of the dichotic presentation situation leads to simplification of response.

As a final note, it may be speculated that left hemisphere is infact endowed to perceive speech sounds better than right. This may be interms of linguistic analysis such as the extraction of features or phonemes categorisation.

Applications of Distinctive Features to Speech/Language Pathology

Distinctive feature theory, has viable applications to a) developmental, b) evaluative and c) treatment aspects of articulation disorders,

a) Developmental or Etiological theories:

Phonetic and phonological development proceed hand in hand in children. When children fail to develop articulatory skills at the expected age, they also often have developmental language delays. Adverse environmental conditions, poor physical or mental health, or severe mental retardation tend to affect both speech and language development.

Menyuk (1968) studied articulation substitutions of American and Japnese children using the feature system of Jacobson, Fant and Halle. Her interpretation of the results of her investigation suggested that features in the speech of both groups of children apparently develop in an orderly sequence. She compared the features of these two groups of children, Whose errors were appropriate for children of their chronological ages with the features of a group of American children with articulatory problems. The study revealed some differences between the 'normals' and those with speech defects pertaining to the nature of sound substitutions. For example, the normal groups often manifested voicing errors, whereas the speech defective group had more errors involving nasality. Menyuk's study provides some encouragement for the application of phonological analysis to the study of speech and language development in children.

Leonard (1973) administered the articulation tests to 200 children and his analysis was based on a phonological model of articulation competance as devised by Crocker (1967,1969) The analysis revealed that approximately 70 percent of the children showed developmental errors, indicating an incomplete mastery of the adult phonological system. The remaining 30 percent presumably did not follow Crocker's model and demonstrated individual phonological systems rather than immature adult ones.

Panagoes and associates (1979) were interested in examining relationships between syntactic errors and phonological deficits in the speech of children. They studied the misarticulations of 17 children with multiple functional articulation problems. They found that 75 percent of the misarticulations were substitution errors and 25 percent were errors of omission. Two explanations were offered by the investigators for the abnormal consonant productions of these children (1) the children were phonologically delayed: and (2) contextual complexities made sound productions less accurate. Singh and associates (1981) used the Singh and Singh (1976) distinctive features system to analyse the articulation errors of a group of 1,077 children. One of the results of their analysis was that the establishment of a hierarchy of difficulty for mastery of features. The authors assert that 'the statistically significant feature differences along the hierarchy were consistent with linguistic, acoustic, statistical, and psycholinguistic theories of language.' The investigators arranged in hierarchy, with the most difficult features first, and found that the strongest features were mastered earliest by the children whose patterns they analysed. In decending order of strength the features were nasality, sonorancy, voicing labiality, sibilancy, front/backplace, and continuancy. That is children in this group mastered nasality first, then sonorancy, and finally continuancy. The weak features were not mastered until the age of eight years.

Thus research has found a positive relationship between delay in language acquisition and errors of articulation. Many children, failing to master an adult phonological system completely, apply their own perceptual and motoric skills to the development of a modified system. Definite patterns of acquisitions of features are found in children with a high degree of consistency. A thorough phonological and phonetic inventory of the speech of a child with multiple communicative problems is a worthwhile procedure (Hanson, 1983).

(b) <u>In Evaluation of Speech/Language Disorders</u>:

Complete assessments provide information about developmental abnormalities and about the present status of speech and language development in the client. There are some regularities in the irregular patterns of children with faulty articulation. Oiler (1973), for example, found that of five developmentally delayed children studied, all showed cluster simplification, all substituted other sounds for fricatives or affricates and all had difficulty with liquid sounds. Oiler concluded". . . . .it should be clear that the rules (followed by these subjects) are apparently not unlike those of normal children at earlier ages.

Similar findings were obtained by McReynolds and Huston, (1971), who analysed the articulation of ten children with severe disorders. Responses of the children to the McDonald Deep test of articulation were analysed according to the Chomsky-Halle features system. Two types of errors were found: (1) absence of certain features, such as stridency and voicing and (2) inappropriate use of features.

McReynolds and Elbert (1981), however, view the conclusions of Oiler and others skeptically, citing their failure to employ adequate qualitative or quantitative criteria in determining whether phonological processes were involved in the children's articulatory problems. Typically, they assert, writers have labelled an articulatory error a "process' even though it occurred only once or twice in a child's speech. In order to be termed a process, McReynolds and Elbert maintain that, the error must be shown to occur in a number of separate sounds, and in the same context a number of times. To test the validity of their assumption these authors analysed the articulation disorders of 13 children, first (1) nonquantitative analysis where only one instance of an error was necessary to determine the existence of a process and (2) quantitative analysis wherein, the error had to occur atleast four times and in atleast 20 percent of the items that could be affected by the process.

McReynolds and Elbert found that the total number of processes identified was reduced by more than 50 percent when quantitative criteria were required. Thus they stress the necessity of establishing some minimal criteria for terming an error a process.

Hanson (1983) gives the following guidelines for evaluating articulatory disorders.

(1) If the only apparent speech disorder - manifested in the child is a single defective phoneme, such as the /r/, /l/ or /s/ or if two relatively dissimilar phonemes are defective, a phonetic description of the error sounds (s) is sufficient.

(2) If several phonemes are produced incorrectly, a phonological (distinctive feature) analysis should be performed along with a phonetic analysis of the defective sounds.

(3) If there are obvious signs of language delay or disorder, along with an articulation problem, a distinctive feature analysis should be carried out.

c) In Treatment:-

Pollack Reese (1972) were one among the first few authers who realized the importance of ulitity of phonological priciples in intervention of speech and language disorder. They stressed that a speech clinician must be aware of the clinical value of such approach. They also provied a medel for the application of distinctive features theory in evaluation of the various disorders. Outcomes of such treatment strategis are found to the promissing. McReynolds and Bennett (1972) showed generalization to untreated phonemes, using this treatment technqued. Using Chomsky and Halle's critaria of distinctive features they analyzed the articulation errors in three children for therapeatic intervention.

In the first phase of training, the children were taught how to produce the feature in a phoneme in the initial position in a nonsense syllable. In the second phase, the feature was taught in the final position of a nonsense syllable. Each phase consisted of five steps. The first step taught the production of the (+) or (-) aspect of the feature in the context of a phoneme i.e., the contrasting features in the context of a phoneme. Next the children learnt to discriminate between its presence and its absence. Two phonemes, one containing the (+) aspect of the feature, and the other the (-) aspect, were trained in different vowel context in syllables. AS mentioned earlier, generalization of features accross untreated phonemes was seem, proving that the use of such treatment programe is highly economical interms of time and energy.

Costello and Onstine (1976) provide some specific instructions regarding the application of distinctive feature theory in articulation training. In their program, features are taught in the context of phonemes, and systematically programmed to be incorporated into spontaneous, connected speech. Correct responses are reinforced with social praise and tokens, which are exchanged for toys. The basic instructional procedure is the modeling of the feature in a phoneme, by the clinician, followed by an attempt at imitation by the child. Sounds are initially taught in releasing and arresting (final) positions in syllables, then in words.

Ruder and Bunce (1981) trained two children with severe articulation problems through the use of distinctive features. For one child instruction was given for the production of the /s/ and /k/ phonemes, to determine whether corrected features of these two sounds might generalise to another phoneme /t/, which contains features that are present in the other two phonemes. As predicted, training on /k/ and /s/ did lead to imitative production of the target sound /t/. This was found to be generalized to /f/ and /ts/ sounds.

The second child received training on three phonemes /b/, /s/ and /k/ (consecutively, not concurrently). Training on the /b/ generalised to the /m/ and /l/. Training on the /k/ generalised to the /p/, /h/, /d/, and /r/ and training on

/s/ the child produced other five phonemes. The acquisition by the second child of a total of nine phonemes following training on three other phonemes is attributed to generalisation of features across phonemes, and also to other factors such as the duration of the training (eight months), sessions held per week (5 sessions): the age at which treatment began (five years old).

A step by step procedure for incorporating distinctive feature theory into treatment for articulation disorders is presented by Winitz (1975). Winitz approach is a marriage between distinctive features and behavioral modification principles. He advocates a search for features as a part of the testing procedure.

Winitz's next step is sound discrimination training. He suggests that such training may, on a given sound, automatically bring about changes in production of that sound if the features for the sound are already produced correctly in other contexts of speech. If this does not occur, production training is postponed until client can discriminate easily between the correct and incorrect sounds in sentences.

Weiner and Bernethal (1978) based on their clinical experience suggested several criteria for selection of a feature for training. These criteria are (1) redundancy

(2) number of features in error (3) Ease of articulation (4) Acoustic contrast (5) More visibility (6) Higher frequency of usage (7) physiological readiness.

Thus distinctive features approach does indicate a strong clinical utility.

Advantages of distinctive features:

The major advantage of the distinctive feature theory is its economy (Pollack and Rees, 1971). The method of teaching articulation using distinctive features is time saving, because many misarticulated sounds can be corrected by correcting one or two features (Costello and Ostine, 1976: McReynold and Benett, 1972).

The process of teaching the feature by the distinctive feature approach and its generalisation has greater validity since by introducing the feature it is more central and stable than merely correcting a misarticulated sound.

A feature gram is preferred to the traditional speech discrimination or articulation tests (Danhaver and Singh, 1975). Processing of phonemes of hard of hearing and deaf cannot be predicted by pure tone audiograms which deals with specific frequencies. Phoneme perception is a function of distinct articulatory features of consonants and vowels. Plotting the patient's speech discrimination or articulation scores in the form of features will be more meaningful. By looking at the feature gram one can plan therapy better. Thus the feature gram can be used for diagnostic, prognostic and therapeutic purposes.

The use of binary principle in the distinctive feature system enables the analysis to be done by a computer system.

Danien Martin and Regrodsky (1974) state that one of the advantages of the distinctive feature is 'it serves both as a phonemic description and as an aid in phonological analysis'.

Criticisms of distinctive features:

The disadvantage of any feature matrix is that: a great number of entries are minuses. The matrices give more information about which features are not present in each phoneme than about those that are present. This condition is inherent in any binary classification system (Hanson, 1983).

A number of other shortcomings have been ascribed to distinctive feature analysis. Walsh (1974) writes that features have considerable value for theoretical linguists, but are ill suited for the evaluation and treatment of articulatory disorders. The abstract, idealised concepts framed by linguists relate very little to the abnormal speech patterns of clients seen by speech/language pathologists.

Walsh also criticises the binary approach, advocating instead, that features, if they are to be used, it should be considered as variably present or absent, rather than as absolutes. Finally, Walsh contrasts the goals of distinctive features with those of the diagnostician in speech/language pathology. The former strives for economy in language description, and seeks principles that have general application within and across languages: the later strives for completeness and clarity in his description of a speech pattern.

Leonard (1973b) argues that co-articulatory influences shape a phoneme in connected speech so assigning plus or minus values to them is unrealistic.

Anderson (1974) directs his comment toward applications of distinctive feature principles in linguistics: "beyond this binary representation, however it is clear that more is required if we are to achieve our goal of specifying all of the ways in which one language can differ from another". Anderson does not advocate wholesale abandonment of distinctive features, but rather supplementation of them by a numerical scale denoting variations in values.

Sommerstein (1977) opines that there is no convincing justification for the doctrine that all features must be underlyinginly binary rather than ternary, quanternery etc. He further adds that the restriction of two underlying specifications creates problems and solves none.

Foley (1970) contending that consonants vary in strength proposes gradual features rather than binary ones. Ladefoged (1975) also argues for multivalued features. He proposed for eg. that the binary feature voice' be termed multivalued, with degrees of openess being depicted as voiceless, breathy voice, murmur, lax voice, tense voice, creaky voice, creak and glottal stop.

Fant (1980) considers that there is no unique method to measure the duration of a phoneme and thus distinctive feature system has a major limitation. He opines that one of the weaker aspects of distinctive feature theory is in the definition of consonants and vowels. Fant (1980) felt that liquids can be both and the classification of /h/ as non consonantal and nonvocalic is arbitrary. Jacobson, Fant and Halle limit the consonantal feature to low intensity alone. Fant (1980) found that it was not so far Swedish vowels.

In concluding the review of literature it would be more apt to quote Hanson (1983) who says ".... distinctive feature theory has viable applications to developmental evaluative and treatment aspects of articulation disorders. A surge of interest has produced a number of studies, the results of which strongly support the value of feature analysis on the other hand, a number of articles have been written that criticise the distinctive feature approach. Until greater uniformity of opinion is reached, it would seem harmless, and in all likelihood profitable, to search for phonological patterns in clients with multiple defective sounds and in clients demonstrating language delay in combination with articulatory defects'.

Studies of distinctive Features done in Indian Language

Ahmed and Agarwal (1969) attempted to find the significant features in the perception of Hindi consonants. A quantitative procedure was adopted to ascertain which features were most significant for listeners and whether or not they are similar in initial and final positions. The amount of information transmitted in bits per stimulus, was calculated for a given feature. Results indicated that semivowels and affricates were most intelligible and that major confusions existed among plosives. In both positions i.e. initial and final, confusions occurred most frequently between classes distinguished by a single feature. They found that in the initial position, confusions generally arise due to manner of articulation, and in the final position, confusions are in terms of place of articulation. They also found that initial and final vowel transitions play a very important part in recognition of consonants.

Gupta, Agarwal and Ahmed (1969) conducted another study, on perception, of Hindi consonants in clipped speech. Effect of peak clipping on intelligibility of individual consonants was found. They also tried to correlate different information of initial consonants and final consonants and to see the difference in perception of the two positions. Results indicated that the average effect of clipping on features were : 1) place of articulation (2) nasality (3) flapped liquids (4) liquids (5) continuants (6) voicing (7) friction (8) aspiration (9) affrication.

Mallikarjuna (1974) found that the native speaker of Kannada who are not exposed to Sanskrit language are not able to make out the differences between aspirated and unaspirated in terms of recognising and reproducing. The same spectrographic studies showed that aspirates and unaspirated /h/ were different.

Somasundaram (1972) did a contrastive analysis of phonology of Tamil, Telugu, Kannada and Malayalam based on distinctive features. 11 distinctive features were necessary to distinguish the phonemes of the four language. 1) Vocal, 2) Consonantal, 3) Nasal, 4) Continuous, 5) Tense, 6) Grave, 7) Compact, 8) Flat, 9) Sharp, 10) Diffuse, 11) Strident. It was found that features (1) to (9) were common to all languages. Whereas, 11th (strident) was significant in both, Tamil and Malayalam and 10th (sharp) was significant only Malayalam.

Valantine (1977) proposed a system for classifying phonological segments (of Malayalam language) into the following features: 1. Back/non back, 2. Nasal/non nasal,
3. Obstruent/non obstruent, 4. Continuant/non continuant,
5. Retracted/non retracted, 6. Retroflex/non retroflex.,
7. Aspirate/non aspirate, 8. Palatal/non palatal,
9. Retracted/non retracted, non lateral, non obstruant,
10. Coronal/non coronal, 11. Lateral/non lateral,
12. Retracted/non retracted non consonantal obstruent.
13. Voiced/voiceless.

Ramaswami (1980) studied phonetic features of Tamil sounds. The features necessary to distinguish vowels are tongue features (high, low and back). Among consonants, stops, affricates and fricatives are non-sonorant or obstruents. Stops and affricates are differentiated by fricatives by the feature continuant. Stops are differentiated from affricates, by abrupt' release, since the release of the arrested sir in the case of stops is abrupt but is delayed in the case of affricates. Point of articulation is also considered to be necessary for distinguishing the sounds. The feature anterior distinguishes sounds that are produced in front of alveo-palatal region and those which are produced at the back of the alveo palatal region.

Falguni Pathak (1982) studied the distinctive feature system in Gujarathi language using both articulatory and acoustic method. The following features were found to be present namely - Aspiration, Nasality, Semivowel, retroflex, velar, Fricative, voicing, labial, alveolar, dental, affrication, lateral and flap.

Arati, V. (1983) attempted to establish distinctive feature system for Malayalam consonants, using both acoustic and articulatory methods. The following features are found to be present, namely (1) Back/non back, (2) Nasal/non nasal, (3) Continuent/non continuent, (4) Obstruent/non obstruent, (5) Voiced/non voiced, (6) Retracted/non retracted, (7) Retroflex/non retroflex, (8) Palatal/non palatal, (9) Aspirated/non aspirated, (10) Coronal/non coronal, (11) Consonantal/non consonaltal.

Venkatesh (1983) and Umadevi (1984) studied the distinctive feature system in Kannada and Telegu languages respectively using both articulatory and acoustic methods. Eight features were found to be present namely, voicing, nasality, Aspiration, Anterior, Coronal, Continuancy, stridency and lateral.

Ferguson and Chowdhury (1960) described Bengali Consonants interms of distinctive features (Jackobson, Fant and Halle 1952). The following features were found to be present vocalic, consonantal, grave, compact, nasal, tense, voiced. In their study they concluded that

1). m, n, n, 1, r, r, vocalic due to presonce of formant like acoustic energy which is combined with noise like acoustic energy.

2) In is neither vocalic nor consonantal.

3) Some consonants are grave some are acute, retroflexes /t/ and /d/ and aspirated retroflexes /th/ and /dh/ are neither grave not acute.

4) Consonant rand are classified as discontinuances..

Thus the review of literature bring to light, the following facts about distinctive features namely

1) they can be used to study speech and language development in a child.

2) To study the phonology of a particular language.

3) To study factors which affect perception and production of speech.

4) To study factors which affect speech communication in a particular context.

5) To apply it to articulatory therapy both at the level of assessment and therapy.

The number of studies done in Indian language are limited and especially since India is a multilingual country, the children will need to understand in depth the phonology and distinctive characteristics of each language he deals with. The present study is thus an attempt to arrive at the distinctive features of Bengali consonants, for a systemic and controlled method of dealing with speech and language pathology.

CHAPTER - III

METHODOLOGY

The present study is an attempt to establish a distinctive features system for the Bengali consonants and to find at the acoustic correlates for the proposed features. It is based on the distinctive features system proposed by Chomsky and Halle (1968). The following set of features were taken for this study.

1) Voicing 2) Nasality 3) Continuant 4) Anterior 5) coronal 6) stridency 7) lateral 8) aspiration.

The Bengali consonants considered in the present study are based on the phonetic classification in terms of manner and place of articulation of consonants in Bengali language (Chatterjee,1920; Appendix...2)

1) Stimulus :- Word pairs contrasting in one consonant have been taken as the stimulus. 339 word pair were made using 30 Bengali consonants. They are basically selected from a Bengali phonetic reader (Chatterjee,1928). In addition to these, native speakers of this language were also consulted for additional word pairs. Word pairs were made to meet the following criteria.

a) Each consonant was contrasted with every other consonants where ever possible.

b) In majority of word pairs, the initial contrast was maintained as for as possible. Medial and final contrast were taken where initial was not available.

c) As for as possible most familiar words were used.

d) The minimal pairs were randomized. Appendix - 3 presents the list of word pairs.

2) Recording :- Recording was done in a quite room using the tape recorder of speech spectrograph. (VIC MK 700). The VU meter was used to monitor the intensity. The output from the spectrograph was fed to a Philips deck tape recorder model (F6112) using a Meltrack cassette. The word pairs were recorded in such a way that between every word of a pair there was a gap of two seconds and between items there was a gap of five seconds. This five seconds gap was utilized to record subject's response.

Speaker :- A male native speakers of Bengali served as the speakers for the recording of the minimal pair list.

Procedure :- The experiment was done in a folds.

1) Perceptual analysis

2) Acoustic analysis

Perceptual Analysis :- A total of 60 subjects 30 native (Bengali as mother tongue, 30 non-native (Tamil as mother tongue) participated in the present study. In each group there were 15 males and 15 females. The age range of Bengali group was 12 to 26 years with mean age of 23 years, and the age range of Tamil group was 17 to 23 years with mean age of 21 years. In Tamil group none of the subjects had any exposure to Bengali language. These subjects had no history of speech and hearing problem.

Instructions

Each of the subjects were given the following instructions.

"This is a small test which I am going to administer. You will hear Bengali word pairs. Please listen to them carefully and repeat them as you have heard. Your responses will be tape recorded". The Bengali group was instructed in Bengali and the Tamil group was instructed in English.

The recorded word pairs were presented individually to subjects. The subjects were seated comfortably in a chair and the list was presented through head phones of the Philips deck tape recorder model (F6112) The responses given by subjects were recorded using Philips tape recorder model (N2218).

CHAPTER - IV

Results and Discussion

The result of this experiment provided the amount of information carried by each distinctive feature and the acoustic correlates of the proposed distinctive feature system of Bengali consonants.

The proposed distinctive feature system of Bengali consonants for the present study were 1) Voicing 2) Nasal 3) continuant 4) Anterior 5) Aspiration 6) Coronal 7) Stidency 8) Lateral.

Perceptual Analysis: The response of 30 Bengali and 30 Non-Bengali (Tamil) speakers were analyzed using a confusion matrix. Using confusion nature, we can portray the stimuli and responses can be protrayed. In the vertical axis 30 phonemes as they occurred in 678 words were represented. In horizontal axis spoken responses of the 60 listeners as they perceived were recorded.

Two confusion matrices were made one for each group. Each matrix was made up of 678 observations of 30 listeners (made up of 20340 observations). The number in each call represented the frequency of occurrence of sound shown in the response column for the sound shown in the corresponding column of the stimuli. The row gave the total frequency of the stimuli presented and column gave the total frequency of the responses which occurred.

The confusion matrix for 30 consonants in Bengali was subdivided into voice network of eight component binary channel of linguistic features based on eight features portrayed. The confusion matrices were four fold matrices.

example:

		Responses	
		voiced	voiceless
Stimuli	voiced		
	voiceless		

In all the confusion matrices thus formed, the sum of numbers in the diagonal line indicated the number of correct responses and numbers scattered around the diagonal line indicated the the errors.

A measure of covariance based on information theory (Shamnon and Weaver, 1963) was employed to calculate information transmission for a composite phoneme channel and for 8 distinctive features. Using the formula

$$T\ (X.Y) = -\sum_{ij} P_{ij} \log 2 \frac{P_i . P_j}{P_{ij}}$$

where T (X.Y) = information transmission from input variable 'X' to output variable Y bits/stimulus

Pi = ni/N
Pj = nj/N
Pij = nij/N
ni = frequency of stimulus i
nj = frequency of response j
nij = frequency of joint occurrence of stimulus i and response j in a sample of N observation.
N = Total number of observations. In Table (1) cell entries are 'nij' row sums are ni; column sums are nj and N is 20340.

To calculate T (X,Y)

For example,

Response

Stimulus		j_1	j_2	
	i_1	a	b	a+b
	i_2	c	d	c+d
		a+c	b+d	

Where N = a+b+c+d

$$T(X.Y) = -\left[a/N \ \mathrm{Log2}\frac{\frac{a+c}{N}\times\frac{a+b}{N}}{a/N} + b/N \ \mathrm{Log2}\frac{\frac{a+b}{N}\times\frac{b+d}{N}}{b/N}\right.$$

$$\left. c/N \ \mathrm{Logz}\frac{\frac{a+c}{N}\times\frac{c+d}{N}}{c/N} + d/N \ \mathrm{Log2}\frac{\frac{b+d}{N}\times\frac{c+d}{N}}{d/N}\right]"1$$

The information value carried by each feature was calculated using the above formula.

The total transmission in bits/stimulus was calculated by adding the information value for the eight features.

The composite channel information transmission was calculated using the formula,

$$H = -\sum_{n=1}^{8} Px \ Log2 \ Px$$

here Px refers to the probability of occurrence of a particular feature. For eg. the probability of occurrence of voicing' (P1) was 18 out of 30 (i.e., out of 30 consonants 18 consonants are voiced) and for 'nasal' (P2) is was 3/30 and so on.

The value of Pi to Pe were substituted in above formula,

i.e. $H = \sum_{n=1}^{8} P1 \ log2 \ P1 + P2 \ log2 \ P2 + \ldots + P8 \ log2 \ P8$

and the composite channel information transmission was found to be 3.5627 bits/stimulus.

<u>Discussion:</u> The percentages of correct responses to the 678 words, by 30 Bengali and 30 Non-Bengali speakers were found to be 95.86% and 79.93% respectively. By observing the pattern of error responses scattered around the diagonal line (see table - 1 & 2). It was inferred that when two sound differ in more number of features the confusion are less than when two sounds differ in less number of feature. Eg. more confusion occurred between /k/ & /k^h/ and less confusion between /k/ & /1/.

Aspirations were more affected in both the groups but in Non-Bengali group it was more severe and laterals were the least affected in both the groups.

The results indicated that several features play an important role in speech sound perception. These features work independent of each other in the perception of speech sounds. However, the features are not completely independent. The composite phoneme channel transmits 3.5627 bits/stimulus, where as the total information transmitted by eight features were 5.5408 bits/stimulus for Bengali and 4.3910 for Tamil speakers which was greater than that for a composite phoneme channel. This difference is due to 'cross talk' or overlap between component channels and was attributed to redundancy of the language. Thus the features were not completely independent.

From table 3 & 4 it was clear that all distinctive features do not have equal importance in speech sound perception. Thus some distinctive feature transmit more information than others. Therefore the hypothesis that "the information content carried by each of these distinctive features vary" is accepted.

The ranking of the features according to the amount of information transmitted indicates that 'voicing' is the strongest feature in the Bengali group and Stridency for the Non-Bengali group. Lateral is found to be the weakest feature in both the groups. (Table 3 & 4) Miller and Nicely (1955) and Venkatesh (1983) found voicing' to be a strongest

Table-1

	k	kʰ	g	gʰ	c	cʰ	ɟ	ɟʰ	t	tʰ	d	dʰ	n	ʈ	ʈʰ	ɖ	ɖʰ	ŋ	p	pʰ	b	bʰ	m	ʃ	r	l	ɽ	ŏ	ĕ	h	
k	576	18			1				22					8					5												630
kʰ	22	643								8					4					10										3	690
g	1		634	9			4				10										2										660
gʰ		20	34	553				2		6		5					7					3									630
c					592	26			3		5													4							630
cʰ					10	784	2	10		4																					810
ɟ							741	30				1								8											780
ɟʰ					2	5	22	611				5					4			11											660
t	9								779	20				34	4	8			16												870
tʰ									6	668					10				6												690
d											654	4				62															720
dʰ		2		9								571			3		7			8											600
n													690																		690
ʈ	11				4	2			3					784					6												810
ʈʰ						2			2			2		22	673				9											10	720
ɖ									4							570	26														600
ɖʰ				2				2				10				18	656					2									690
ŋ													5					265													270
p	2								12					2					764												780
pʰ		8								6										594										22	630
b			2																		688										690
bʰ		2		4															4	12	2	696									720
m																							690								690
ʃ	4				5	4													3	4				784						6	810
r					2											2									798		8				810
l																2										838					840
ɽ																									8	2	560				570
ŏ																												480			480
ĕ																													570		570
h		2																		2										596	600
	625	695	670	577	616	823	769	658	831	712	669	598	695	850	694	662	700	265	813	649	692	701	690	788	806	840	568	480	570	637	20340

Confusion matrix for Bengali group showing the

Table-2

	k	k^h	g	g^h	c	c^h	j	j^h	t	t^h	d	d^h	n	ṭ	$ṭ^h$	ḍ	$ḍ^h$	ṇ	p	p^h	b	b^h	m	ʃ	r	l	ṛ	ɔ̃	æ̃	h	
k	471	50	10	5					51					39	4																630
k^h	54	533	7	43						18					21															14	690
g	4	8	565	54							12					8								4	5						660
g^h		45	22	543							4	5					1					6								4	630
c	2				511	46	29	10				2		11						1				18							630
c^h				7	50	694	16	43																							810
j					36	4	679	55		2														4							780
j^h		5			7	83	43	518																4							660
t	22				10		13		578	40	23	13		126	21	6	3		9						6						870
t^h		13				14			29	519		44			43		16		12												690
d			2						10	4	425	87	8	23		110	20				31										720
d^h								5		17	35	468			18	6	11			12		28									600
n	2								3				682			1			2												690
ṭ	24			13						41	7	8		551	121	13	10		12						6					4	810
$ṭ^h$		9				12		13		37		23		40	537		17		4	28											720
ḍ	1			13			25		12	6	19	46	14		6	347	68			10	18	7	8								600
$ḍ^h$		7			4	6	7		5		6	41		6	42	28	518				2	18									690
ṇ			3										23	11				233													270
p	40	6							22	10	6			52	6				567	49	8		4							10	780
p^h	11								10	49		12							51	440		32								25	630
b			10								19								17	19	481	87	57								690
b^h		22	8	14					16	5		25				9	12		13	28	38	509	9							12	720
m													4					2	4		8		672								690
ʃ	11	7	4		41				10										6					702		7				22	810
r																									780	8	22				810
l													16													771	53				840
ṛ														13											23	14	500		20		570
ɔ̃																												462	8	10	480
æ̃																										13		4	552	1	570
h	11			23		8				16		14			17				12	36		13								450	600
	653	705	631	715	669	867	812	644	746	764	556	788	747	872	836	528	676	235	709	623	686	700	750	732	820	813	575	466	580	552	20340

Confusion matrix showing the responses to Stimuli for non-Bengali group.

TABLE - 3

Table showing information transmission in bits stimulus for eight linguistic features and the ranking of these features according to the amount of informations transmitted in Bengali speakers.

SL No	Features	Ranking	Information transmitted in bits stimulus
1.	Voicing	I	.9338
2.	Anterior	II	.8618
3.	Coronal	III	.8519
4.	Aspiration	IV	.7952
5.	Continuant	V	.7511
6.	Stridency	VI	.6962
7.	Nasal	VII	.4047
8.	Lateral	VIII	.2461

Total transmission in bits / stimulus = 5.5410

Composite phoneme channel transmission = 3.5627

TABLE - 4

Table showing information transmission in bits stimulus for eight linguistic features and the ranking of these features according to the amount of information transmitted in non Bengali (Tamil) speakers.

SL	Features	Ranking No	Information
1.	Stridency	I	.6889
2.	Continuant	II	.6878
3.	Voicing	III	.6811
4.	Coronal	IV	.6667
5.	Anterior	V	.5750
6.	Aspiration	VI	.5293
7.	Nasal	VII '	.3583
8.	Lateral	VIII	.2039

Total transmission in bits / stimulus = 4.391

Composite phoneme channel transmission = 3.5627 feature in English and Kannada respectively. Where as retroflex in Gujrathi, consonantal in Malayalam, stridency in Tamil and coronal in Telegu were the strongest.

A comparison of the ranking (Table-5) differences between the two groups could be attributed to the fact that information carried by the features are not similar in these two languages.

A significant difference was found in the listening performance of Bengali and Non-Bengali subjects. Inspite of different origin of these two languages the percentage of correct responses was 79.9% for Tamil group. This may be because of the use of almost the same set of distinctive features by both the groups. Thus the findings indicate the possible existence of universal features (Chomsky & Halle, 1968; Menyuk 1968).

A comparison of distinctive features of Bengali, Kannada Telugu, Malayalam, Tamil and Gujrathi reveals that many of features are common to all the six languages thus showing universality of distinctive features. Further, all features are not found in all languages.

Though many of the features were common to all the six languages compared, the ranking of these features were not found to be same in all the languages. This implies that some features carry more information in one language than in other.

TABLE - 5

Table showing the comparison of ranking between Bengali and Tamil listener

SL No	Features Bengali listener	Ranking	Features non Bengali listener (Tamil)
1.	Stridency	I	Stridency
2.	Continuant	II	Continuant
3.	Voicing	III	Voicing
4.	Coronal	IV	Coronal
5.	Anterior	V	Anterior
6.	Aspiration	VI	Aspiration
7.	Nasal	VII	Nasal
8.	Lateral	VIII	Lateral

TABLE - 6

Table showing the distinctive feature of Bengali, Gujrathi, Kannada Malayalam, Tamil and Telegu ranked according to the information transmission.

Ranking	Bengali	Gujrathi	Kannada	Malayalam	Tamil	Telegu
1	Voicing	Retroflex	Voicing	Consonantal	Stridency	Voicing
2	Anterior	Velar	Coronal	Obstruent	Continuant	Coronal
3	Coronal	Dental	Stridency	Nasal	Voicing	Anterior
4	Aspiration	Labial	Anterior	Continuant	Coronal	Anterior
5	Continuant	Alvelar	Continuant	Back	Anterior	Strident
6	Stridency	Voicing	Aspirated	Coronal	Aspiration	Aspirated
7	Nasal	Aspiration	Nasality	Retroflex	Nasal	Nasal
8	Lateral	Affrication	Lateral	Palatal	Lateral	Lateral
9		Nasality		Retracted		
10		Friction		Voiced		
11		Aspirated		Aspirated		
12		Lateral				
13		Flap				

* Features not ranked according to information theory,

Acoustic Analysis

Wide band spectrogram for 32 words were studied. A close inspection of the spectrograms revealed distinct acoustic characteristics for each feature proposed. The distinctive acoustic characteristics for the proposed distinctive features were as follows.

1. Voicing: The essential acoustic characteristics for voicing distinctions seen in the spectrograms were;

a) Presence of low frequency energy termed as 'buzz' (Jakobson, Fant & Halle 1952) in voiced sound and absence of this in a voiceless sound. The presence of this characteristics was marked by voice bars along the base of the spectrogram which could be identified as vertical striations occurring at regular intervals.

b) Voice on set time was identified as voiced lead in voiced sounds and as voicing lag in voiceless sounds.

c) The energy concentration in the noise components of the spectrum either in stop or fricative sound was greater in voiceless than in voiced sounds.

The following characteristics were observed in the consonants (/g/, /d/, /d/) of Bengali which were analyzed spectrographically.

1. Regular vertical striation in low frequency region which occur simultaneously with the burst (step or friction) indicating voice load.

2. Decreased intensity of burst when compared to its voiceless counterpart.(/k/,/p/,/t/)(Appendix-7,Fig 1)

2) Nasality :- The nasal sounds are characterized by low nasal formants at around 200 Hz and a tail like appearance. According to Jakobson, Fant and Halle several weaker high frequency formants (not always seen in spectrogram) may occur only typically at 2200 Hz. The above mentioned characteristics i.e., 1) The presence of low frequency formants and 2) Tail like appearance, were present in the nasal consonants (/m/, /n/, n/, /n/) studied. These characteristics were not found in non nasal sounds (/p/, /b/).

3) Aspiration :- The acoustic one for this feature is the presence of aperiodic noise in the higher frequency region mincing the friction noise in steps fricatives and officiate. These characteristics was found in the Bengali sounds (/p^h, /b^h/) and was not seen in unaspirated sounds (/P/, /b/) Fig (3)

4. Stridency:

This feature is characteristics by high frequency turbulences for longer duration with high intensity. These acoustic cues were present in the Bengali sounds (/s/, /c/) examined. Fig (4)

5. Lateral:

According to Jakobson, Fant and Halle (1952) state that lateral sounds are associated with vowel like and consonant like characteristics. The continuous bars in them are representative of vowels and the gaps are characteristic of consonant parts. This feature was noticed in Bengali consonants (/l/) studied. Fig (5).

6. Coronal:

The inspection of the consonants with + and 2 - coronal feature indicate the following acoustic characteristics as distinctive from the consonants with out this features.

1. Gradual upword movement of F1 and gradual downword movement of F2 in + coronal (/t/) where as sudden downword movement of F2 and sudden upword movement of F2 in non - coronal. Bengali consonants showed the presence of this feature Fig(6).

7. Continuant:

The acoustic characteristics seen in this feature are: a gradual on set of vibration, which is continued for a considerable length of time as seen in of /s/,/l/,/r/, /o/, /e/ consonants, where as non-continuants present a sudden burst of vibration for a very short duration as seen in /p/ /b/ /t/ /d/. Thus the acoustic characteristics seen are 1) gradual onset (increase in intensity with time) 2) longer duration of vibration. This feature was also found in Bengali /s/, /1/ and /r/. Fig (7).

8. Anterior:

It is not possible to differentiate Anterior and non-Anterior' as these sounds vary interms of duration of VOT and transition of formants. As the constriction of vocal tract move backwords, the duration of VOT increases. However, Chomsky & Halle, have considered all labial, labio-dental, dental and alveolar sounds as anterior and palatal, retroflex, relax and glottal sounds as non-anterior. Based on this place of articulation the acoustic characteristics are provided as follows.

Labial:- Downward transition, low frequency peak and short less VOT were seen in (/p/, /b/,/m/).

Dental: Characterized by upword shift, higher frequency peale when compared to labial sounds and shorter VOT were found in (/t/, /d/).

Alveolar: Shortened transition upwards or downwards, high frequency peak, greater VOT when compared with labial and dental sounds. These was seen in /n/, /n/, /r/.

Retroflex: Upward shift and low frequency peak. Were found /t/ & /d/.

Velar: Upward shift of transition, mid frequency peak, greater VOT when compared with other sounds. Eg./k/ /g/

All the features were found with reference to Bengali consonants studied.(Fig -8)

Thus the acoustic analysis of Bengali consonants reveal distinctive acoustic characteristics for each of the proposed feature. Thus supports the hypothesis that each of the distinctive feature proposed presents distinctive acoustic characteristics is accepted.

It is possible to analyze consonants in Bengali language using these distinctive features. Thus the hypothesis stating consonants in Bengali are made up of following features; a) voicing, b) nasality, c) continuant, d) anterior, e) coronal, f) stridency, g) aspiration, h) lateral has been accepted.

Thus the distinctive feature system in Bengali has eight features which has been proposed based on the phonetic description of Bengali consonants. This the hypothesis "it is possible to propose a distinctive feature system in Bengali based on phonetic description is accepted.

For speech and language pathologists the distinctive feature system as described by others (Jakobson, Fant & Halle 1952; Chomsky and Halle 1968) seem to be very useful tool in describing the developmental aspects of articulatory behavior, in planing therapy and in assessing the cases of misarticulation mid their programs. The results of the present study has relevance to the above mentioned facts.

CHAPTER - V

SUMMARY AND CONCLUSION

Language is a composite set of words, words of sounds or phoneme and phonemes of features which are distinctive from each other. An explicit simple sound is thus composed of several parameters which can be seen in the form of features which describe it. These features which provide us the information about the various distinction between these speech sounds are called distinctive features. In essence the distinctive features can be thus referred to as the 'building blocks of the phoneme'.

Distinctive features are now considered to be the psycho logical and physical realities of a phoneme (Singh,1976). This definition thus clearly brings to light two aspects of the features the perceptual and the acoustic.

The establishment of a distinctive features system has been achieved by various methodologies, such as perceptual method, articulatory method, acoustic method and by using computer.

The present study aimed at establishing a distinctive features system of Bengali consonants. 339 word pairs were prepared such that there was at least one feature difference between the two consonants of the word pair. Perceptual and acoustic analysis were carried out to establish the features.

Perceptual analysis was carried out in two stages, Part I & Part II;

Part I: The word pairs were presented to a group of 30 subjects (individually) who were native speakers of Bengali. Subjects had to speak out what they heard and these responses were recorded for further analysis.

Part II: The same stimuli were presented to a group of 30 Non-Bengali speakers (Tmil Speakers) and their responses were recorded.

The perceptual data was analyzed using confusion matrices and by calculating the information content of each feature.

32 words were analyzed spectrographically to observe the acoustic characteristics of each feature.

The following conclusions were drawn from the study:-

1. It is possible to propose a distinctive features system in Bengali based on phonetic description of Bengali language

2. Consonants in Bengali are made up of the following features a) voicing b) nasality c) continuant d) anterior e) coronal f) stridency g) aspiration. h) Laterality
3. Information carried by each feature differs.
4. Each feature has distinctive acoustic characteristics.
5. Significant difference were found between the listening performance of Bengali and Non-Bengali speakers when the word pairs were presented in a quite situation.

IMPLICATIONS:

1. The distinctive features system thus established gives an indepth analysis into the phonology of Bengali.
2. The distinctive features system can be used to study the phonological acquisition of Bengali in children, to assess articulation disorders and in planning articulation therapy.
3. Distinctive feature discrimination tests can be developed for audiological testing (speech discrimination).
4. An articulation drill book in Bengali can be prepared based on this.
5. It can be used to improve the telecommunication system for transmission in Bengali.

6. It can be used in the development of speech synthesizer.
7. It can be used to study the perception of individuals who are both normal and hard of hearing.
8. It can be used in studying automated speech recognition.

Recommendations:

As evidence accumulated to support the distinctive features approach in general, one need to bear in mind that there are still significant issues that remain unresolved.

1) Is there an universal set of distinctive features?
2) Is there an universal feature hierarchy?
3) Are all features binary?
4) Which is the optimal level(s) for specifying the features (articulatory, acoustic, perceptual)?

These and other important questions are still open to debate. So further studies should be done to give answer for these unresolved questions and make it a powerful tool in clinical work.

Further study can be done on:

1. Substitution analysis, that is which of the features are substituted by the other features.
2. An articulation test in Bengali can be developed on the bases of the established distinctive features system.
3. Distinctive features system for vowels in Bengali.
4. Distinctive features can be established using different methodology.

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Appendix - 1

Definition of distinctive features proposed for Bengali consonants.

1) <u>Voicing</u> :- In the production of voicing consonants the vocal folds vibrate, and in the production - voicing consonants vocal folds do not vibrate.

eg :- + Voicing : /g/,/g^h/, / j / , / j^h / , /d/, /d^h/, /n/, /d/,
/d^h/, /g/, /b/, /b^h/, /m/, /e/, /r/, /r/, /6/, /l/.

- Voicing : /k/,/k^h/, /c/, /c^h/, /t/, /t^h/, /t/,/t^h/
/P/, /p^h/, /s/, /h/, .

2) <u>Coronal</u> : The + coronal sounds produce with the blade of the tongue raised from its neutral position, and - coronal sounds are produced with the blade of the tongue in neutral position.

eg : + Coronal : /c/, /c^h/, / j / , /jh/, /t/, /t^h/, /d/, /d^h/,
/n/, /t/, /th/, /d/, /dh/, /r/, /r/, ///, /!/.

- Coronal : /k/, /k^h/, /g/, /g^h/, /p/, /p^h/, /b/, /b^h/,
/m/, /n/, /&/, /e/, /h/.

3) <u>Strident</u> :- The + strident consonants are marked acoustically by greater noisiness.

eg : + Strident : /s/, /c/, /c^h/, / j / , / j^h / , /h/.

4) <u>Anterior</u> : All the front sounds are known as + anterior i,e., bilabial dental, alveolar sounds are anterior sounds. The palatal retroflex velar and glottal sounds are Anterior sounds.

eg : + Anterior : /t/, /t^h/, /d/, /d^h/, /n/, /b/, /b^h/, /p/,
/ph/, /m/, /r/, /l/, /&/.

- Anterior : /k/, /kh/, /g/, /gh/, /c/, /c^h/, / j / , / j^h / ,
/r/,/t/, /t^h/, /d/, /d^h/,/d/, /d^h/, / y , /e/, /s/, /h/.

5) <u>Continuant</u> :- The continuant consonants are produced with the constriction in the vocal tract regulated in such a way that complete closure or blocking of air passage never occur.

eg : /e/, /r/, /l/, /o/, /s/, /h/, /r/.

6) Nasal =- + Nasal consonants are produced with the lowered velum and - nasal consonants are produced with the raised velum.

eg : + Nasal : /n/, /n/, /m/.

7) Aspiration :- The aspirated sounds are characterized by extra energy concentration in aperiodic portion of the consonants at high frequencies.

eg : + Aspiration : /k**/, /gh/, /c^h/, /j^h/, /t^h/, /d^h/, /t^h/, /d^h/, /p^h/, /b^h/.

8) :- The + Lateral consonants are produced by lowering the mid sections of the language.

eg : + Lateral : /l/.

Appendix - 2

CHATTERJI'S CHART OF BENGALI CONSONANTS

	Bilabial	Labio-dental	Dental	Alveolar	Retro. flex	Palato-alveolar	Palatal	Velar	Glottal
Plosive	p b		t d		t d			k g	
[Aspirate	[ph bh]		[tb dh]		[th dh]			[kh gh]	
Affricate		..	..			cj	.. .. ..		
[Aspirate]						[ch jh]			
Nasal	m		.. n		.. ..			.. .. ..	
Lalbrul	..	..		.. l	.. ..		.. .. ..		
Rolled	..			.. r	.. . . .		. . . .		. .
Flapped	..	. .		.. (r)	r . .				.. .. ..
Fricative	(F~)	(fv)	s (z) ..			.. *h*			.. .. *h*(h)
Semi-vowel	Θ	..	.. ..		.. . . .		e		

Sounds shown in brackets [ ] are the aspirates; those in parentheses ( ) are variants of the sounds or subsidiary members of phonemes.

Appendix-3

WORD-PAIRS

কাঁটা - ঘটা
গব্য - নব্য
লেখা - রেখা
বালা - জ্বালা
ফুল - কল
ডানা - খানা
হাল - চাল
গান - ডান
লিপি - ছিপি
গাথা - মাথা
খেলা - মেলা
হাত - রাত
কাঠি - ঘাটি
তোপ - লোপ
দালার - ভালার
কাত - ভাত
চুড় ঠাড়
আম দাম
লোকল কাকল

গলার - তলার
দান - টান
খুন - চুন
বান - মান
তুলি - চুলি
দাম - বাম
খালা - হালা
কাল - দাল
খুঁটি - কুটি
চুরি - ঘুরি
মাঠ লাঠ
গানের - টানের
চলন - ঢলন
জোড় - ক্রোড় -
বক্স - ঠক্স
ফুল - ভুল
লাকের - মাকের
গলাচ - বলাচ
ওলার - কলার
বালি - ডালি
চূড় - ঝাড়
চাল - ডাল

লোকশ - ঠোকশ
কুঁড়ি - কুড়ি
থান - টান
চুর - সার -
কল - তল
দাল - বাল
চুস - রুস -
মকল - দকল
ঝরন - লোরন
ছের - ঝের -
দলে মলে
বলার - ভলার
চুকরি - চিলকি
দালন - ভালন
মোক্ষর - রোক্ষা
কত - রত -
ঘাস - ঠাস
ওলার - চলার
ছেলে - রেলে
খাপ - দাপ
খাত - বাত -

ঝুল

- ঝুর

গাঁও - গিঁও

সোনার - সেঁওনার

সোনা - সেঁওনা

মাথা - মাথা

ঝাও - ঝাও

ঘাল - মাল

মাছু - মাছু

উঠিল - উঠিল

উঠক - উঠক

উঠল - উঠল

ঝাঁপর - মাথর

ঝাঁপ - ঝাঁপ

চিনার - চিনার

ঝুলার - মলার

ঘাও - ঘাও

ররার - ঝরার

খাঁলার - খাঁলার

কাম - কাম

লীল - লীল

লাঠ - লাঠ

পাথর - পাথর

লেখী - লেখী

তোলার - তোলার

তোলার - তোলার

তেল - তেল

মেল - মেল

মান - মান

টিকটিক - টকটক

ঝোঁঝে - ঝোঁঝে

কাকর - কাকর

টেলার - টেলার

দাওয়ার - দাওর

ওথার - ওথার

পাওয়ার - পাওর

কলকল - কলকল

মাথ - মাথ

হাত - হাত

মাথার - মাথার

খেওর - খেওর

ঠাম - ঠাম

কাঠ - কাঠ

ঝুল - ঝুলু

ঝুমার - ঝুমার

দাদর - দাদর

দাড় - দাড়

মাথা - মাথা

মাম - মাম

কাদর - কাদর

কামার - কামার

কাম - কাম

কওয়ার - কওর

ঝাম - ঝাড়

ঝুঁটর - ঝুঁটর

কোমার - কোমড়

পাকর - পাড়র

সাধর - সাধর

তল - তড়

তাথ - তাড়

দামার - দাড়র

তোলার - তোড়র

পাকর - পাড়র

ঝুঁকর - ঝুঁকর

কড়র - কড়র

ঠলার - ঠড়র

মাথা - মাথা

হাতর - হাতর

কাগজ - টাগজ

ঝড় - টড়

পাড়ুর - টুড়ুর

বাতিল - টাতিল

পাগল - টুগল

ছাগল - ঠাগল

ঢাক - টাক

কাগল - টাগল

বেগল - টেগল

চুলি - টুলি

বাগল - টাগল

টাক - টাক

ঝাল - টাল

ঝাটার - ঝাটার

পাঠা - টাঠা

বেকর - টাকর

কাগল - টাগল

ঘর - টেড়র

মাতন

ঢাগল

বেগল - টেগল

ভালা - টিলা

কাড়ার - টুড়ার

পাড় - টাড় -

ভাট - টাট

মলা - টালা

মলার - টালার

কাঁটার - টাঁটার

ঝাড় - টেড়

পাশ - টাশ

ভাল - টাল

বেড়র - টাড়র

ঝাম - টাম

পাড়র - টাড়র

ভাল - টাল

আমার - টামার

বেগার - টেগার

কাবন - টাবন

মাছ - টাছ -

ঝুড়ি - টুড়ি

পাগল - টাগল

ভাড় - টাড় -

কাগল - টাগল

মিল মল

পাড়র - টাড়র

মাঠ - টাঠ

ঝাট - টাট -

পাড় - টেড় -

ভাল - টুল

কাড় - টাড়

টাল - টেল

চাল - টাল

মাল - টুল

ঝাট - টাট -

পাশ - টাশ

ভাম - টাম

বেগল - টেগল

কাক - টাক

বেগল - টেগল

ঝাম - টাম

পাঠ - টাঠ -

ভাজী - টাজী -

তেলার - টেলার
কাজর - ড়াজর
কাকল - ছেকল
মাছুর - ড়াছুর
তুপ - তপ
তাসর - ড়াসর
ঘাসর - টাসর
টার - ঘুর
পাকার - মাকার
তিল - তিল
তপ - তপ
টাকল - লোকল
টট - ঘুট
পাকার - ডাকার
তপ - মপ
মাকার - মাকার
টাকল - হাকল
পাম - টাম
মেলার - টেলার

তল - মকল
টাকা - মাকা
তারক - পারক
মারক - টারক
পাতর - হাতর
টকটক - মকমক
মর - হর
পাকল - টাকল
মেকার - লোকার
টাকা - মাকা
তারক - চারক
টারক - মটারক
টেকর - পেকর
মলার - মলার
মাটর - মাটর
তাকার - টাকার
মতল - হল
মাস - চাস
তের - ঘের
তুলার - তুলার
দাসর - হাসর
হলার - টেলার

মোকর - মোকর
টেলার - টেলার
বুংকা - বুংকা
তাকার - লোকার
টাকর - টাকর
মাতর - পাতর
টাকল - চাকল
তাকল - হাকল
চল মকল
বর্ম - মর্ম
চাতুল - চাতুল
তুল - তুল
বাকার - পাকার
তিক - তিক
নাম - হাম
বাট - লাট
নর - কর
বাকল - টাকল
নাম - মাম
বাঁকর - মাঁকর
তল - মকল

জল-টল
কেবল-টেবল
উপর-টপর
চড়-থড়
জানলা-টানলা
হাব-টাব
উক-টক
কিত-টিত
খের-টের
উড়ি-টুড়ি
তাল-টাল
জাম-টাম
হাড়-টাড়
উচল-টচল
কুর-টুর
জড়-টড়
হল-টুল
কিক-টিক
কুর-টুরি
হসক-টুসক
তাল-টাল

বোতল-টোতল
সুন্দর-টুন্দর
হাত-টাত
কিস-টিস
কুমড়ো-টুমড়ো
আলমারি-টালমারি
ফুল-টুল
তেতুল-টেতুল
কুট-টুট
কুমল-টুমল
হাড়-টাড়
হাল-টাল
কুল-টুল
ফুল-টুল
চেয়ার-টেয়ার
বোতল-টোতল
সুঁচ-টুঁচ
গাছ-টাছ
ভয়-টয়
কিল-টিল
তাল-টাল

হাড়-ঝাড়
ভাম-ঝাম
হাল-তাল
ভগর-মগর
নাম-ধাম
তাল-চাল
আদা-কাদা
হয় নয়
মুক-শুক
হাকর-মাকর
কাগজ-টাগজ
নাম-ধাম
খেলা-টেলা
আম-টাম
হাত-টাত
মাত-দাত
ভুক-টুক
মাঠ-ঘাট
সকাল-টকাল
আদা-ওদা
শীত-মীত
আদর-টাদর

ছুরওয়া - ছুরড়র

রং - রস

ছুরত - ছুরওয়া

দাক - দাঙ

চরদার - চরওয়া

রং - রয

ছুরওয়া - ছুরড়র

রং - রয়

মাওয়া - মাহুর

দাঙ - দায়

দাওয়া - দালার

গাঙ - গাব

মাওয়া - মাঝর

রং - রস

দাওয়া - দালার

হিং - হিম

চাওয়া - চাকর

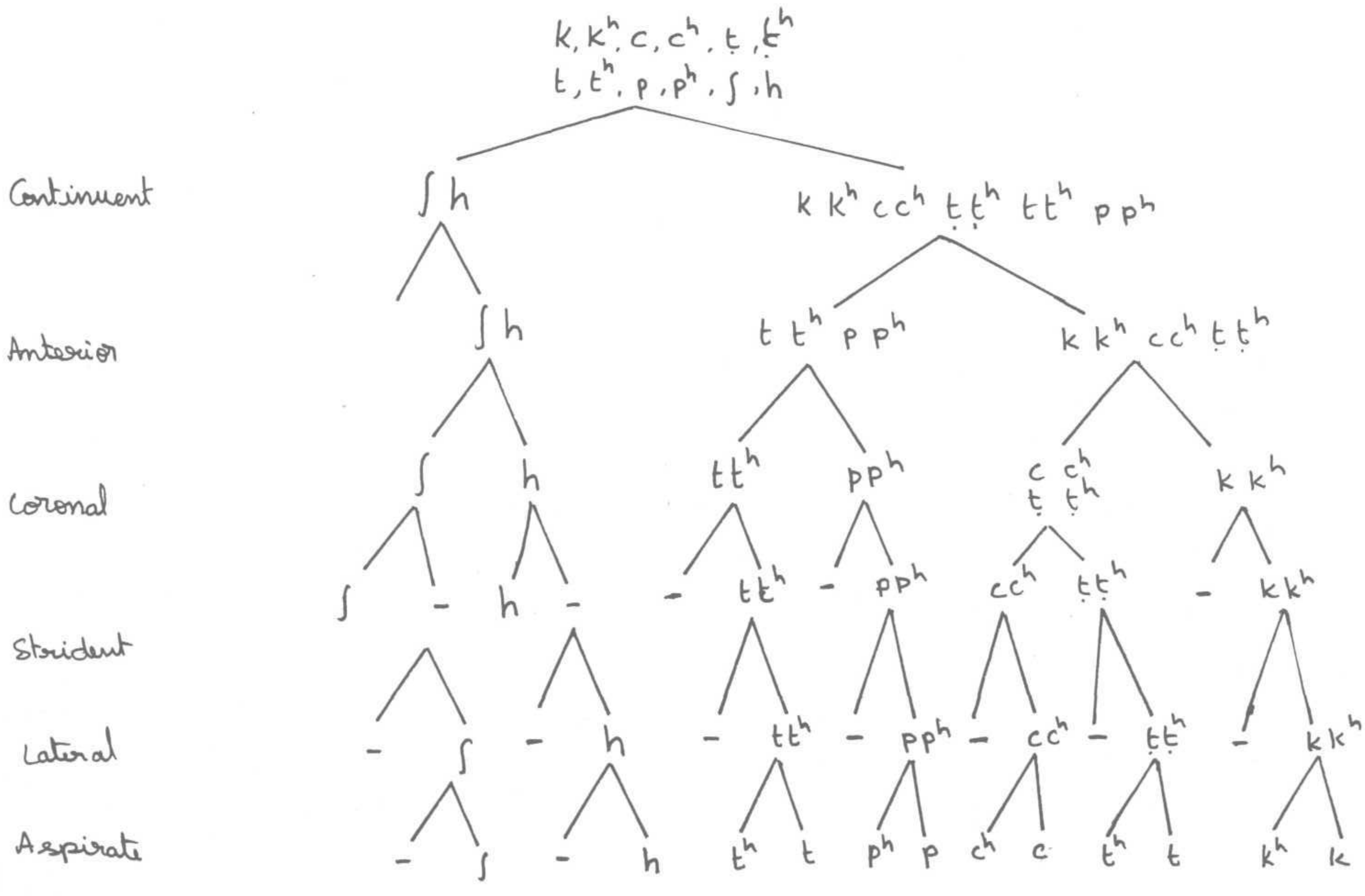
ঝিঙ - ঝিমলি

চাওয়া - চাহর

হিত - হিং

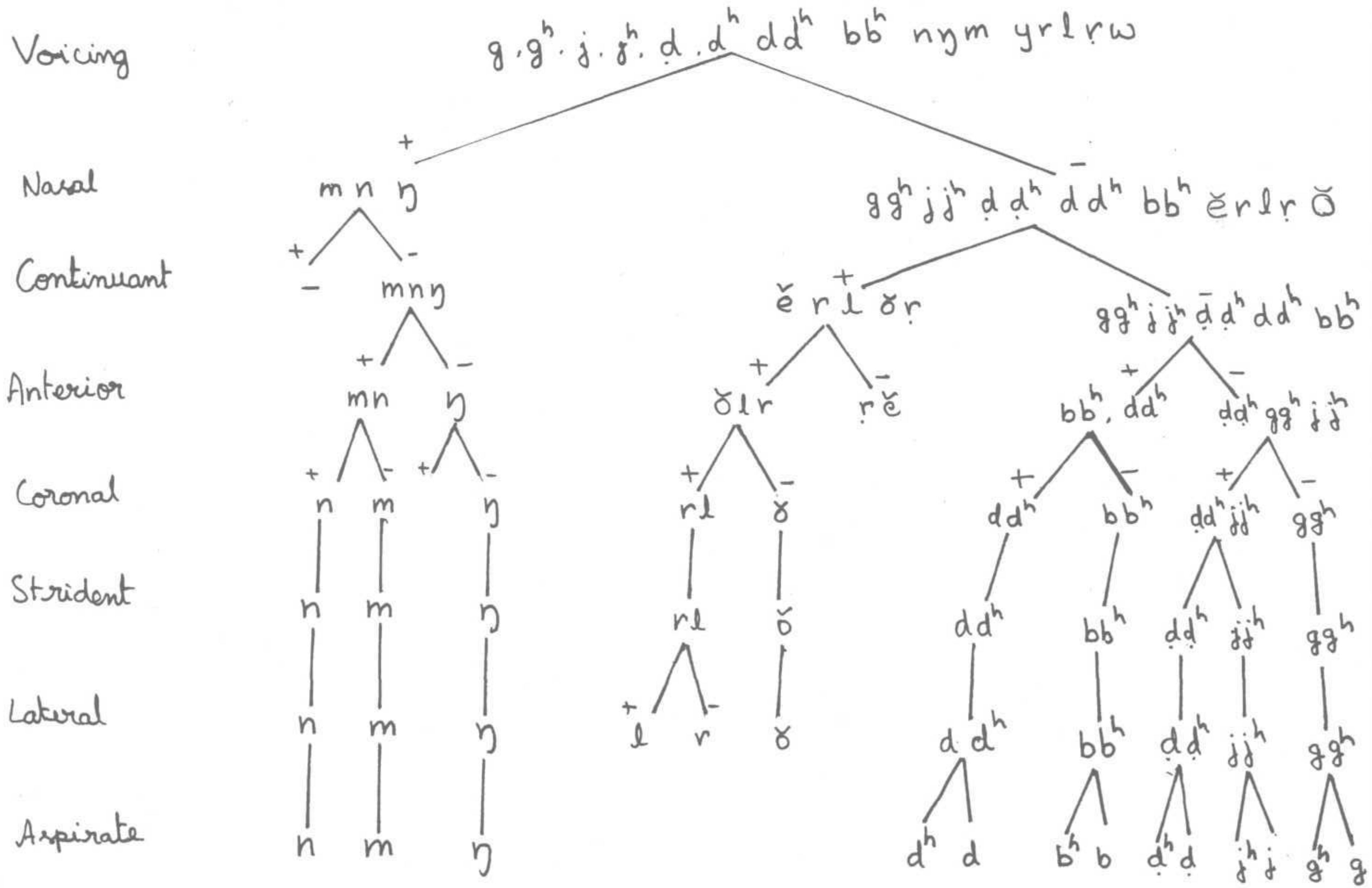
Appendix-4b

Tree diagram showing various features for voiceless consonants in Bengali



Appendix-4a

Tree diagram showing various Features for voiced consonants in Bengali



APPENDIX - 5

Distinctive features of Bengali language

Sounds	k	k^h	g	g^h	c	c^h	j	j^h	t	t^h	d	d^h	n	t	t^h	d	d^h	n	p	p"	b	b^h	m	e	r	1	o	s	r	h
Voicing	-	-	+	+	-	-	+	+	-	-	+	+	+	-	-	+	+	+	-	-	+	+	+	+	+	+	+	-	+	-
Nasal	-	-	-	*	-	-	-	-	-	_	-	-	+	_	_	_	_	+	_	_	_	_	^	_	_	_	_	_	_	_
Continuant	-	-	-	-	-	-	-	-	.	.	.	.	.	-	-	-	-	-	-	-	-	-	_	+	+	+	+	+	+	+
Anterior	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	-	+	+	+	-	-	-
Coronal	-	-	-	-	+	+	+	+	+	+	+	+	-	+	+	+	+	+	-	-	-	-	-	-	+	+	-	+	+	-
Strident	-	-	-	-	+	+	+	+	-	-	-	-	-	-	-	-	-	_	_	_	_	-	_	_	_	_	_	+	_	+
Lateral	-	-	-	-	-	-	-	-																						
Aspiration	-	+	-	+	-	+	-	+																						

APPENDIX - B

	k	k^h	g	g^h	c	c^h	j	j^h	t	t^h	d	d^h	n	t	t^h	d	d^h	n	P	P^h	b	b^h	m	e	r	o	s	h	r	1
k	0																													
kh	1	0																												
g	1	2	0																											
g^h	2	1	1	0																										
c	2	3	3	4	0																									
c^h	3	2	4	3	1	0																								
j	3	4	2	3	1	2	0																							
j^h	4	3	3	2	2	1	1	0																						
t	1	2	2	2	1	2	2	3	0																					
t^h	2	1	3	2	2	1	3	2	1	0																				
d	2	3	1	2	2	3	1	2	1	2	0																			
d^h	3	2	2	1	3	2	2	1	2	1	1	0																		
n	2	3	1	2	4	5	3	4	3	4	2	3	0																	
t	2	3	3	4	2	3	3	4	1	2	2	3	4	0																
t^h	3	2	4	3	3	2	4	2	2	1	3	2	5	1	0															
d	3	4	2	3	3	3	2	3	2	2	1	2	3	1	2	0														
d^h	4	3	3	2	4	2	3	2	3	1	2	1	4	2	1	1	0													
n	4	5	3	4	4	4	3	4	3	4	2	3	2	2	2	1	2	0												
P	1	2	2	3	2	4	4	5	2	3	2	3	3	1	2	2	3	3	0											
p^h	2	1	3	2	3	3	5	4	3	2	2	2	4	2	1	3	2	4	1	0										
b	2	3	1	2	3	5	3	4	3	4	2	3	2	2	3	1	2	2	1	2	0									
b^h	3	2	2	1	4	4	4	3	4	3	3	2	3	3	2	2	1	3	2	1	1	0								
m	3	4	2	3	5	6	4	5	4	5	3	4	1	3	3	2	3	1	2	3	1	2	0							
g	2	3	1	2	4	4	3	4	3	4	2	3	2	4	5	3	4	3	3	4	2	3	3	0						
r	4	5	3	4	4	4	3	4	3	4	2	3	4	2	3	1	2	2	4	4	2	3	3	2	0					
o	3	4	2	3	5	6	4	5	4	5	3	4	3	3	4	2	3	3	3	3	1	2	2	2	2	0				
s	2	4	4	5	1	2	2	3	2	3	3	4	5	3	4	4	5	5	4	4	5	6	6	3	3	4	0			
h	2	3	3	4	2	3	3	4	2	3	3	5	4	4	5	5	6	6	3	3	4	5	5	2	4	3	1	0		
r	3	4	2	3	3	4	2	3	3	3	1	2	3	3	4	2	3	3	5	5	3	4	4	2	1	2	2	3	0	
l	5	6	4	5	4	6	4	5	4	4	3	4	5	3	4	2	3	3	4	5	3	4	4	4	1	2	4	4	2	0

Appendix-7

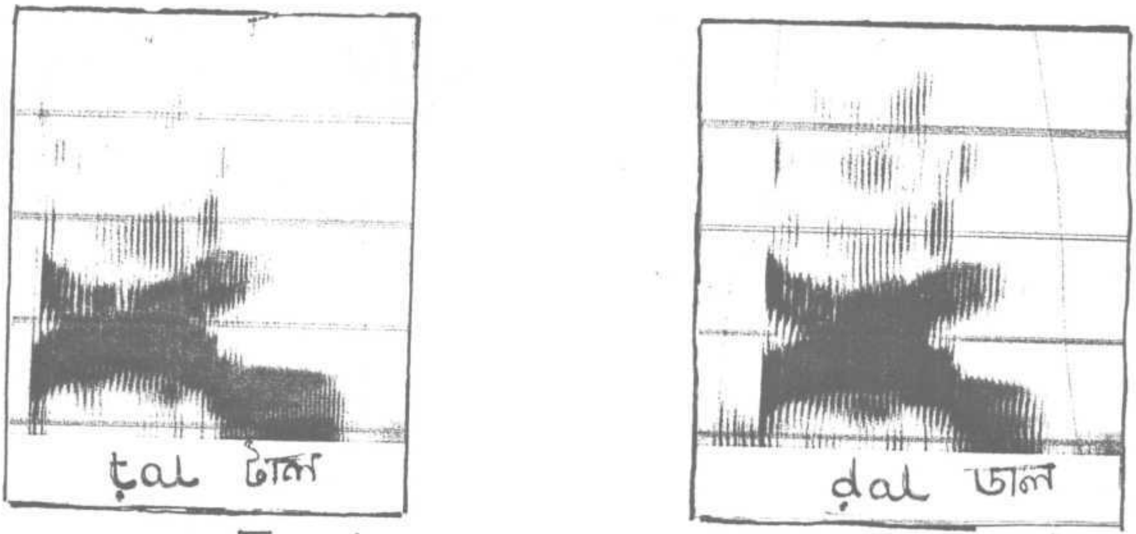


FIG-1 VOICING

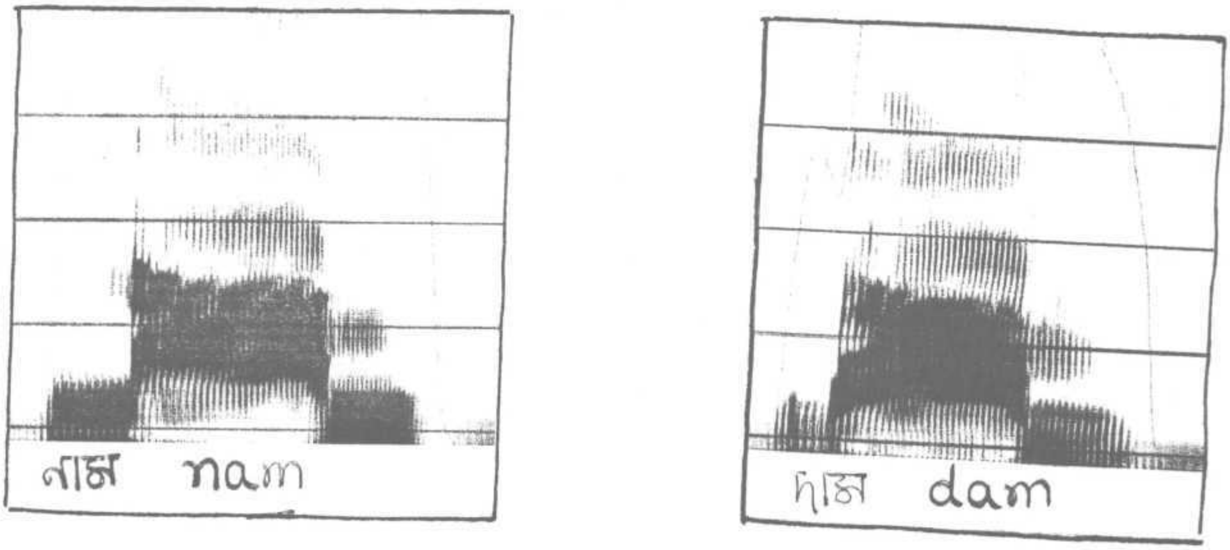


FIG-2 NASALITY

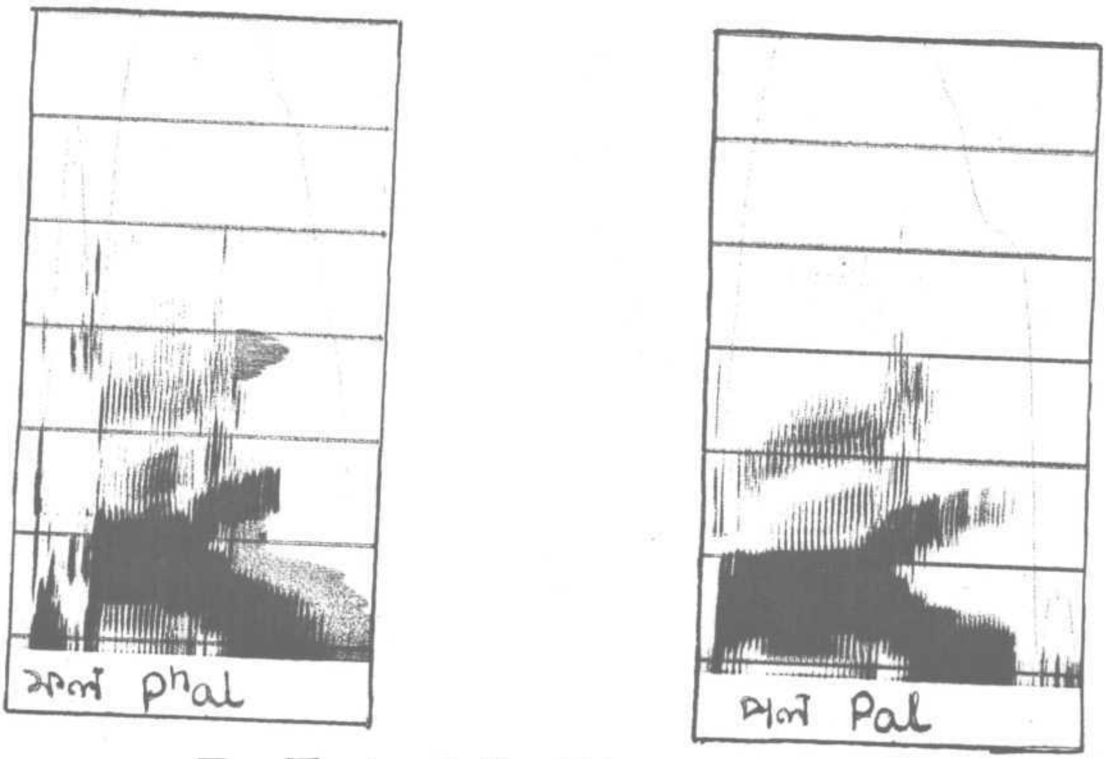


FIG-3 ASPIRATION

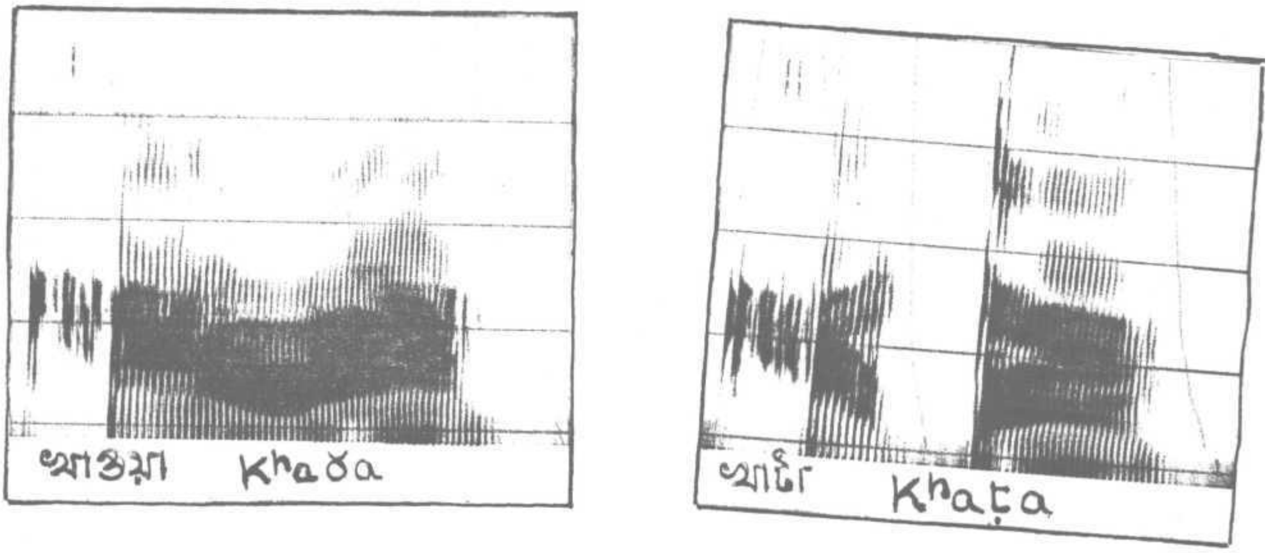


FIG-7 CONTINUANT

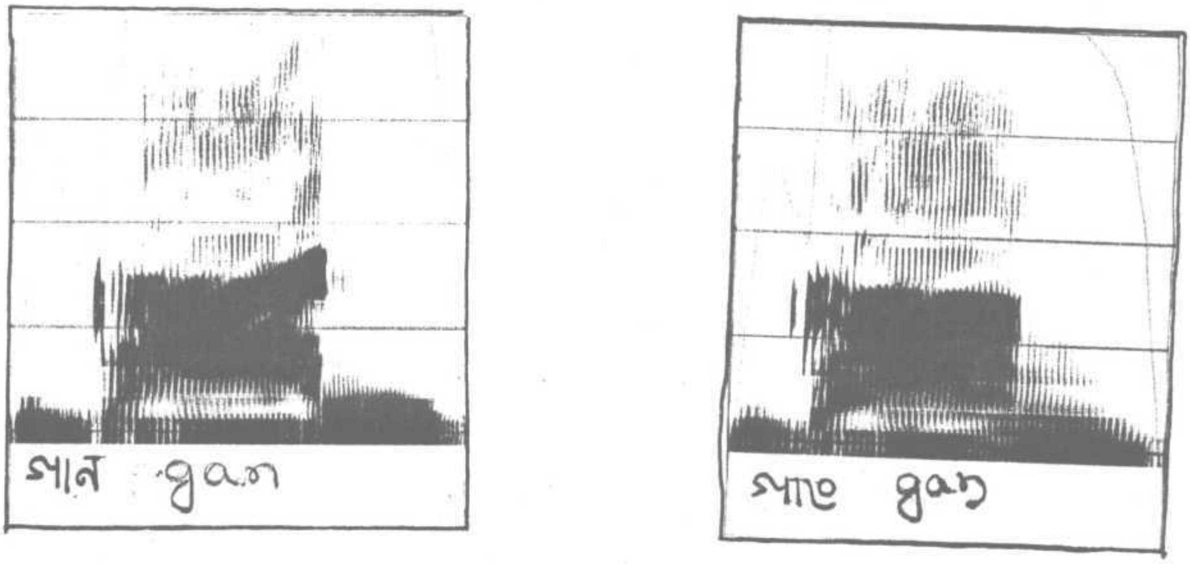


FIG-8 ANTERIOR

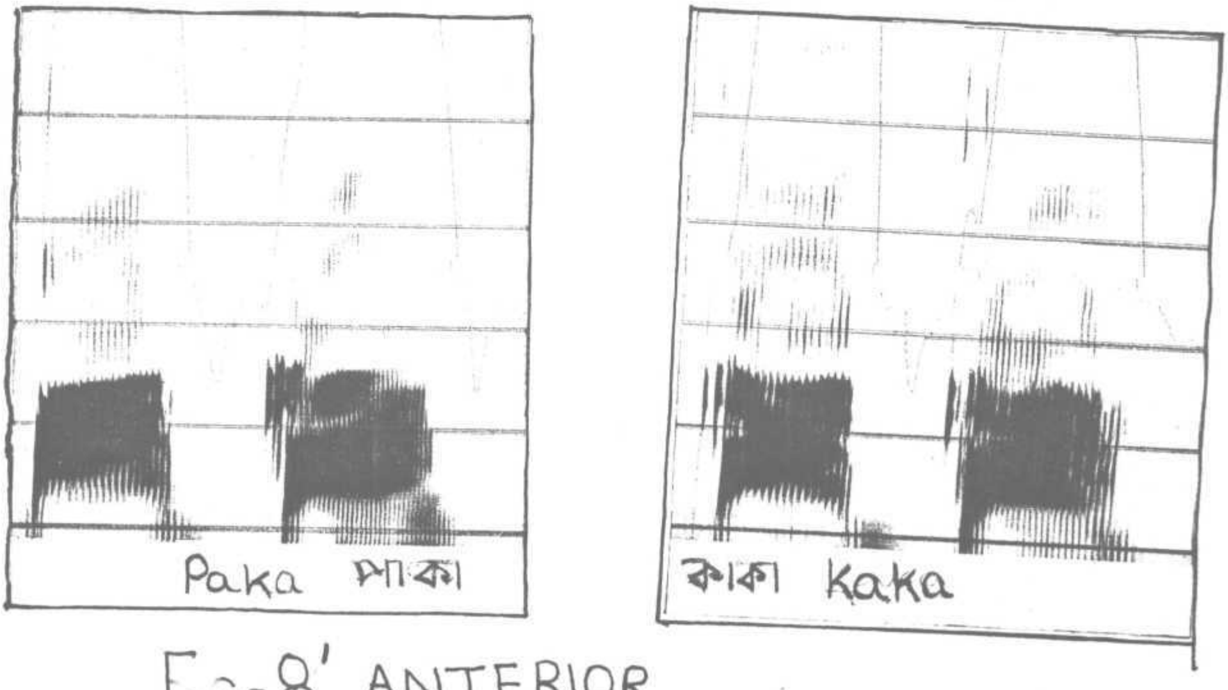


FIG-8' ANTERIOR

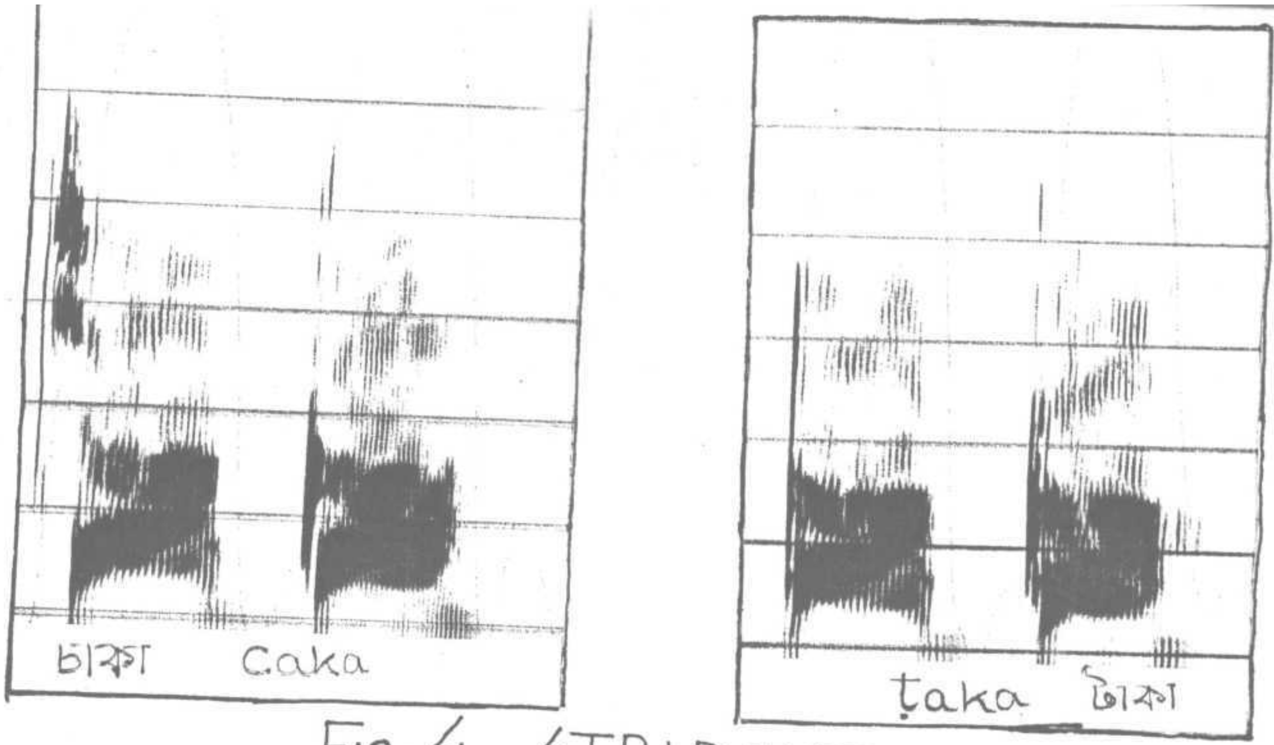


FIG-4 STRIDENT

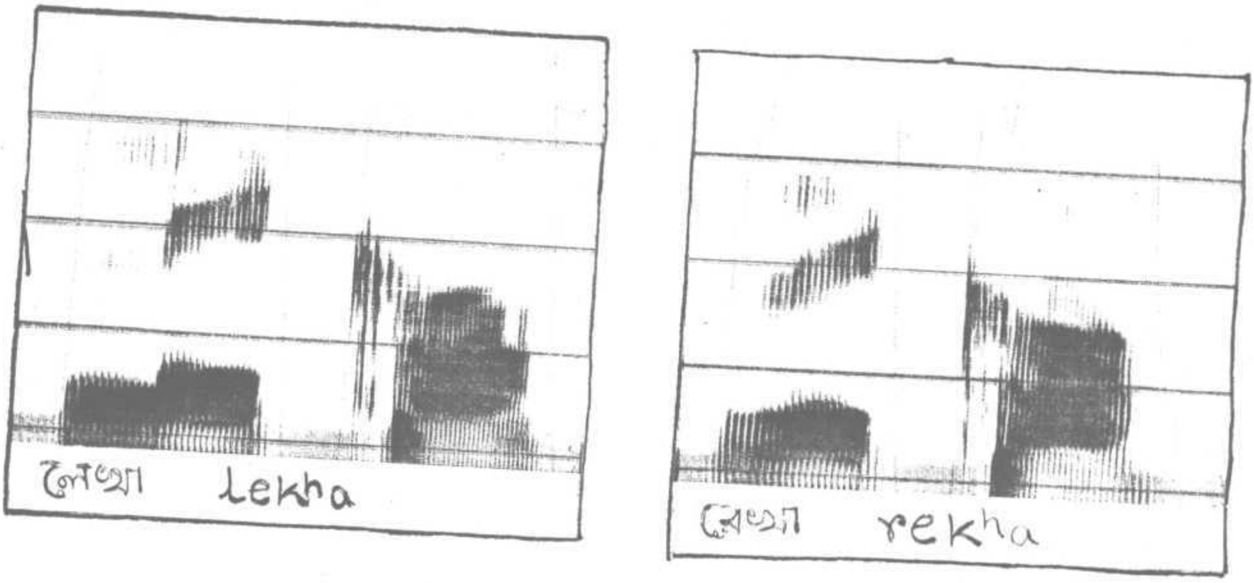


FIG-5 LATERAL

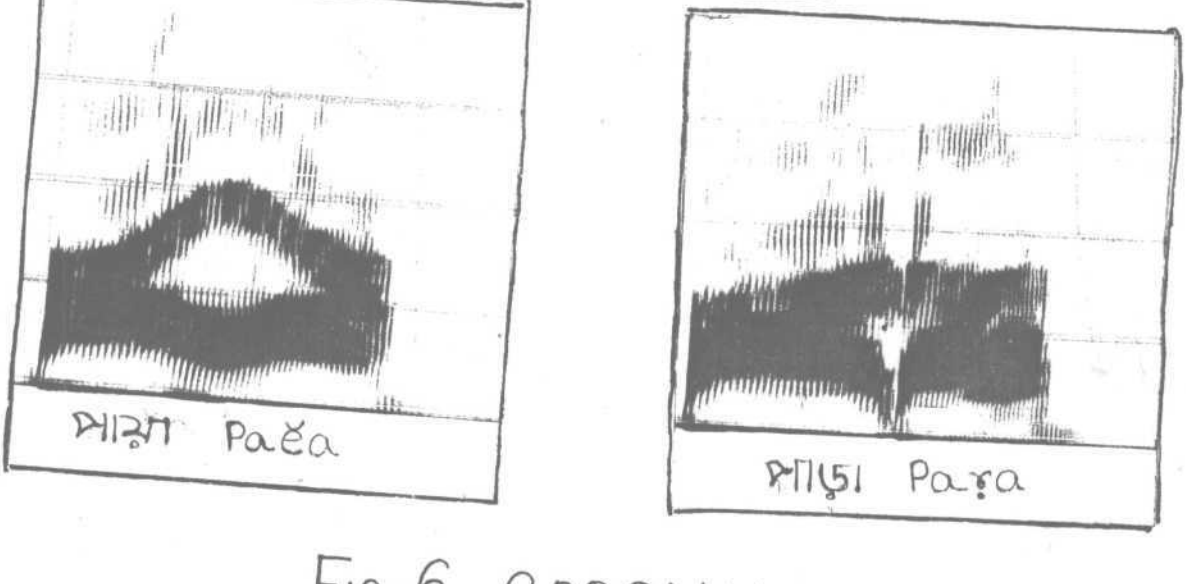


FIG-6 CORONAL